Habitat Restoration and Monitoring Plan

Landscape-Scale Adaptive Weed Management and Habitat Restoration Plan to Conserve the Biodiversity of Catalina Island

Prepared for

CATALINA ISLAND CONSERVANCY™

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EXECUTIVE SUMMARY

The Catalina Island Restoration Project (Project) aims to restore ecological integrity on Catalina Island, 88 percent of which is owned and managed by the Catalina Island Conservancy in Los Angeles County, California. The Project focuses on mitigating threats posed by nonnative ungulates, invasive plant species, human-caused fire ignition, and a changing climate, which have collectively led to biodiversity loss, erosion, decreased water capture, and reduced habitat quality.

Project components include:

1. Seed farm facilities: Supporting native plant community restoration through the establishment of new facilities.
2. Invasive plant management: Continuing existing efforts to control high-priority invasive species.
3. Landscape-scale habitat restoration: Reversing habitat type conversion and enhancing native plant and wildlife populations.
4. Long-term monitoring: Tracking plant and wildlife populations to inform management actions.
5. Nonnative mule deer removal: Addressing overbrowsing, creating opportunities for landscape-scale habitat restoration of endemic native plants and higher quality wildlife habitat.

Four habitat restoration approaches will be implemented using an adaptive management framework:

1. Whole Island passive recovery: Biodiversity recovery through mule deer removal and invasive plant control.
2. Island Scrub Oak Chaparral Restoration: Increasing diversity and native plant recruitment by replacing low-diversity nonnative annual grass understories with higher-diversity native shrubs, herbs, and grasses.
3. Top-of-Watershed Habitat Restoration: Prioritizing habitat restoration from the top down, to improve soil health and increase biodiversity in critical watershed management units with significant cultural and biological resources.
4. Infrastructure Maintenance and Cultural-Based Native Revegetation: Integrating best practices for native revegetation into infrastructure maintenance and promoting opportunities to plant culturally significant native species in consultation with tribal representatives.

A distinctive aspect of the plan is the integration of modeling techniques to (1) characterize the influence of environmental factors on vegetation recovery following drought, fire, and invasive ungulate removal, and (2) identify suitable habitat restoration targets and plant palettes for highly disturbed natural communities. Additionally, the plan incorporates landscape-scale habitat restoration approaches that leverage natural processes to provide feasible and cost-effective methods. Key strategies include:

1. Site preparation and weed management: Employing natural rainfall-driven grow-and-kill events to deplete the weed soil seed bank, reducing competition with native species.
2. Soil health improvement: Implementing erosion control measures in areas with significant topsoil loss, along with the introduction of low-diversity native cover crops, to build soil nutrients and structure over time. This will enable the establishment of island chaparral in areas currently unsuitable due to degraded soil conditions.

By combining modeling techniques with adaptive habitat restoration approaches, the Project strives to address the complex challenges posed by the island's European land use history, endemic flora and fauna, and rugged topography. The Project is vital for preserving the island's unique ecosystems, enhancing climate resilience, and protecting endangered wildlife, such as the Catalina Island Fox. By employing a comprehensive and adaptive approach, the Project will help ensure the long-term conservation of Catalina Island's rich biodiversity.

1 INTRODUCTION

The Catalina Island Habitat Restoration and Management Plan (HRMP) identifies suitable habitat restoration targets for degraded island vegetation communities, provides restoration principles that leverage natural ecological processes, prioritizes restoration opportunities by watershed management unit, and provides best practice for high quality, cost-effective habitat restoration and enhancement at the landscape scale to support the long-term conservation and restoration of the island's unique ecosystems. The plan is structured as follows:

Section 1: Introduction

- Purpose of the HRMP
- Description and expected outcomes of the Project
- Conceptual approach to the development of the plan
- Goals and management hypotheses of the restoration Project
- Key habitat restoration principles

Section 2: Existing Conditions

- Legacy impacts of human activities on island habitat health and ecosystem function
- Current environmental conditions and their interaction with the island's flora and fauna
- Summary of past and current habitat restoration efforts

Section 3: Habitat Restoration and Enhancement Opportunities and Priorities

- Identification of opportunities for passive and active habitat restoration
- Prioritization of active restoration approaches by watershed management unit

Section 4: Adaptive Weed Management and Habitat Restoration

- Description of the key components of whole island habitat restoration, including mule deer removal, invasive plant control, and native plant production
- Elements of site-specific project design for active habitat restoration approaches, include site-selection, native plant palette design, erosion control measures, adaptive weed management, seeding methods, and site maintenance

Section 5: Biological Monitoring and Sensitive Species Protection

- Presentation of site-specific restoration project biological monitoring methods
- Description of protections for sensitive and protected species
- Presentation of long-term monitoring methods for invasive plants, vegetation change, and wildlife
- Integration of monitoring data to assess and adapt the HRMP to changing conditions

The HRMP is designed to provide a flexible and adaptive framework for achieving the goals of the Catalina Island Restoration Project. By integrating scientific knowledge, management expertise, and ongoing monitoring and evaluation, the HRMP aims to support the long-term health and resilience of the island's unique ecosystems.

1.1 PROJECT LOCATION

The Catalina Island Restoration Project (Project) is located on land owned and managed by the Catalina Island Conservancy (Conservancy), a 501(c)(3) nonprofit organization, in the County of Los Angeles, California (Figure 1-1). Catalina Island, also known as Santa Catalina Island, is approximately 33 kilometers (km) long and 12.5 km across at its greatest width and is situated about 34 km southwest of Los Angeles and approximately 50 km away from Orange County. The island is part of the Channel Islands archipelago, also referred to as the California Channel Islands, and is accessible by ferry from the mainland. Catalina Island is known for its rugged and hilly terrain, with steep cliffs and deep canyons that create a dramatic and varied landscape (Figure 1-2). The island is also home to a variety of plants and animals, including at least sixty endemic species that are found nowhere else in the world. The Conservancy is dedicated to balancing conservation, education, and recreation, and offers visitors the opportunity to explore the island's natural beauty through a range of activities such as hiking, biking, scuba diving, snorkeling, and kayaking, as part of its mission to be a model steward of the island's resources.

The Project encompasses all the Conservancy land in unincorporated LA County, which is roughly 88% (approximately 17,000 hectares or 42,087 acres) of the island (approximately 19,400 hectares or 47,992 acres total) (Figure 1-3). The City of Avalon has 1,409 land parcels comprised of public and private landowners, totaling approximately 700 hectares, or 1,809 acres. Outside Avalon, in addition to the Conservancy, there are five other private landowners: Santa Catalina Island Company (15 parcels, including El Rancho Escondido and Two Harbors, totaling approximately 1,600 hectares or 3,986 acres); two private landowners (two parcels totaling approximately 30 hectares or 73 acres); Southern California Edison (11 parcels totaling approximately 10 hectares or 21 acres); University of Southern California (USC Wrigley Institute for Environment and Sustainability [WIES] Dornsife Wrigley Marine Science Center, approximately 5.6 hectares or 14 acres).

1.2 PURPOSE

The purpose of the Project is to restore the ecological integrity of Catalina Island by protecting and enhancing the biodiversity of native plants and wildlife habitats. The ecosystem of Catalina Island has been negatively impacted by a history of nonnative ungulates reducing vegetation cover and selectively browsing on rare and endemic plants, as well as the spread of invasive plant species that outcompete native plants in areas degraded by past ranching practices. These factors have led to a loss of biodiversity, extirpation of native species, diminished climate resiliency, increased soil erosion, decreased water capture, and reduced wildlife habitat quality.

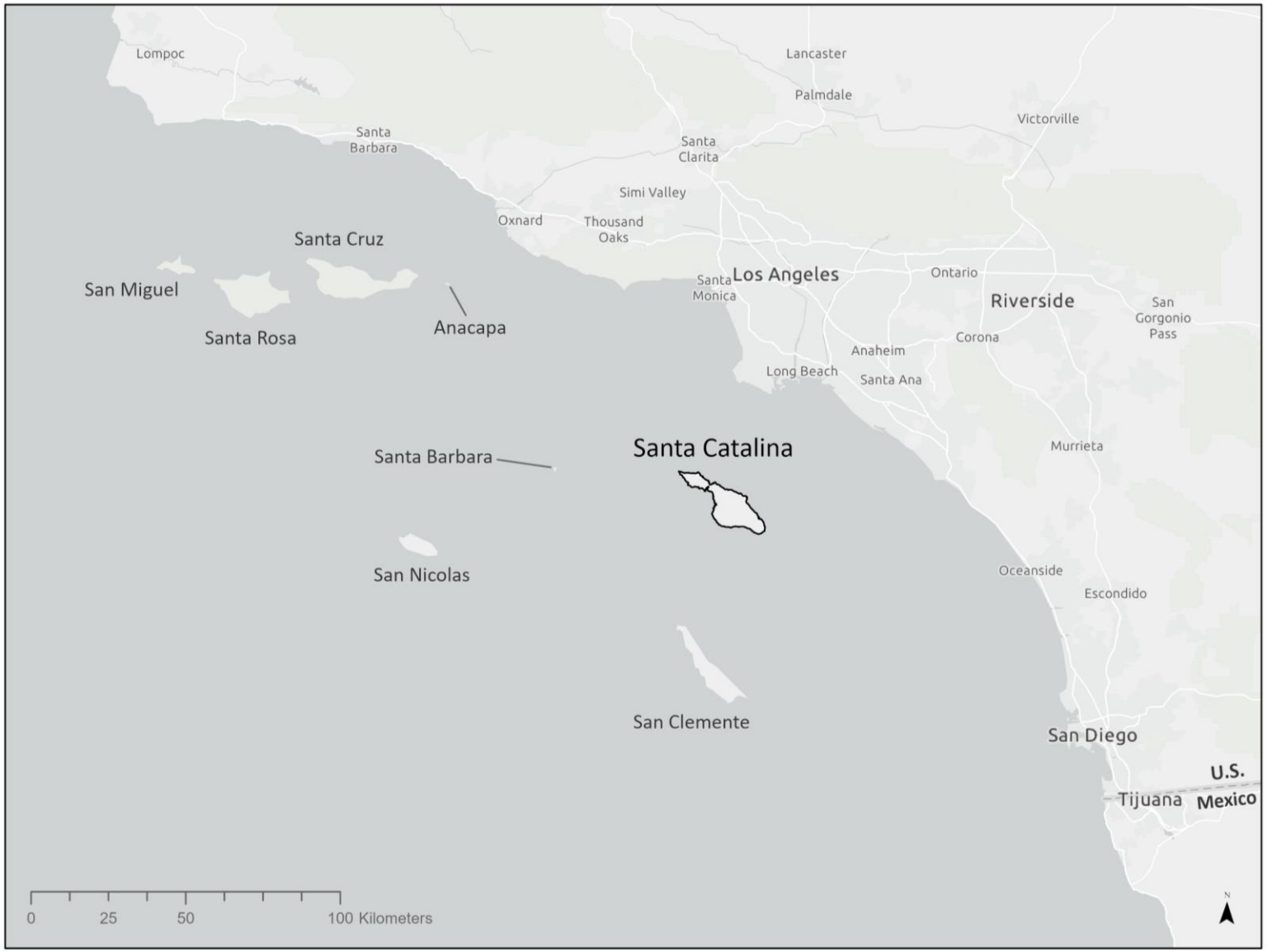

Figure 1-1 Catalina Island Regional Location.

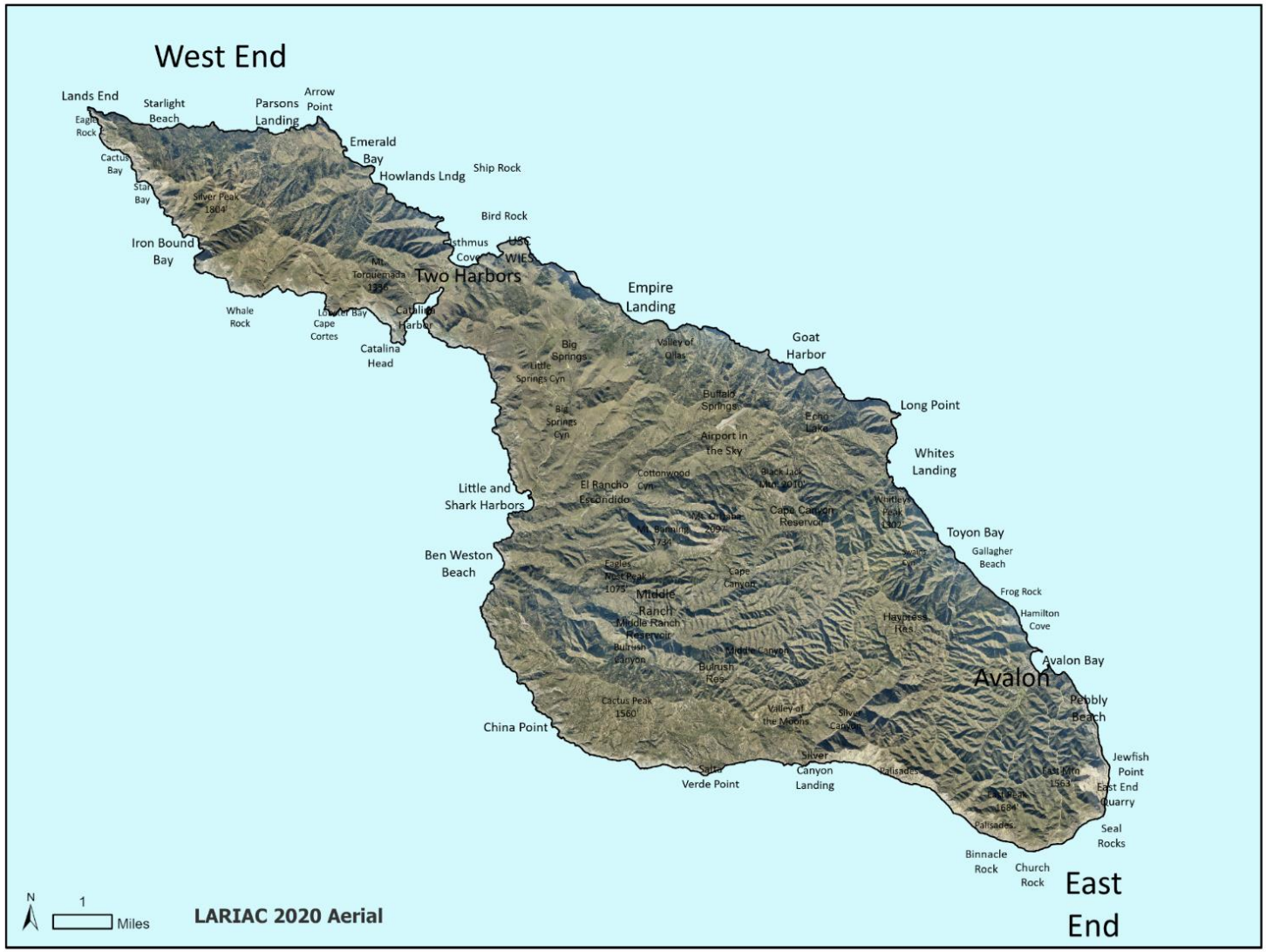

Figure 1-2 Catalina Island Aerial.

Aerial Source: LARIAC Aerial Image from 2020.

Figure 1-3 Catalina Island Landownership.

Aerial Source: LARIAC 2020. Parcel data provided by the Conservancy.

As climate change intensifies and fire regimes change, Catalina faces further risks to its habitat and rare species due in part to the depletion of the native soil seed bank. The Project addresses these issues through the removal of nonnative mule deer (*Odocoileus hemionus*), new seed farm facilities to support restoration of native plant communities, continuing and the existing invasive plant management program (Appendix A), implementing landscape-scale habitat restoration to reverse habitat type conversion, and long-term monitoring of plant and wildlife populations to inform management actions.

1.2.1 EXPECTED PROJECT OUTCOMES

The Project will improve climate resiliency, protect cultural resources, conserve state and federally listed species, and enhance public access and safety in several ways:

1. Increasing biodiversity and native vegetation cover: Removing nonnative mule deer will allow island endemic plants to recover and naturally recruit in the absence of nonnative ungulates that they lack defenses against. This will increase biodiversity and restore the island's native vegetation, promoting a more resilient and diverse ecosystem. Additionally, the recovery of native plants can help improve soil health, stabilize slopes, and provide habitat for native wildlife, further enhancing the resilience and sustainability of the island's ecosystem.
2. Restoring native habitats: By restoring areas that are currently infested with invasive plants, such as coastal sage scrub (CSS), island chaparral, island scrub oak chaparral, maritime cactus scrub, dune mat, riparian, and native grassland, the Project will help improve the resilience of the island's ecosystem to climate change by promoting biodiversity and improving ecosystem function. The resulting higher quality habitat across the island will provide increased opportunities for native wildlife species to thrive, including seeking refuge, breeding, and foraging.
3. Enhancing habitat connectivity: By improving the quality and connectivity of habitats across the island, the Project can help species adapt to climate change by providing them with the resources they need to move and survive in a changing environment.
4. Reducing invasive species: By reducing the population of invasive plants and animals on the island, the Project can help protect native species and habitats, including those of state and federally listed species.
5. Conserving soil: Reducing topsoil erosion is crucial for improving soil health, restoring native habitats, and protecting downstream sensitive species and cultural resources. To achieve this, the Project will implement erosion control measures and restore native vegetation in highly degraded areas. Researchers have shown that deeper soils can be held intact under shrublands when they would fail under grasslands (Gabet and Dunne 2002). This will help stabilize

slopes, increase water infiltration, and reduce sedimentation in waterways, ultimately enhancing the resilience and sustainability of the island's ecosystem.

6. Increasing carbon sequestration: The Project's focus on revegetation of native perennial vegetation communities, such as CSS, chaparral, and native bunch grasses, can help increase carbon sequestration, thereby mitigating the effects of climate change and improving the island's resilience to its impacts (e.g., Koteen et al. 2011).
7. Increasing water retention and stormwater quality: Restoring native perennial vegetation can significantly improve the island's water retention and infiltration capacity. This will help reduce stormwater runoff, decrease erosion, and increase groundwater recharge, ultimately benefiting the island's freshwater supply. The restoration of deep-rooted native plants can also help capture and store more water in the soil, making it available for use by plants and animals during dry periods. In addition, increased water retention can help mitigate the impacts of drought and climate change on the island's ecosystem, supporting island ecosystem resilience and sustainability. Native vegetation will reduce the amount of nitrogen and suspended sediments in stormwater runoff.
8. Enhancing public access and recreational opportunities: By restoring the island's habitat and increasing biodiversity, the Project will create new opportunities for the public to appreciate and enjoy the natural beauty of Catalina Island. Visitors will be able to explore restored backcountry areas, observe a greater variety of native wildlife, and admire the vibrant wildflowers that will thrive in the enhanced ecosystem. This will not only provide a more enriching experience for visitors but also increase public awareness and appreciation of the importance of conservation and restoration efforts. The Project will thus not only enhance the island's natural beauty but also promote environmental education and stewardship.
9. Reducing the risk of catastrophic wildfires: The restoration of native perennial vegetation is crucial in mitigating the risk of wildfires, particularly those fueled by “flashy” dry fuels from nonnative annual plants. By replacing these highly flammable plants with less ignition prone native species, the Project can help reduce the likelihood of fire ignition and slow the spread of wildfires if they do occur. This is particularly important in protecting the community of Avalon, as well as the island's unique flora and fauna. By promoting a more fire-resilient ecosystem, the Project can help create a safer and more sustainable future for Catalina Island, reducing the risk of catastrophic wildfires and their devastating impacts.
10. Monitoring and adaptive management: By monitoring the success of the restoration efforts and adapting management strategies as needed, the Project can help ensure that the island's ecosystem remains resilient to climate change and other stressors over the long term.

1.3 PROJECT DESCRIPTION

1.3.1 BACKGROUND

Catalina Island has been significantly altered since the arrival of European colonists in the early 1800s and was managed in a different way by the indigenous people of the Los Angeles Basin and southern Channel Islands for approximately 9,000 years prior to European settlement. The contemporary landscape of the island retains many of the native plant and animal species that are common to the Channel Islands and coastal California, although their distribution and abundance has been altered due to legacy impacts to the ecosystem and habitat over the last 200 years (Table 1-1). Some of these impacts were of sufficient scale and/or duration to have resulted in the extirpation or near loss of many island endemics.

The primary vision for Conservancy's current 5-Year Strategic Plan (2023 to 2028) is landscape restoration, to complete a "major Catalina Island landscape restoration project, protecting native plants and animals from extinction and enhancing people's engagement with and understanding of the Island." The Conservancy is taking action to implement this vision by planning to remove the invasive mule deer population, which paired with the existing invasive plant control program, Catalina Invasive Plant Program (CIPP), will allow for "passive" recovery of island biodiversity. Mule deer, while important to mainland ecosystems, are invasive to Catalina Island's unique flora. The island is special with over 60 endemic plants—meaning they're found nowhere else on earth. The introduction of nonnative browsers to the island has had significant negative impacts on those endemic plants, and native wildlife habitat. The Conservancy has already seen success with the removal of feral pigs and goats, which resulted in improved biodiversity and native habitat recovery (e.g., Laughrin et al. 1994, Knapp 2009). With the removal of the mule deer, island endemic plants, which did not evolve natural defenses to large ungulates, will have the opportunity to passively recover in parts of the island that have enduring native soil seed banks and in areas that are actively managed as part of active habitat restoration projects.

The planned removal of the mule deer is a game-changing moment, allowing for significant recovery of the island's biodiversity and habitat restoration opportunities at the landscape scale to protect wildlife. With a changing climate, Catalina Island's relatively stable climate (due to its proximity to the ocean) makes it an ideal spot to preserve California's biodiversity. Removing the invasive mule deer will also help revitalize habitat for island wildlife, including habitat for Catalina Island Fox (*Urocyon littoralis catalinae*), a state and federally listed as threatened wildlife species.

The removal of invasive mule deer from Santa Catalina Island has become even more crucial due to the increased threat of large wildfires, such as the 2007 Island Fire that burned almost 5,000 acres, or about 10 percent of the island. This event marked the largest recorded fire on the island in the last 100 years.

Table 1-1 Summary of Legacy Impacts on Catalina Island's Native Habitat Over the Past 200 Years.

Legacy Impact	Causes
Loss of Island Endemic Plants	Selective browsing pressure by intensive livestock farming (e.g., sheep) and by other invasive ungulates (e.g., feral pigs, feral goats, mule deer) and rooting for bulb plants and roots by feral pigs. The impact of browsing and rooting also extends to plants that are not endemic but preferred food sources.
Topsoil Loss & Excessive Erosion Features	Overgrazing and browsing from intensive livestock farming (e.g., sheep and cattle) and invasive ungulates (e.g., feral pigs, feral goats, mule deer) that are not native to the island ecosystem denuded many watersheds of vegetation cover, increasing bare ground, reduced soil water retention and organic matter. Road construction and maintenance.
Loss of Wetland & Salt Flat Habitat	Development in Avalon, Two Harbors, and smaller impacts in other developed bays, especially on the channel side.
Loss of Floodplain Scrub & Willow Woodland in Large Watersheds	Felling of trees for fuel and construction material. Cultivation of crops. Addition of Harding grass (*Phalaris aquatica*) to help reduce topsoil loss in Middle Canyon from intensive livestock farming. Construction of dams to create reservoirs and livestock ponds.
Reduced Water Infiltration & Water Quality	Type-conversion of native vegetation communities to nonnative annual grassland following clearing or intensive livestock farming combined with the intentional or accidental introduction of Eurasian annual grasses (e.g., ripgut brome, wild oats, soft chess, red brome) and forbs (e.g., fennel, thistle, mustard). Many of these plants are now naturalized and will be impossible to eradicate.
Loss of Scrubland Habitat	Accidental release of highly invasive plants, such as Mediterranean broom (*Genista linifolia*), which was first planted in the early 1900s at Saint Catherine Hotel in Descanso Canyon and subsequently invaded the hills of the Avalon watershed, displacing native scrub to become the dominant shrub in many areas. Control in the interior has been effective, but new populations continue to be found in the backcountry and require treatment to contain the population in Avalon. Type-conversion of upland coastal sage scrub and island chaparral following clearing or intensive browsing and grazing from introduced ungulates combined with the introduction of Eurasian grasses and forbs. The impacts of ungulate browsing on native vegetation are magnified following wildfire when resprouting shrubs and germinating plants are more palatable.
Increase in Size & Frequency of Fire	Human-ignition sources have increased during the dry season, leading to larger and more frequent fires than would have occurred historically, especially in the past 20 years (e.g., 2006 Empire Fire and 2007 Island Fire that combined burned 12% of the island). This trend is also coincident with an increase in vegetation cover following the removal of feral goats and pigs in the early 2000s. From evidence on the mainland, Indigenous island people likely managed the island using fire to increase access to other parts of the island through canyons with dense understories and to manage food sources such as chia and acorns but the fire frequency on Catalina was historically much lower than that on the mainland.

Typically, Catalina's native vegetation can recover successfully from fires if they do not occur too frequently, allowing the plants to naturally recover through seed bank replenishment and basal resprouting. However, the pressure exerted by invasive herbivores, including mule deer, on native plants can lengthen the time it takes for recovery. This extended recovery time leaves the habitat vulnerable to irreversible damage from subsequent fires and periods of extended drought (e.g., see Appendix C). Additionally, browsing from invasive mule deer can even halt the recovery of certain rare species or sensitive habitats altogether. With wildfires becoming more common and more destructive, and the invasive plants and mule deer putting extra pressure on native plants, the island's delicate ecosystem faces a perfect storm of threats. The combination of these factors increases the likelihood of larger and more frequent fires, which further threatens the island's biodiversity and ecological integrity.

Past Conservancy habitat restoration efforts have necessarily been relatively small and focused on caged planting of island shrubs and trees, or fenced exclosures that allow for plantings and natural recruitment by keeping out the invasive ungulates. For example, between 1999 and 2005, the Conservancy planted over 35,000 island scrub oak (*Quercus pacifica*) acorns in experimental trials to evaluate strategies to overcome invasive ungulate browsing pressure on oak regeneration, such as exclosures and tree tubes (e.g., see Figure 1-4, Stratton 2009). The results inform the development of restoration strategies in this HRMP, especially the need to remove invasive mule deer to scale up the recovery of native island habitat.

In 2016, the Catalina Island Conservancy initiated a native tree-planting project near Haypress Recreation Area and Laura Stein Volunteer Camp with the aim of replacing nonnative trees. The Conservancy chose to plant several rare and native species, including the Catalina Island ironwood (*Lyonothamnus floribundus* subsp. *floribundus*) and the island oak (*Quercus tomentella*). To protect the newly planted trees from damage by invasive mule deer, the Conservancy installed steel caging around each individual plant. However, despite these protective measures, the planted trees were unable to thrive and grow beyond their cages due to the intense browsing pressure from mule deer (e.g., see Figure 1-5).

Following the 2007 Island Fire, the Conservancy constructed White's Exclosure, a large, fenced area designed to allow native plants to grow and recover without being damaged by invasive mule deer (e.g., see Figure 1-6). Many of Catalina's rarest species, such as island rush-rose (*Crocanthemum greenei*) and island bush poppy (*Dendromecon harfordii*), were able to flourish. In 2022, the Conservancy constructed the Little Harbor Exclosure and installed 100 native plants grown in the Conservancy's Ackerman Native Plant Nursery (Figure 1-7). This is a small exclosure, protecting just 0.03 acres. This exclosure conserves two rare species that have been nearly extirpated from Catalina, malva rosa (*Malva assurgentiflora* subsp. *glabra*) and cliff spurge (*Euphorbia misera*). Malva rosa only exists naturally on Bird and Indian Rock where it is protected from browsing. Most of the cliff spurge populations on the island have been extirpated, with only two remaining isolated populations near Little Harbor remaining (Conservancy data).

Figure 1-4 *Island Scrub Oak (Quercus pacifica) Restoration Trial Plantings in Middle Ranch, 2003.*

Photo taken by the Conservancy in 2003.

Figure 1-5 *Deer Cages Protecting Endemic Catalina Island Ironwood (Lyonothamnus floribundus* subsp. *floribundus) Plantings.*

Note the mule deer browse damage outside the protective deer cages, and how the trees area unable to grow past the boundaries of the cages due to extensive browsing. Photo taken by the Conservancy on October 10, 2023.

Figure 1-6 *Two Catalina Island Ironwood (Lyonothamnus floribundus subsp. floribundus) groves protected inside White's exclosure.*
Photo taken by the Conservancy on March 14, 2013.

Figure 1-7 *Little Harbor Exclosure Constructed in 2022 and Planted with Nursery Grown Plants.*
Photo taken by the Conservancy on January 30, 2024.

While deer exclosures have been successful in protecting small areas in the past, it's simply not practical or feasible to expand this approach island-wide. The rugged terrain of the island makes it prohibitively expensive and difficult to construct and maintain large fenced exclosures. Fenced exclosures are regularly breached due to erosion, wind, and animal damage (e.g., see Figure 1-8). Despite regular maintenance and repairs by the Conservancy, the effectiveness of these exclosures is limited to protecting just 0.3% (56.6 hectares or 140 acres) of the island.

To achieve the landscape restoration vision, which is critical to island conservation, education, and recreation, the Conservancy is taking several other actions, including the reorganization of Conservancy staff structure to support the new Strategic Plan, building a residence Hall to support larger restoration crews and collaborators such as Conservation Corps Long Beach, and increasing the amount of key plant seed through seed bulking.

Figure 1-8 *Damage to White's Exclosure (left) after a series of winter storms with high winds and after repairs (right).*

Photos taken by the Conservancy on February 28, 2023.

1.3.2 HABITAT RESTORATION APPROACHES

Passive restoration of island habitat will occur following the removal of the invasive mule deer population, which will allow for natural recruitment and growth of island endemics and other native vegetation that are not deer resistant. However, island habitat recovery will not be complete without additional interventions due to competition from a significant weed soil seedbank (Pearson et al. 2016), native seed limitation due to a depleted soil seed bank (Seabloom et al. 2003), lack of seed dispersing animals (e.g., Catalina lacks scrub jays to help disperse acorns), and other legacy effects (e.g., Magnoli et al. 2013), such as loss of topsoil due to past ranching practices. To recover island habitat and ecosystem function in areas affected by invasive species or other disturbances, active habitat restoration efforts will be necessary (see Section 4).

Four habitat restoration approaches have been developed, which will be implemented in an adaptative management framework:

1. *Whole Island passive recovery of biodiversity through removal of mule deer and high priority invasive plant control using the existing CIPP program*
2. *Island Scrub Oak Chaparral Restoration*
3. *Top-of-Watershed Habitat Restoration*
4. *Infrastructure Maintenance and Cultural-Based Native Revegetation*

1.3.3 Removal of Invasive Mule Deer

Removing mule deer from Catalina is a critical component of achieving the Project's goals, as their continued presence and browsing habits inhibit the restoration of native vegetation and habitat. This removal will be accomplished through ground shooting, as well as sterilization of select "Sentinel" deer to ensure thorough population control. In populated areas, deer will be managed through capture using bait followed by culling, chemical immobilization followed by euthanasia, and sterilization. Deer will be found via detection dogs in remote areas and aerial detection methods. In remote areas, deer will also be captured via aerial net capture. No deer will be dispatch via firearm from a helicopter. The timing of removal efforts will be carefully planned to coincide with the mule deer's reproductive cycle, specifically during the estrus period when they are more social, to maximize efficiency and minimize the need for additional removals. All project activities will be conducted in accordance with the American Veterinary Medical Association's Depopulation guidelines for humane handling of animals, ensuring that the removal process is carried out in a safe, ethical, and responsible manner.

To minimize any potential environmental impacts during removal operations, the Project will use non-lead ammunition and retain carcasses on the landscape. Carcasses will be removed from areas frequented by people, such as populated areas or near trails, paths, and roads, and placed in more remote areas to decompose naturally. This will not only minimize potential health risks to humans and domesticated animals but also provide a valuable source of nutrients for the local ecosystem. The carrion of large animals is rich in nutrients and can benefit plant growth and a diverse range of wildlife, including arthropods, insectivorous birds, small mammals, scavengers such as eagles, and top predators. Overall, the Project is committed to undertaking removal operations in a responsible and environmentally conscious manner (see Section 4.2).

1.3.4 High Priority Invasive Plant Control Program

The Conservancy has an existing invasive plant management program, called the Catalina Invasive Plant Program (CIPP) (see Appendix A), which includes the following features:

1. Early Detection and Rapid Response (EDRR) to detect, monitor, and eradicate new invasive plant introductions before it can spread.

2. Eradication of all known populations on the island, or from natural areas, of species that have significant ecological impacts and are feasible to eliminate.
3. Control of species too widespread to be eradicated by reducing invasive plant populations in high priority watersheds, restoration areas, and high use areas.
4. Corridor Management of species too widespread to be eradicated and commonly found along corridors, such as the roadways, that serve to spread invasive plant propagules.

CIPP will be an important part of achieving the restoration goals of the Project. Passive recovery of native habitat following removal of the invasive mule deer will be significantly enhanced by controlling invasive plants that might otherwise outcompete native vegetation and impair ecosystem functions (e.g., water retention, soil health). CIPP includes annual invasive plant surveys, followed by targeted control of high priority invasive species, which are determined to be the greatest island threats. This invasive plant monitoring program will be integrated into the long-term monitoring plan, as part of the adaptive management scheme of this HRMP (see Section 4.1.1).

1.3.5 Island Scrub Oak Chaparral Restoration Projects

The island scrub oak (*Quercus pacifica*), a dominant species of the scrub oak chaparral community and a common tree across island upland habitats, occupies approximately a quarter of the island area, primarily on north-facing slopes (Knapp 2002). Between 1943 and 2005, Knapp (2007) estimated that there was a 30 percent loss of island scrub oak habitat. Consequently, there is significant concern about the long-term viability of the island scrub oak population and the low diversity and cover of native species in the understory and between canopies of many areas of the vegetation community due to mule deer impacts, and the legacy effects of past ranching practices (e.g., land clearing, intensive livestock production, and overbrowsing), feral pigs (e.g., rooting), and an infestation of invasive Eurasian grasses and forbs (Sratton 2007).

For this restoration approach, island scrub oak chaparral that is dominated by an understory of nonnative annual grasses and forbs will be restored with diverse native island upland scrub, herbs, and grasses. This will help to build healthy soil and recreate regeneration niches for island scrub oak acorns. Potential restoration areas in proximity to accessible roads will be prioritized, which allow timely seasonal weed management for multiple years using natural rainfall-driven “grow-and-kill” cycles to deplete the weed soil seed bank (Section 4.8).

Diverse native seed mixes will be the focus of this restoration approach (Section 4.5.5), including a full range of plant functional groups to replicate the natural disturbance recovery process that island chaparral is adapted to (e.g., early successional forbs, perennial grasses, woody shrubs).

1.3.6 Top-of-Watershed Habitat Restoration Projects

To restore areas with highly eroded topsoil due to historical overgrazing and overbrowsing from past ranching practices and the introduction of invasive ungulates

(e.g., feral goats, pigs, and mule deer), which have contributed to the loss of native vegetation cover and increased soil erosion, we propose implementing a targeted active restoration approach. We will restore these areas with a series of strategies:

- Implement erosion control measures to reduce sheet and rill erosion (Section 4.7)
- Reduce the nonnative soil seed bank through a series of rainfall-driven "grow-and-kill" weed management events over multiple years (Section 4.8)
- Strategically plant nodes or small clusters of container plants of key shrub and tree species that are underrepresented in the watershed and do not establish readily from seed (Section 4.11.2)
- Install a low-diversity native cover crop (Section 4.5.6).

The intent of the native cover crop is to establish native perennial vegetation to help rebuild healthy soils, intercept rainfall to reduce topsoil erosion, and establish the conditions for long-term recruitment of diverse native island vegetation communities through natural recruitment. In some cases, it may be appropriate to install a high-diversity native seed mix, when the seed material is available or if there is an immediate need to protect a sensitive species in the short-term through the establishment of higher diversity native cover (Section 4.5.5).

It is essential to conduct most, if not all, weed management prior to seeding to (1) optimize the success of native seed addition and minimize the impact of weed management on native vegetation establishment, (2) reduce the total cost of weed management. Weed management methods will include mechanical (e.g., mowing, line trimming) and chemical (e.g., targeted foliar applications of post-emergent, systemic herbicides) treatments. In highly degraded areas, the use of large, mechanized equipment or broadcast herbicide applications is more cost-efficient, as there are fewer native plants to avoid. Following native seed addition, most mechanized and chemical weed control methods can be detrimental to successful vegetation establishment from seed (Brooks et al. 2019). Hand weeding is often the preferred method for weed management after seeding; however, it is generally not cost-effective or feasible at the landscape scale. Therefore, the goal of this approach is to focus on intensive weed management in the early stages of restoration, leveraging the efficiency of large-scale weed control methods to reduce the weed seedbank and create a more favorable environment for native seedling establishment. This proactive approach can help ensure the successful restoration of native plant communities and enhance the resilience of the restored ecosystem.

The areas targeted for the top-of-watershed approach are identified in Section 3.4 and have the following qualities: significantly impacted by topsoil loss; accessible by a well-maintained road to allow for crew access to consistently conduct timely seasonal weed management and container transplant watering and basin weeding. This habitat restoration approach will be prioritized across watershed management units based on the sensitivity of biological resources (e.g., rare, or protected plant or wildlife

populations) down watershed that will be protected and enhanced by this top-of-watershed approach (Section 3.4).

1.3.7 Infrastructure Maintenance and Cultural-Based Native Revegetation Projects

For the maintenance and repair of existing infrastructure, such as roadways, buildings, and equipment, revegetation efforts should prioritize the use of native plant species that are compatible with the adjacent built environment and complement the surrounding native habitat (Section 4.1.3). These restoration activities should align with the methods outlined in this plan for other active habitat restoration methods, but may require modifications to accommodate specific constraints, such as fuel modification zone requirements.

Cultural-based native revegetation projects restore indigenous plants with cultural significance, benefiting both local wildlife and tribal nations. For instance, planting tule (e.g., *Schoenoplectus* spp., *Typha* spp.) near reservoirs offers opportunities for cultural material collection while enhancing bird habitat by providing screening from human activity. This approach fosters biodiversity and supports the overall health of the ecosystem.

1.3.8 Native Plant Material Collection and Production

To support the habitat restoration activities of the Project, a native plant seed farm and seed processing facility will be developed at Middle Ranch. This facility will focus solely on meeting the needs of the restoration project and will not engage in commercial seed production (Section 4.5).

To ensure a reliable supply of native seeds for landscape-scale habitat restoration projects, both wild seed collecting and bulk production on farmland in Middle Ranch will be employed. The native seed farm building will also house a micropropagation laboratory, facilitating seed germination trials, viability testing, and the production of rare and endangered plants of special concern. Third-party testing by an accredited seed testing laboratory will also be utilized to ensure the quality and viability of the native seeds.

This approach allows for a diversified and robust native seed supply chain, supporting the long-term success of restoration efforts. By incorporating both wild seed collection and bulk production, the Project can leverage the strengths of each approach to produce high-quality native seeds that are well-suited to the specific needs of the restoration sites.

Native seed that is not available in sufficient quantities for collection on Catalina and not feasible or reasonable to bulk in the Middle Ranch seed increase fields, may be bulked on the mainland. A native plant production decision tree is included in this HRMP to help the Conservancy identify which plant species are suitable and more economical to produce on the mainland, while maintaining biosecurity, genetic integrity, and appropriate climatic adaptation for island restoration (Section 4.5.4). As a rule, island

endemic plants and natives with high cross-pollination potential will be collected and bulked on the island.

The Conservancy will use their existing nursery infrastructure in Middle Ranch to produce container plants to support outplantings for the top-of-watershed habitat restoration and infrastructure maintenance native revegetation approaches (Section 4.11). For larger planting projects, when appropriate biosecurity measures can be assured, an offsite mainland nursery may be used to propagate native material collected on the island.

Potential seed application methods include but are not limited to sowing by hand, broadcasting by hand and with devices such as seed spreader, seed ball broadcasting, mechanical broadcast seeding with devices such as a push or motorized broadcast spreader, drill seeding manually or with a mechanized drill seeder, hydroseeding, imprint seeding, and remedial seeding. Selection of an appropriate technique for a site will be based primarily on conditions and accessibility (Section 4.10).

1.3.9 BIOLOGICAL MONITORING

To ensure the effectiveness of habitat restoration efforts and achieve island restoration goals, two scales of biological monitoring will be implemented: site-specific restoration project monitoring for active restoration approaches (Section 0) and long-term vegetation and wildlife monitoring (Section 5.3).

Site-specific biological monitoring includes:

- **Protected Species Monitoring**: Measures will be taken to avoid and minimize impacts to sensitive and protected species (Section 5.1).
- **Seasonal Horticultural Monitoring**: This monitoring will determine the optimal timing of weeding and supplemental irrigation events (Section 5.2.1).
- **Seasonal Plant Establishment Monitoring**: This monitoring will track seed and nursery-grown transplant germination and growth (Section 5.2.2).
- **Annual Spring Monitoring**: This monitoring will assess progress towards site-specific habitat restoration goals (Section 5.2.3).

Together, these monitoring efforts provide insights into the effectiveness of restoration activities at each site and help inform the adaptation of HRMP approaches and methods as needed to meet restoration goals.

To gain a comprehensive understanding of island-wide habitat health and assess the success of conservation efforts, long-term monitoring will be conducted in three domains:

- **Invasive Plant Control Program Monitoring**: The success of the high-priority invasive plant control program in mitigating the threats posed by invasive species will be assessed annually through the CIPP program (Section 5.3.7).

- **Vegetation Structure and Composition Change**: To enable detailed monitoring, biodiversity monitoring stations and vegetation transects will be established and monitored every 5 to 10 years across Catalina (Section 5.3.2). These stations will serve as data collection points, providing information on the health of the ecosystem, including the diversity and abundance of plant and animal species, as well as abiotic conditions. And to assess island-wide changes in vegetation structure, land cover change (e.g., tree, shrub, herbaceous vegetation cover classes) will be assessed following the methods in Appendix C and discussed in Section 5.3, Long-Term Monitoring Plan. Large wildfire events, or other significant disturbances to island habitat may necessitate more frequent or additional monitoring events to assess island health and recovery.
- **Sensitive and Protected Wildlife Monitoring**: The status of sensitive and protected species will be regularly monitored to guide adjustments to the plan (Section 5.3.4). Existing wildlife monitoring programs are conducted for the Catalina Island fox, Catalina Island shrew (*Sorex ornatus willetti*), and breeding seabirds.

By integrating these monitoring efforts, the Project can gain a comprehensive understanding of the status of the island's ecosystems and the effectiveness of restoration efforts. This data will enable informed decision-making and continuous improvement of restoration approaches, supporting the long-term sustainability and resilience of Catalina's ecosystems.

Regular assessments of plant and wildlife populations will be conducted to track trends and identify areas where further interventions may be necessary. This information will be used to inform the adjustment of habitat restoration strategies and priorities over time, ensuring that conservation efforts remain aligned with the changing needs of the island's ecosystems.

1.4 CONCEPTUAL APPROACH

The Conservancy has identified landscape island restoration as the primary focus of their current 5-Year Strategic Plan (2023 to 2028). In addition to conserving and restoring high quality habitat for sensitive and protected species, the HRMP must address changing climate, more frequent large fires, existing integrated planning efforts (i.e., invasive plant control programs, infrastructure maintenance, educational programs, public open space for passive recreation), and biosecurity issues that arise for an island that has multiple landowners and is a popular ecotourism destination.

Coordinating and organizing efforts across the landscape scale requires the use of Geographic Information Systems (GIS), which is the preferred method to evaluate opportunities and threats to restoration at the landscape scale (Meinke et al. 2009). The development of this plan and its specifications therefore depend on modern spatial data management and modeling tools that have become more common in conservation planning and landscape management.

To develop an effective and comprehensive HRMP, this updated plan draws upon the rich experiences of the Conservancy's more than 50 years of stewardship and the insights gained from the scientific and technical literature on restoration ecology.

First, at the scale of hectares, successful habitat restoration is correlated with the environmental niches that define conditions for plant species to survive and thrive (Palik et al. 2000). Data and analysis on the conditions associated with dominant plant species are therefore necessary to establish ecologically appropriate restoration targets across the landscape (Meinke et al. 2009). Successful habitat restoration is correlated with getting appropriate species in a location (site) and then corresponding with annual weather conditions necessary for plant establishment (i.e., the key variables of habitat restoration are site and year). Finding the appropriate locations for different plant communities in the absence of detailed historic vegetation maps will be supported by spatial environmental niche modeling (Appendix D).

Second, even if plant distributions are well-understood at the scale of hectares across the landscape, it is difficult to predict how plant species will respond within a site at the scale of meters. Because data on soils, topography, and disturbance conditions are not available at this scale, a restoration specialist never knows how a vegetation community will develop on a site without experimentation and adaptation to local conditions. Microsites—the variation at the scale of meters—are critically important in determining what species will grow where (Eliason and Allen 1997, Morzaria-Luna et al. 2004, Blumler 2018). This plan therefore presents a set of practices, starting with weed management and leading to seed-based plant material addition that plans for local site variation within a hierarchical system of vegetation niche mapping (Section 4).

Third, even with careful planning, habitat restoration has inherent uncertainty. Historical data to fully understand vegetation distributions may be lacking and require significant effort to locate and synthesize (e.g., Mattoni and Longcore 1997, Stein et al. 2010). Unknown past land uses may impact soil and site conditions at a fine scale. The local watershed may be altered, impacting hydrological conditions. Climatic changes, such as increasing soil aridity earlier in the season (Cooke et al. 2004), require consideration (Choi et al. 2008, Gelviz-Gelvez et al. 2015). Highly variable events, such as rainfall and Santa Ana wind conditions, influence a site from year-to-year, along with associated wildfires and droughts. This plan therefore seeks to manage these uncertainties by utilizing an adaptive management process that is resilient to even these uncertainties, in which site-specific project and longer-term change monitoring (Section 5) inform adjustments to the plan.

Fourth, island habitat has been recovering from a 200-year legacy of ranching and introduced ungulates that preferentially browsed on endemic plants, along with the added challenge of invasive plants. Between 1943 and 2005, a loss of 30 percent cover of island scrub oak chapparal habitat was observed (Knapp 2007a), however, in 2023 there are observations of crown resprouting in some of the impacted areas. Native vegetation cover and diversity has been increasing for over twenty years since the feral goats and pigs were removed by the early 2000s, a process that began in the 1990s. Two

large human-ignited wildfires (2006 Empire Fire and 2007 Island Fire) occurred that have resulted in loss of native tree and large shrub cover, as a result of the interaction of mule deer browsing on native resprouts and seedlings during an extended period of drought. Understanding the island-wide trajectory of lifeform change of tree, shrub and herbaceous cover would be useful and should influence the restoration strategy. We therefore analyzed 38 years (1985 to 2022) of US Department of Agriculture, Forest Service (USFS) Landscape Change Monitoring System (LCMS) data for the island to characterize how island vegetation cover has responded to the removal of feral goats and pigs, climatic trends, and large fire events (Appendix C).

Fifth, the vegetation communities have been significantly impacted by past ranching practices, selective grazing and browsing pressure on island endemic plants, and recent large fires, resulting in vegetation communities that may not always reflect pre-colonial species assemblages. Therefore, we conducted clustering and network analysis on co-occurring species observations with key diagnostic species in the Consortium of California Herbaria CHH2 database to identify likely groupings of species (Appendix E). These groups were compared to the existing descriptions of island vegetation communities to guide the development of restoration plant palettes for island vegetation communities. Further, the ecological niche models (Appendix D) for the diagnostic species were combined to identify suitable restoration locations for these vegetation community targets (Section 3).

Together, this conceptual approach involves quantifying island-wide vegetation change over the past 38 years (Appendix C), modeling the environmental conditions associated with the potential distribution of key native plants (Appendix D), identifying likely island vegetation assemblages (Appendix E), and synthesizing the ecological niche and species assemblage clustering results to identify suitable habitat restoration targets for island vegetation communities (Section 3).

This conceptual approach has two implications that are necessary compromises to achieve the greatest restoration benefit in the most cost-effective manner. First, the precise location of specific habitat restoration areas might not be planned ahead of time within a larger area under management. For example, to achieve a hectare of coastal sage scrub restoration, several hectares of land might be treated and seeded and the hectare that is ultimately suitable for scrub development would not necessarily be identified at the outset. Second, it is nearly inevitable that intransigent areas may not respond to habitat restoration efforts and will remain as weedy/nonnative grass inclusions (i.e., stuck sites) within a matrix of restored habitats. Rather than invest significantly in converting those sites with finite restoration resources, accepting such inclusions is in the best interest of accomplishing the most extensive restoration at the landscape scale. Such concessions reduce the area supporting native plants—however, nonnative annual grasslands can have wildlife benefits in terms of supporting higher densities of native snakes and raptors compared with native perennial grasslands (Wolf et al. 2017). An example of an exemption to this recommendation would be if the intransigent site is of high value to a target species of conservation, or if the site is a

significant source of high priority invasive species that are invading the adjoining native habitat—in which case, more intensive management activity may be warranted.

1.5 ISLAND HABITAT RESTORATION GOALS, MANAGEMENT HYPOTHESES, AND PRINCIPLES

1.5.1 HABITAT RESTORATION GOALS

The HRMP is designed to enhance critical ecosystem functions, restore the diversity and life-form of island plant communities, and protect locally rare, threatened, or endangered native species. The plan focuses on the restoration of terrestrial habitats that have been greatly altered since European colonization in the 1800s but does not include the island's marine environment. The HRMP's overarching goal is to improve the island's habitats and biodiversity while also supporting human wellness and recreational opportunities. The plan's specific goals are as follows:

1. **Increase Native Habitat Cover and Quality for Wildlife** - This goal aims to enhance the quality and coverage of native habitats to support a diverse range of wildlife species.
2. **Improve the Health and Vigor of Island Endemic Populations (Plant and Wildlife Species)** - The HRMP seeks to protect and enhance the populations of plant and wildlife species that are endemic to the island, ensuring their long-term survival.
3. **Stabilize Soil in Highly Erosive Areas** - By focusing on soil stabilization, the HRMP aims to reduce erosion and improve the health of the island's soils.
4. **Increase Soil Water Retention** - This goal involves improving the soil's ability to retain water, which is essential for supporting healthy plant growth and ecosystem function.
5. **Control, Reduce, and Eradicate Invasive Species Populations** – Managing the impacts from invasive plant species is a key objective of the HRMP, as these species can pose significant threats to native biodiversity and ecosystem health.

1.5.2 MANAGEMENT HYPOTHESES

The following management hypotheses have guided the development of this HRMP. Many of these hypotheses assume that the invasive mule deer population has been removed, or substantially reduced, at the time of implementation and will be entirely removed soon thereafter. With landscape-scale habitat restoration, there is a focus on identifying and leveraging natural processes and ecological systems to achieve a desired end state or target in a cost-effective and scalable manner. Data from future monitoring efforts can be used to revise these management hypotheses or generate new ones.

1. Native forb and woody plant cover will increase following the removal of mule deer and the on-going management of the bison herd size, which will be the last introduced ungulate on the island.

2. Restoration and enhancement of shrubland and woodland island plant communities will benefit Santa Catalina Island fox (*Urocyon littoralis catalinae*), which is a habitat generalist, apex predator and keystone island species.
3. Fennel (*Foeniculum vulgare*) occurrences, which are high priority for control, will not significantly increase after mule deer removal, because they are not highly palatable to deer and therefore have not been kept in check by browsing since the removal of feral goats (full eradication by 2005) from the island.
4. The removal of the mule deer population will have an insignificant impact on the cover of nonnative annual grass because mule deer are highly selective feeders, with most of their diet comprised of leaf and twig browse of woody shrubs (Collins and Urness 1983), supplemented with forbs in spring and summer (Longhurst et al. 1952), and acorns in fall and early winter when nutritional stress is highest (Cronemiller and Bartholomew 1950, Harlow et. al 1975, Ashcraft 1979, Pine and Mansfield 1980).
5. After removal of mule deer, a one-time prescribed fire event at locations that are both suitable for island chaparral and have an extant island endemic seed bank from long-lived seed species, will increase biodiversity of island chaparral vegetation communities.

   The use of prescribed fire should be considered as a once in 200-year opportunity to reset the biodiversity of island chaparral communities after mule deer removal. However, repeated fire in the same area is not recommended because the natural fire return intervals in maritime chaparral can exceed 100 years. Indigenous residents likely used fire as a management tool on the island, such as for food resources (e.g., chia, acorn) or to thin dense woodland or chaparral understory in steep canyons for improved access, but past cultural use of fire is not well understood, and we do know that frequent or high intensity fire can have negative impacts on many island plants and wildlife.

6. The cover of island scrub oak (*Quercus pacifica*) has increased over the past twenty years (2003 to 2022) with the removal of feral goats, which browse on basal resprouts. Without herbivory, a multi-stem tree can regenerate its canopy continuously, although individual branches have a maximum lifespan of 100 to 115 years. The removal of mule deer will further increase basal sprout recruitment.
7. The ecosystem function of highly denuded areas with topsoil loss and excessive erosive features will be rehabilitated to support woody island plant communities (e.g., island woodland and island chaparral) by modifying the connectivity of water and wind pathways (e.g., sheet flow erosion, erosion rills and gullies) to promote the accumulation of resources (e.g., moisture, organic matter, silt, litter, seed) in patches.

8. Restoration of native vegetation cover in areas with moderate to high levels of nonnative annual grass will improve water retention, reduce erosion, and improve water quality in the watershed.
9. Island scrub oak chaparral understory and the open areas between trees are currently dominated by nonnative annual grass and forbs. Revegetating these gaps with coastal sage scrub associated flora will promote acorn regeneration niches with reduced competition with nonnative grasses, reduced topsoil erosion, increased silt and soil organic matter, and increased soil water holding capacity.

1.5.3 HABITAT RESTORATION PRINCIPLES

The following are key habitat restoration principles, with the goal of increasing biodiversity and ecosystem function on the island. By applying these principles, the Conservancy can develop effective and sustainable strategies to improve island habitat and support the recovery of rare, listed, and protected island species.

1. Focus restoration efforts at the top of the watershed for multiple benefits, including (a) reduction of topsoil loss and expansion of erosive features, (b) maximization of natural seed dispersal processes downslope by gravity and water, (c) protection of rare plant populations (e.g., Catalina ironwood, *Lyonothamnus floribundus* subsp. *floribundus*) and/or at-risk wildlife (e.g., Santa Catalina shrew) directly downslope or lower in the watershed, and (d) accessible restoration project areas near access roads and trails for crew and equipment.
2. Ecological sites with low native diversity in one or more plant functional groups (e.g., early successional species, grasses, herbaceous forbs, woody shrubs, trees) are most efficiently restored by diverse seed mix applications with natural rainfall rather than transplanting nursery grown container plants, which typically require expensive temporary irrigation systems and water.
3. To reduce the competitive effects of nonnative annual grasses and forbs on native plant establishment, a holistic weed management approach is necessary. This approach involves implementing at least three or four years of consistent "grow-and-kill" weed management, where three or four weeding events per year are conducted with natural rainfall to control weeds before significant viable seed set. The term of weed management should include at least one year with above-average rainfall, to ensure that the weed soil seed bank is adequately reduced before native seed addition. This weed management approach should be focused on areas that are consistently accessible throughout late winter through summer. By concentrating weed management efforts in these accessible areas, the Conservancy can ensure that seasonal crops of weeds are not regularly missed, thereby increasing the likelihood of successful habitat restoration.
4. It is significantly more efficient to use larger mechanized equipment (e.g., mowing with a tracked skidsteer or tractor, walk behind mower) or broadcast

herbicide application (e.g., grass-specific herbicide; broad-spectrum herbicide where there is little to no native vegetation) when desirable native vegetation can be avoided during the control of nonnative vegetation, such as in a nonnative annual grassland.

5. Pre-emergent herbicides are not compatible with habitat restoration in most circumstances because they reduce native cover and diversity by suppressing the native seedbank and seeded material—except in the case of highly invasive plants that do not have a feasible alternative and are a threat to at risk wildlife habitat or spreading into other watersheds.
6. Plant palettes for vegetation communities that are selected for specific ecological sites on the island are more likely to establish and will minimize waste of Conservancy and natural resources for plants that are not ecologically suitable for an area.
7. Plants that are (a) locally rare in a watershed due to legacy impacts, (b) either culturally significant, rare plants that need population expansion, or provide critical wildlife habitat, and (c) require digestion by animals (or artificially treated with acid by nursery propagation techniques) to germinate, such as berry producing plants (e.g., cherry, manzanita, redberry, elderberry, poison oak), can be strategically planted to encourage wildlife consumption and seed dispersal (e.g., Bartel et al. 2023).

   Collecting, propagating, or planting species that are state or federally listed as threatened or endangered is not a focus of this HRMP; the Conservancy would need to obtain the appropriate permissions or permits from either California Department of Fish and Wildlife (CDFW) or U.S. Fish and Wildlife (USFWS) to incorporate listed plant species in a specific habitat restoration project.
8. Plants that do not readily establish from seeding applications, do not have sufficient propagules in the watershed, and/or are critical to establish to avoid temporal impacts to at risk wildlife, can be strategically planted from nursery stock.
9. When nursery grown transplants are required, they should be planted in groupings that provide multiple project benefits including concentrating weed maintenance and temporary supplemental irrigation of the planting basins near accessible roads and trails, modifying connectivity, and maximizing natural rainfall capture by planting in erosion rills and gullies, and increasing protection of rare plant or at-risk wildlife populations downslope.
10. Do not actively remove, but not necessarily maintain stock ponds or reservoirs that are not part of the drinking water supply for the human population or for the welfare of the bison herd. Allow the ponds to fill up during high rainfall years and provide migratory and local birds with open water habitat. Retention of water increases groundwater recharge and increases near surface soil moisture downstream later into the dry season. Invasive amphibians like American

bullfrogs (*Lithobates catesbeianus*) can be cost-efficiently controlled in most of the island backcountry ponds in higher rainfall years after successive low rainfall years that dry out the ponds.

11. Successful island habitat restoration requires the involvement and support of a wide range of stakeholders, including local communities, land managers, and scientists. Engaging these groups in the island restoration project through compatible education, community volunteer, and recreational opportunities can help to build support for conservation efforts and ensure the long-term sustainability of Catalina Island.

2 EXISTING CONDITIONS

Nestled within the California Pacific Islands, Catalina Island forms part of the California Floristic Province, a globally recognized biodiversity hotspot teeming with plant life found nowhere else on Earth (Myers et al. 2000). This remarkable ecological region owes its high diversity and endemism to a relatively stable climate throughout the Pleistocene epoch (Lancaster and Kay 2013, Sniderman et al. 2013). Catalina Island's separation from the mainland, which occurred over 5 million years ago (Vedder and Howell 1980), has resulted in a rich tapestry of unique plants and animals found only on its shores. This high level of endemism highlights the island's immense value for conservation, as oceanic islands like Catalina often harbor species distinct from their mainland counterparts (Ratay et al. 2014).

The California Pacific Islands, a chain of 18 islands stretching from the Farallones in the north to Isla Natividad in the south, are an ecological marvel off the Pacific coast of California and the Baja California Peninsula. These islands share a distinctive and diverse flora, rich in endemic genera, species, subspecies, and varieties that cannot be found on the mainland. Collectively, the California Pacific Islands are home to 1,239 native plant taxa (Knapp and Randall 2017). The California Channel Islands, a subset of this archipelago, boast approximately 100 endemic species, significantly contributing to more than 10% of California's known flora. The California Channel Islands can be further divided into northern and southern groups, each characterized by its unique composition of flora. The northern group consists of Anacapa, Santa Cruz, Santa Rosa, and San Miguel, while the southern group includes San Clemente, Santa Catalina, Santa Barbara, and San Nicolas (Junak et al. 2012) (Figure 1-1).

Although the vegetation communities on these islands are like those found on the mainland, island-endemic taxa are a prominent feature across most of them. On Catalina Island, vegetation evolved over millions of years without mid-sized or large herbivores. The only land mammals arguably native to Catalina Island are the deer mouse (*Peromyscus maniculatus catalinae*), Catalina Island shrew, Catalina Island fox, which was introduced 6,000 years ago (Sacks et al. 2022), harvest mouse (*Reithrodontomys megalotis catalinae*), and Catalina ground squirrel (*Otospermophilus beecheyi nesioticus*) (Rick et al. 2012). The island's maritime-moderated Mediterranean climate and isolation led to the evolution of numerous island-endemic plant species, all of which developed in the absence of larger herbivores.

Catalina Island's significance extends beyond its ecological riches, as it also holds a wealth of cultural history dating back thousands of years. Evidence of human settlements on the island can be traced back to 6,165 to 5,745 years before present through radiocarbon dating (Radde et al. 2024). Neighboring San Clemente Island and San Nicolas Island have documented settlements from around 8,500 (Gusick et al. 2021) and 8,400 (Rick et al. 2005) years before present, respectively. Indigenous settlements are found along the island's coasts and terraces, with some sites now submerged due to the island's gradual sinking and rising sea levels (Porcasi et al. 1999). Indigenous peoples

actively managed the island's vegetation through fire (Hardiman et al. 2016), while their staple foods primarily consisted of marine resources (Salls 1988, Raab et al. 1994, Porcasi and Fujita 2000). Catalina's Indigenous communities were present during Vizcaino's 1602 visit (Williamson 1903) and endured hardships during conflicts with Russian fur traders (Mead 1899) and the Spanish Mission period. By the 1830s, as deduced from baptismal records at the San Gabriel Mission (The Huntington Library 2006, Chavez 2017), the island's entire indigenous population had either died or relocated to the mainland to work in missions or as ranch hands for private landowners. This displacement occurred because of various factors, including the arrival of European explorers, the spread of diseases, and the impacts of colonization (Williamson 1903).

Spanish exploration led to the island being claimed for the Spanish Empire in the 16th century. During the Mexican ownership period, which began in 1821, the island was primarily used for ranching purposes by various settlers. In 1846, Thomas Robbins became the first private landowner of the island through a Mexican Land Grant. Upon the conclusion of the Mexican–American War in 1848, the United States annexed the Mexican territory of Alta California. The westernmost part of this territory eventually transitioned into the American state of California. The island changed hands several times, eventually falling under the ownership of James Lick in 1864. Lick attempted to develop the island as a resort destination but ultimately sold it to the sons of Phineas Banning in 1891. The Banning Brothers established the Santa Catalina Island Company in 1894, which played a significant role in developing the island's tourism infrastructure, including hotels, attractions, and roads. In 1915, William Wrigley Jr. purchased a controlling interest in the Santa Catalina Island Company. Under his direction, the island saw further development, such as the construction of the Catalina Casino. The Wrigley family continued to own and manage the island until 1975, when they transferred most of their holdings to the Catalina Island Conservancy.

Today, the Catalina Island Conservancy owns and manages approximately 88% of the island, focusing on preserving the island's natural and cultural resources. The Santa Catalina Island Company, a descendant of William Wrigley Jr.'s original company, owns another 11% and focuses on tourism and hospitality services.

Recognizing Catalina Island's unique biological and cultural heritage is crucial as we undertake habitat restoration initiatives. This understanding ensures the protection of its irreplaceable flora, fauna, and human history, all of which contribute to the island's distinct identity. The island's remarkable evolutionary history emphasizes the vital role of conservation efforts in maintaining the region's ecological balance. By prioritizing the preservation of Catalina Island's unique plant and animal life, we safeguard these extraordinary ecosystems for future generations to enjoy, study, and protect. Ultimately, these efforts will secure Catalina Island's future as a sanctuary for both nature and culture, allowing its rich heritage to thrive for years to come.

2.1 ISLAND HISTORY AND HABITAT DEGRADATION

2.1.1 GEOLOGY

Santa Catalina Island's geology dates back over 200 million years, composed mainly of metamorphic rocks formed by ancient geological events. Intense heat and pressure transformed surrounding materials, creating the island's unique foundation. Since its formation, the island has experienced significant erosion, volcanic activity, and changing sea levels, contributing to the diverse landscape we see today.

As summarized in the recent USDA Natural Resources Conservation Service (2008) Soil Survey of Catalina Island, around 65 million years ago, at the end of the Cretaceous period, the rate of subduction and uplift slowed significantly. In the following 40 million years, erosion outpaced any significant geological uplift, carving out the landscape and depositing silt and sandstones across other islands and along the California coast. Approximately 30 million years ago, in the Oligocene period, the California borderland's transform fault system emerged. As tectonic plates transitioned from a head-on collision to the lateral motion now parallel to the coast, numerous faults formed, causing extensive land repositioning. This period marked the beginning of another phase of volcanic activity, which lasted from about 23 million to 5 million years ago, during the Miocene period. During the Miocene Epoch, the portion of Catalina Island we see today was submerged beneath the ocean. Evidence of underwater andesite extrusion sits adjacent to a large quartz diorite pluton on the island's eastern end, labeled as map code “Tmqd” on Figure 2-1.

Catalina Island comprises two primary geological provinces: the igneous and metamorphic formations. The igneous province of rock extends from the eastern end to the western slopes of Black Jack Mountain and Mount Orizaba, marked by the map codes "Tv" and "Tmqd" on Figure 2-1. This younger igneous layer overlies the basement metamorphic formation, spanning from Salta Verde Point in the south to the western end of the island.

The basement rock consists of a mélange of metamorphic components, such as Catalina schist (blueschist and greenschist), amphibolite, serpentinite, hornblende gneiss, muscovite, and talc (USDA 2008). This assemblage, known as the Franciscan Formation, is identified by the map code "Jcs."

The igneous province is further categorized into extrusive and intrusive regions (Rowland 1984). From east of Avalon to Thompson Reservoir, intrusive igneous rock, Catalina Island pluton, quartz diorite is represented by the map code "Tmqd." Moving westward, various andesite rock, a fine-grained extrusive igneous rock that is formed when volcanic magma erupts and crystallizes outside of the volcano, encompasses prominent landmarks like Mount Banning, Mount Orizaba, and Black Jack Mountain, signified by the map code "Tv."

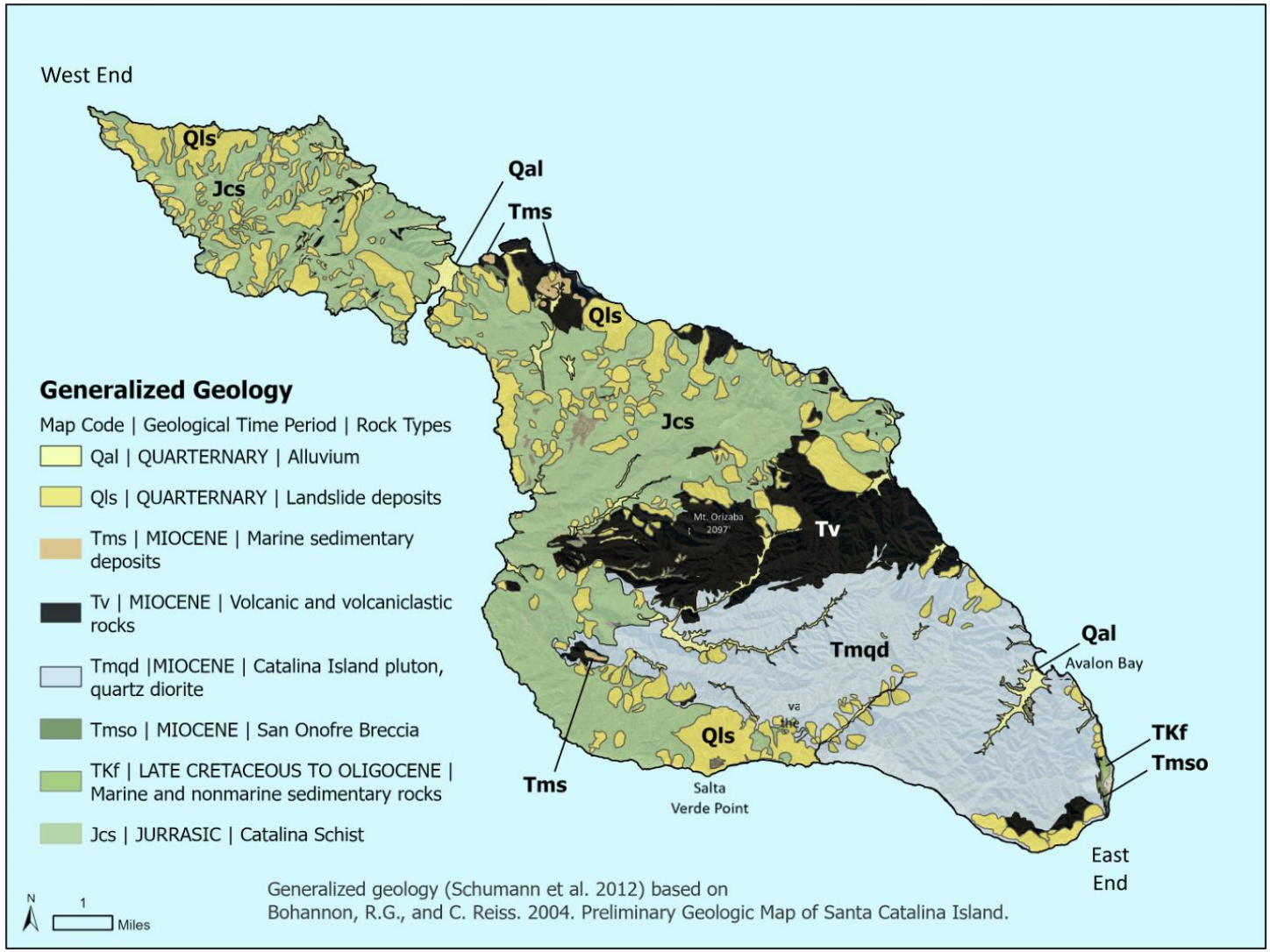

Figure 2-1 Generalized Geology Map for Catalina Island.

During the Quaternary Period, spanning the last 2.58 million years, numerous landslide deposits (Qal) and alluvium accumulations (Qls) formed. This period encompasses the Pleistocene and Holocene epochs, characterized by significant geological and climatic events. The Pleistocene was marked by multiple cycles of glacial growth and retreat, while the Holocene, which began 11,700 years ago, saw the final glacial retreat and the spread of humans across the globe, including to California and the California Pacific Islands. Alluvium (Qls) is found lower in the watershed in larger alluvial plains and at the Isthmus.

Less extensively found are marine sedimentary deposits (Tms), San Onofre Breccia (Tmso) (breccia is rock composed of large angular broken fragments of minerals or rocks cemented together by a fine-grained matrix), and marine and nonmarine sedimentary rocks (Tkf).

2.1.2 TOPOGRAPHY

Santa Catalina Island's landscape is characterized by steep, dissected mountains, and hills, with watersheds that predominantly flow laterally towards the northeast and southwest. The island's highest point is Mount Orizaba, which reaches an elevation of 639 m (2,097 ft) while Silver Peak, located on the western end, stands at 550 m (1,804 ft) (Figure 2-2). The island's watershed structure exhibits an asymmetrical pattern, with longer, more gradual stream systems on the windward side, contrasting with steeper and shorter systems on the leeward side.

The topography of the island was first surveyed between 1853 and 1878 by the United States Coast Survey (USCS) and these maps are commonly referred to as “T-sheets” (see Figure 2-3 to Figure 2-5) (NOAA 2023). Land IQ used aerials from 1942 (Fairchild Aerial Surveys 1943) and 1953 (Pacific Air Industries 1953) to create historic georectified photo mosaics of the island: Figure 2-6 and Figure 2-7. These surveys and historical aerials do not predate the initial impacts by invasive herbivores and ranching practices on the island. Sheep (*Ovis aries*), cattle (*Bos taurus*), and goats (*Capra hircus*) were introduced in the 1820s. However, reconstruction of the historic topography from the T-Sheets and historic aerials when compared to recent surveys may elucidate areas that may have experienced change in the past 150 years, such as recently completed by Longcore and Ethington (2023) for selected indigenous village sites in southern California.

The north-facing, channel-facing side of the island is generally leeward, along with the north-facing slopes of Middle Canyon and Bullrush Canyon (Figure 2-8). These valleys bend westward due to active tectonic forces influencing the southeastern portion of the island (Legg et al. 2004). Major valleys on the windward side, such as Avalon Canyon, Middle Canyon, Cottonwood Canyon, Cape Canyon, Silver Canyon, and Bullrush Canyon, are characterized by significant alluvial deposits, narrow hillslopes, and flood deposits (USDA 2008).

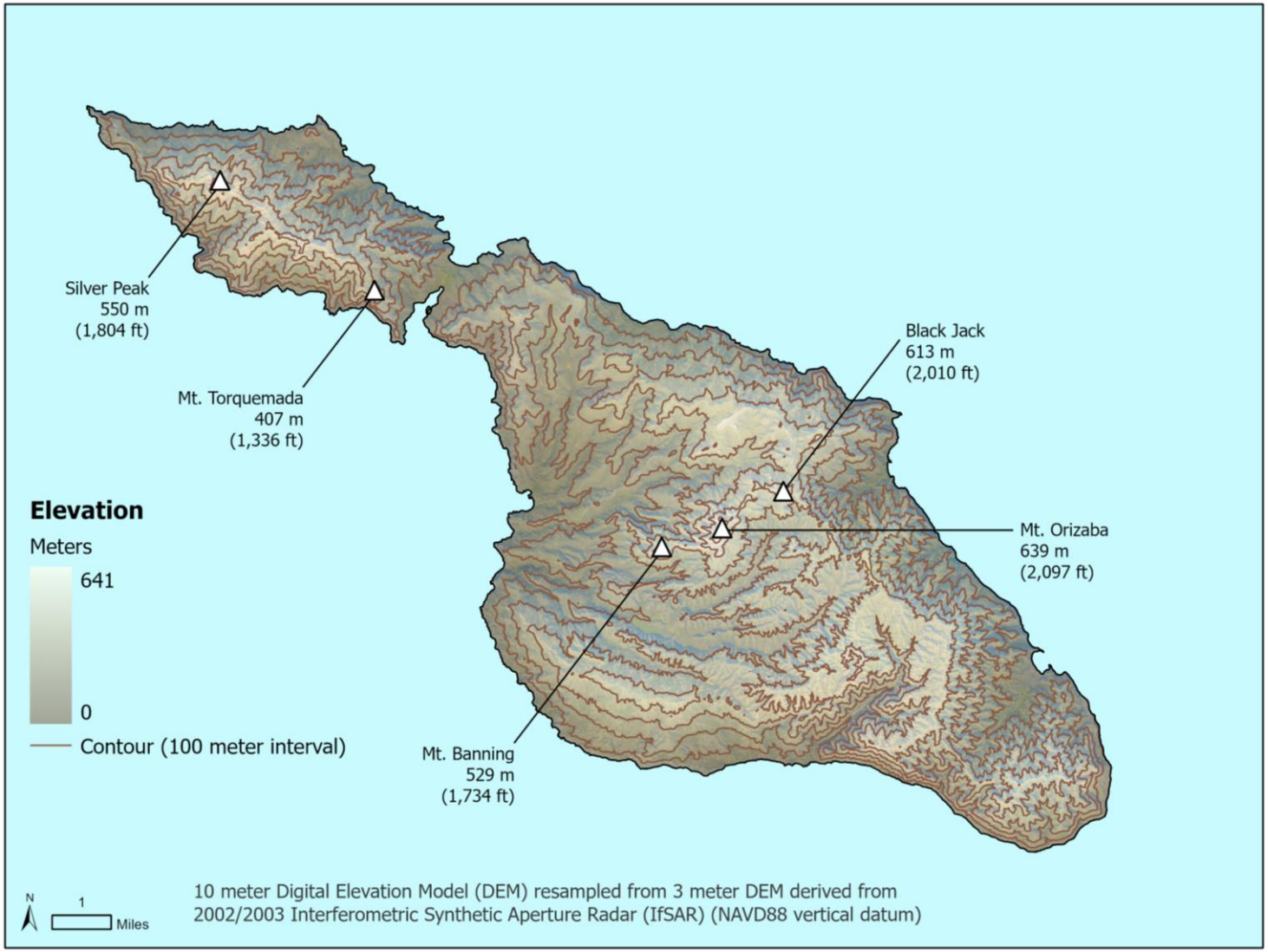

Figure 2-2 Elevation.

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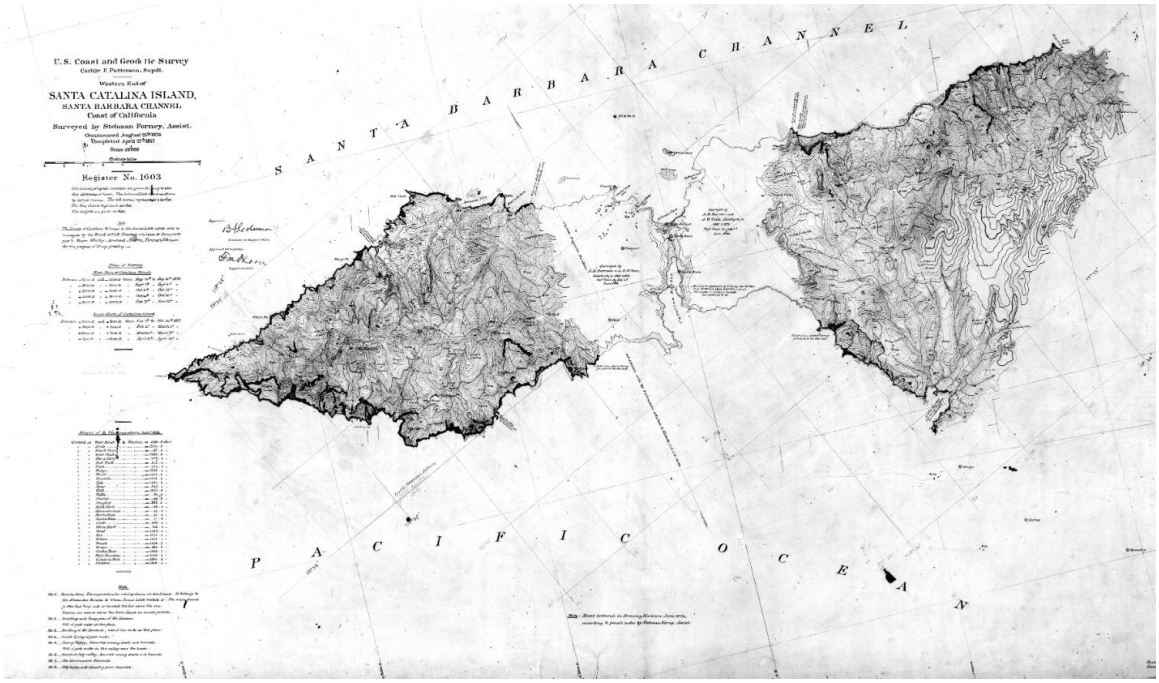


Figure 2-3 Western End of Santa Catalina T-Sheet 1603, Surveyed 1876 to 1877.
(USDA 2023).

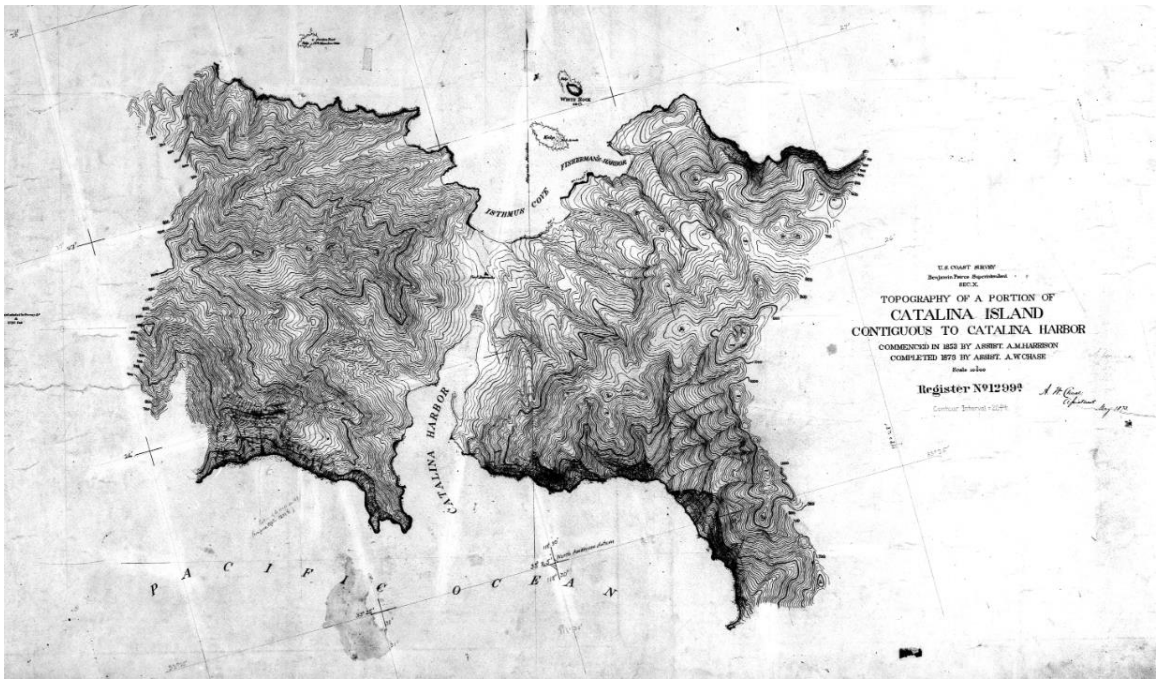


Figure 2-4 Western End of Santa Catalina T-Sheet 1603, Surveyed Between 1853 to 1873.
(USDA 2023).

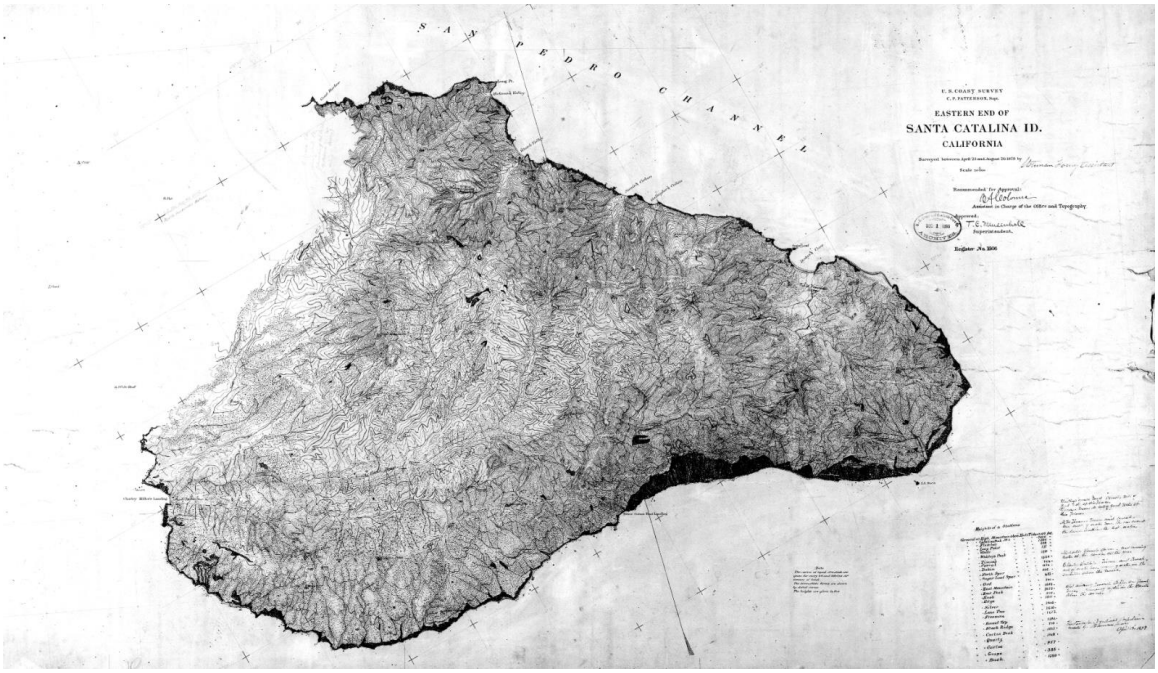


Figure 2-5 Eastern End of Santa Catalina T-Sheet 1603, Surveyed in 1878.
(USDA 2023).

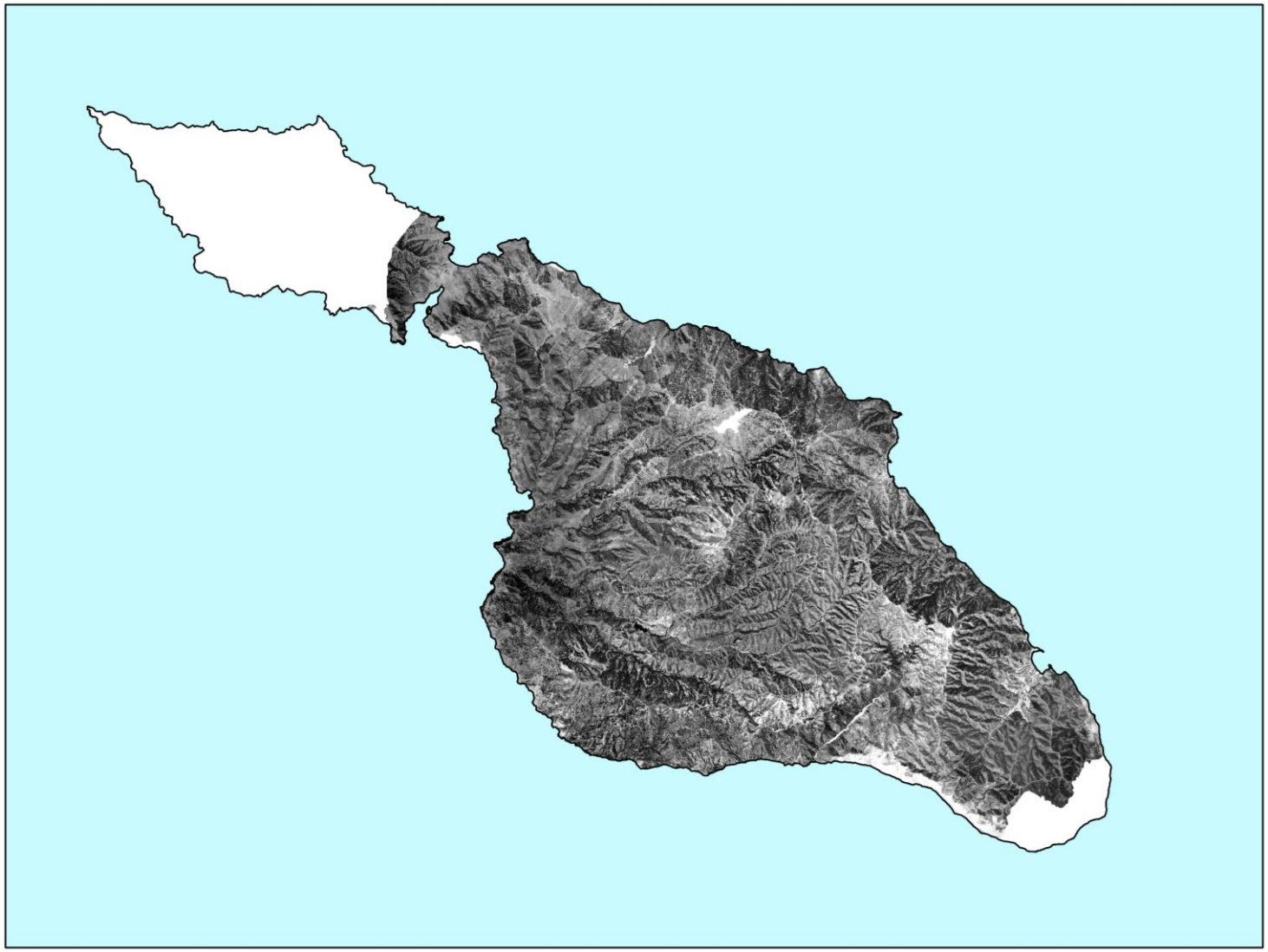


Figure 2-6 Aerial Photomosaic from 1943.

The historic aerials (Fairchild Aerial Surveys 1943) are courtesy of UCSB Library Geospatial Collection.

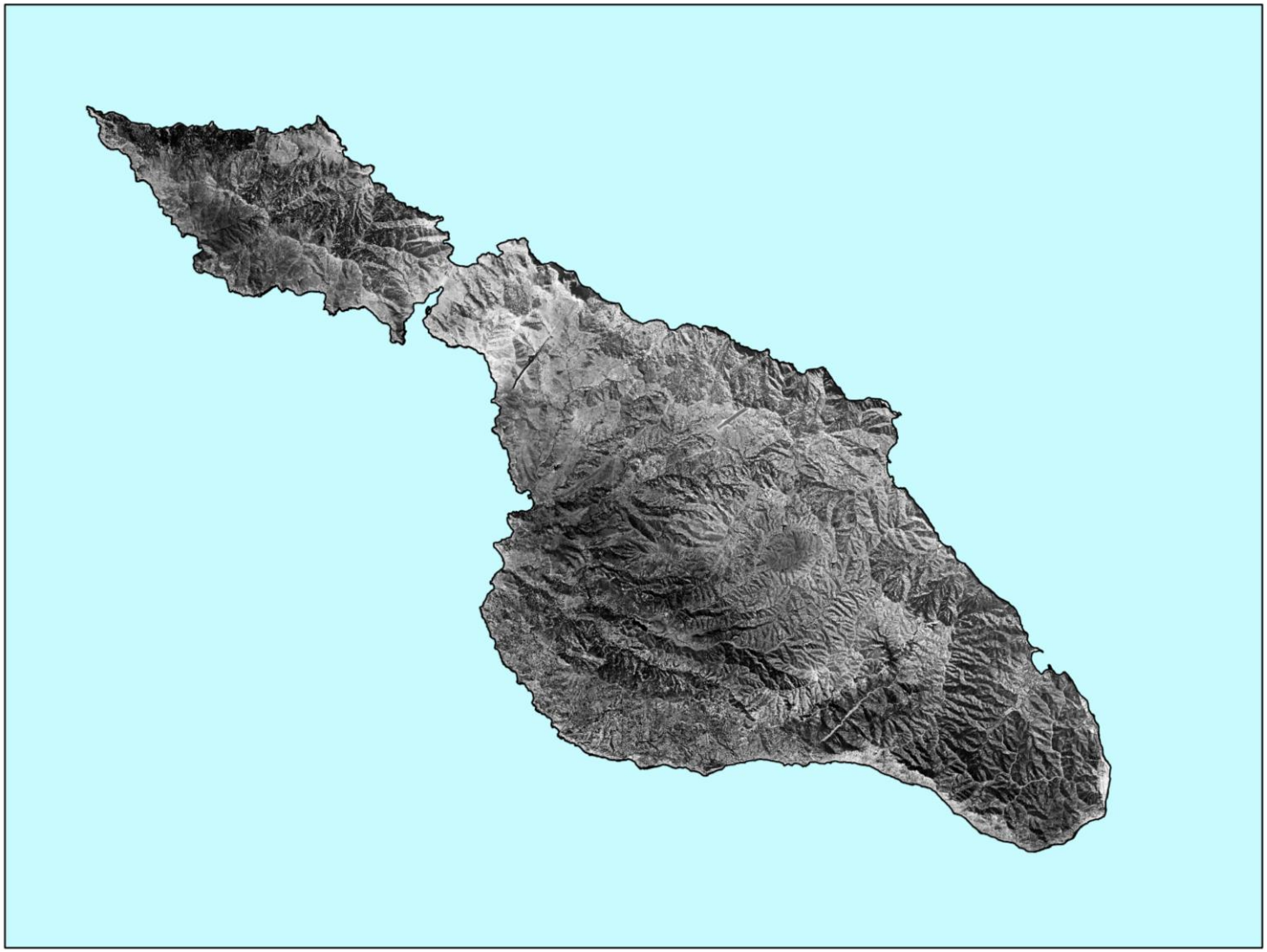


Figure 2-7 Aerial Photomosaic from 1953.

The historic aerials (Pacific Air Industries 1953) are courtesy of UCSB Library Geospatial Collection.

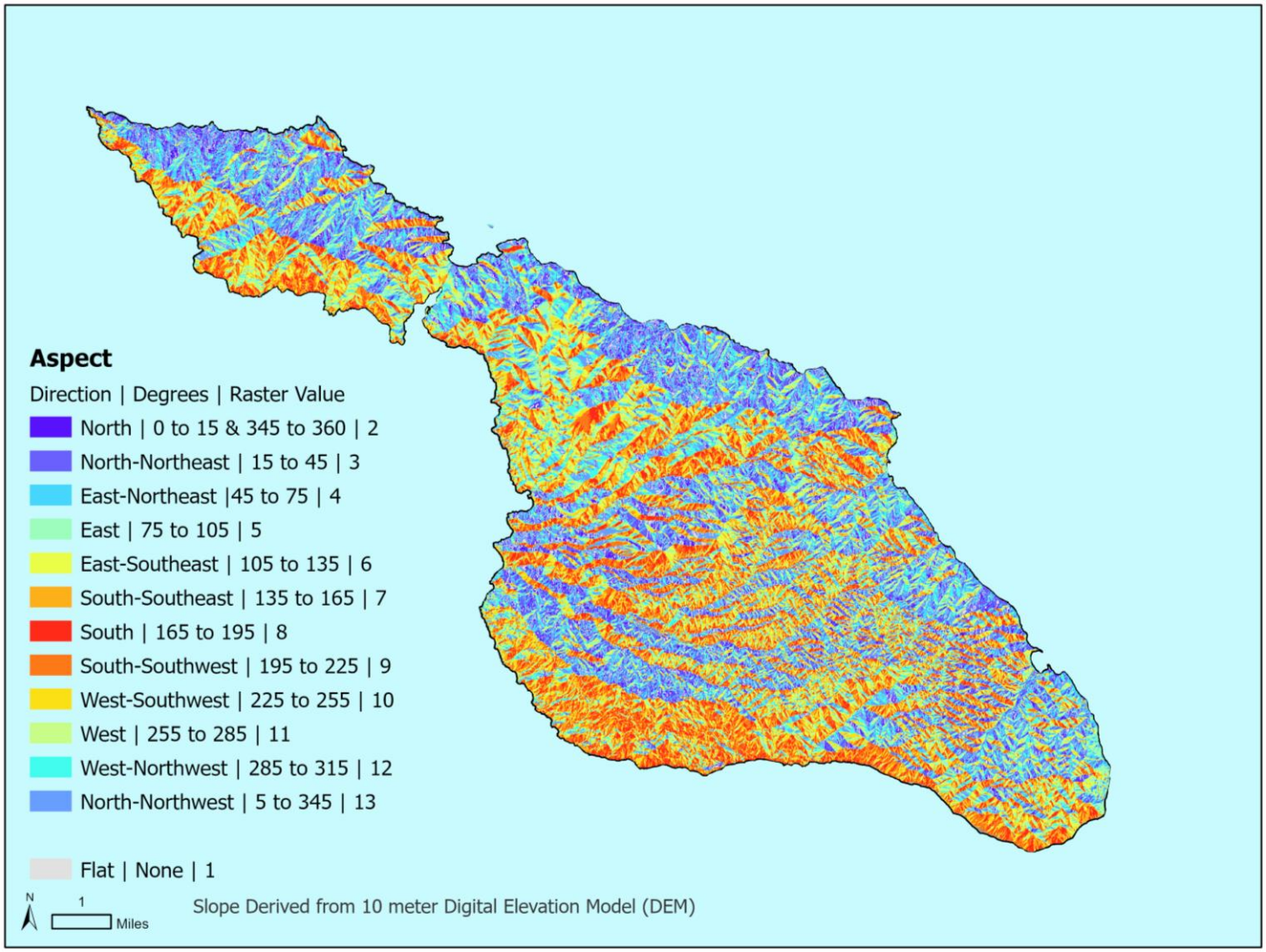


Figure 2-8 Aspect of Slope.

Steep side slopes (Figure 2-9) often terminate in narrow drainageways. In certain regions, particularly at the island's eastern end, these drainageways exhibit a distinctive pattern, forming curved, continuous S-shaped structures as they collect material from the side slopes. This unique curving feature signifies that the side slopes are eroding at a more rapid pace than the material being transported by the drainageways directly beneath them. Moreover, this characteristic is typical of the quartz-diorite parent material, which is more durable when compared to the metamorphic Catalina schist rock. Some of these drainageways are experiencing an increase in their base levels or a filling sequence, further contributing to the dynamic nature of the island's geological landscape. The northern coast has many large alluvial deposits that meet the shoreline (USDA 2008).

Human activities have significantly altered numerous drainageways across the island's valleys. Historically, various check dams and water reservoirs were constructed to support ranching operations, with many of these retaining water year-round. Examples include Cape Canyon, Buffalo Springs, and the Upper and Lower Buffalo Corral Reservoirs. There are several more unnamed dams in Middle and Cape Canyons. Middle Canyon was dammed to help maintain sufficient hydrostatic pressure in the interior aquifer, to increase the reliability of the groundwater supply for the island's municipal needs (USDA 2008). Potable water is also provided through a desalination plant.

Perennial streams and seeps can be observed throughout the island for several weeks following the rainy season, with some areas in Bullrush, Cottonwood, and Middle Canyons with surface water throughout the year, except in periods of extended drought. Echo Lake, the island's only natural lake, sits at an elevation of approximately 396 m (1,300 ft) (USDA 2008) (Figure 2-10).

2.1.3 CLIMATE

Santa Catalina Island exhibits a Mediterranean climate featuring warm, dry summers and cool, moist winters, often accompanied by year-round fog. This climate is primarily influenced by ocean currents and mainland pressure gradients. The prevailing northwesterly winds and subtropical storms drive the ocean currents, which flow south around Point Conception and follow the California coast as it curves eastward. During summer and fall, subtropical storms push warm air and water northward over the mainland (USDA 2008).

The island experiences considerable interannual rainfall variation and multi-year trends of wetter or drier periods, with a 100-year average precipitation of 312 mm (12.3 in.) (Figure 2-11). Orographic factors significantly affect rainfall distribution across the island, causing higher rainfall at elevated locations (Figure 2-12). Nearly all precipitation occurs between November and April (Figure 2-13), with rare occurrences of summer thunderstorms.

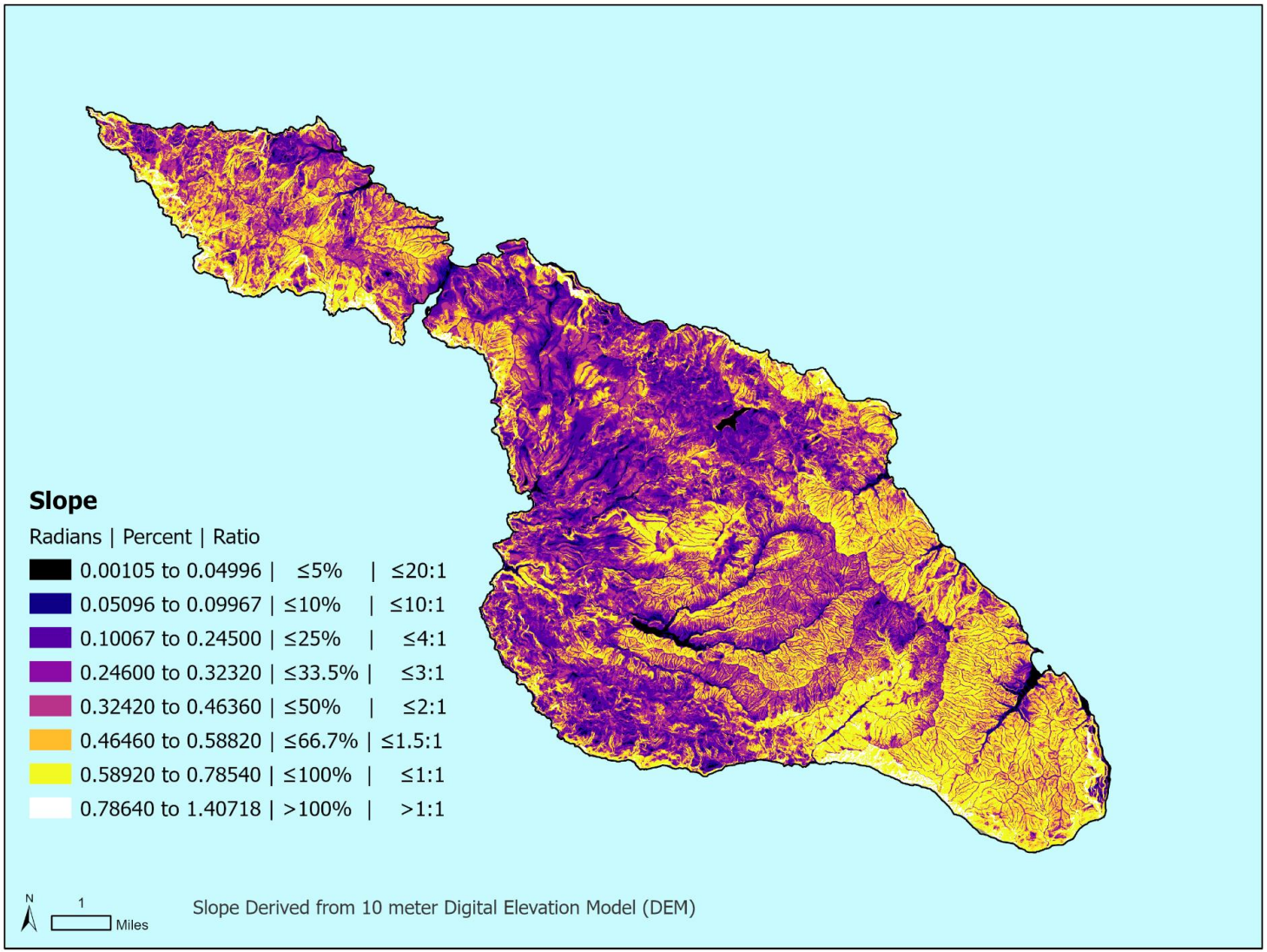


Figure 2-9 Slope Steepness.

Figure 2-10 View of Echo Lake.

Photo Taken April 28, 2023, from the main road looking north. The island's only natural lake, which functions as a vernal pool.

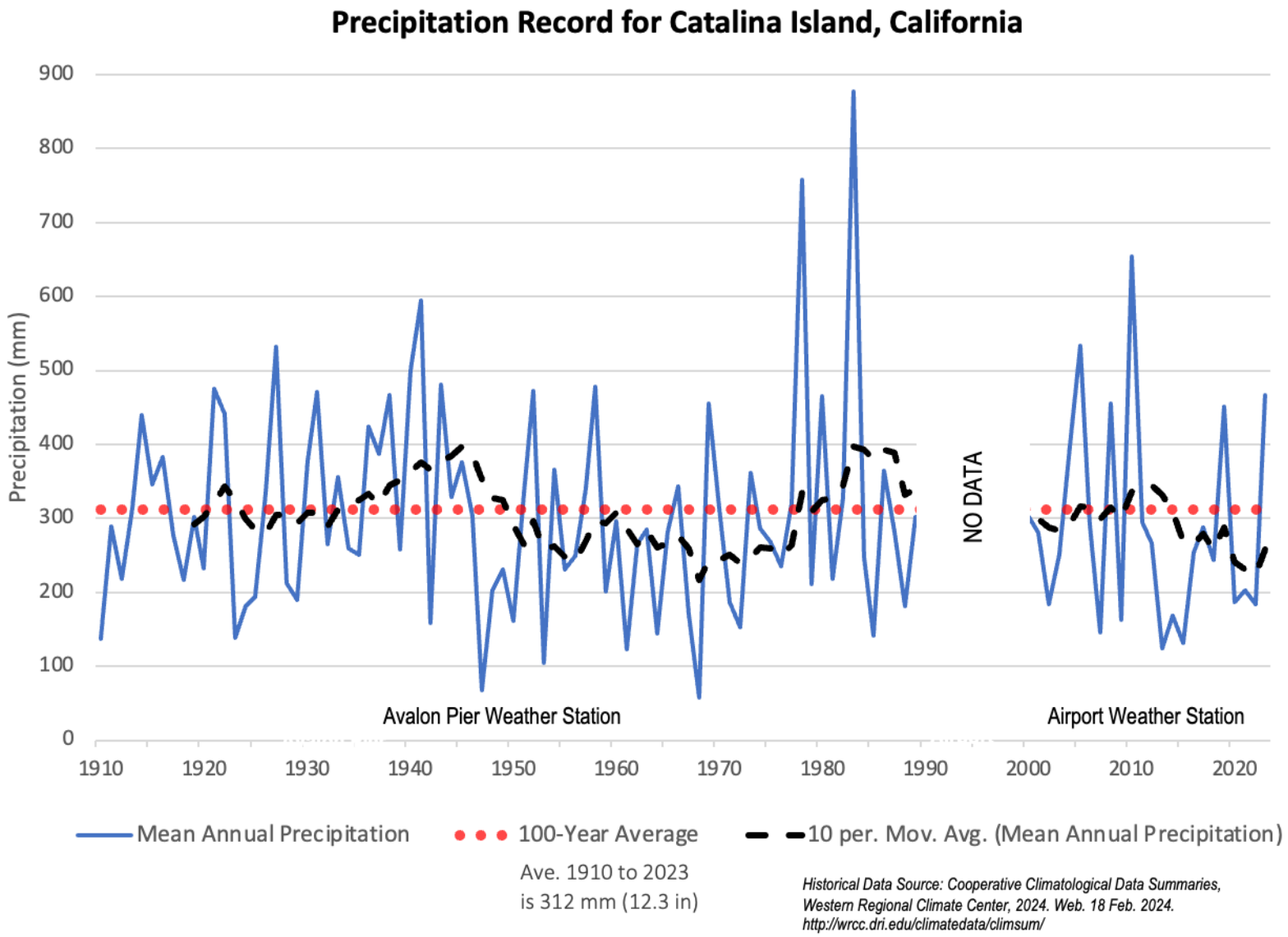


Figure 2-11 Precipitation Record for Catalina Island.

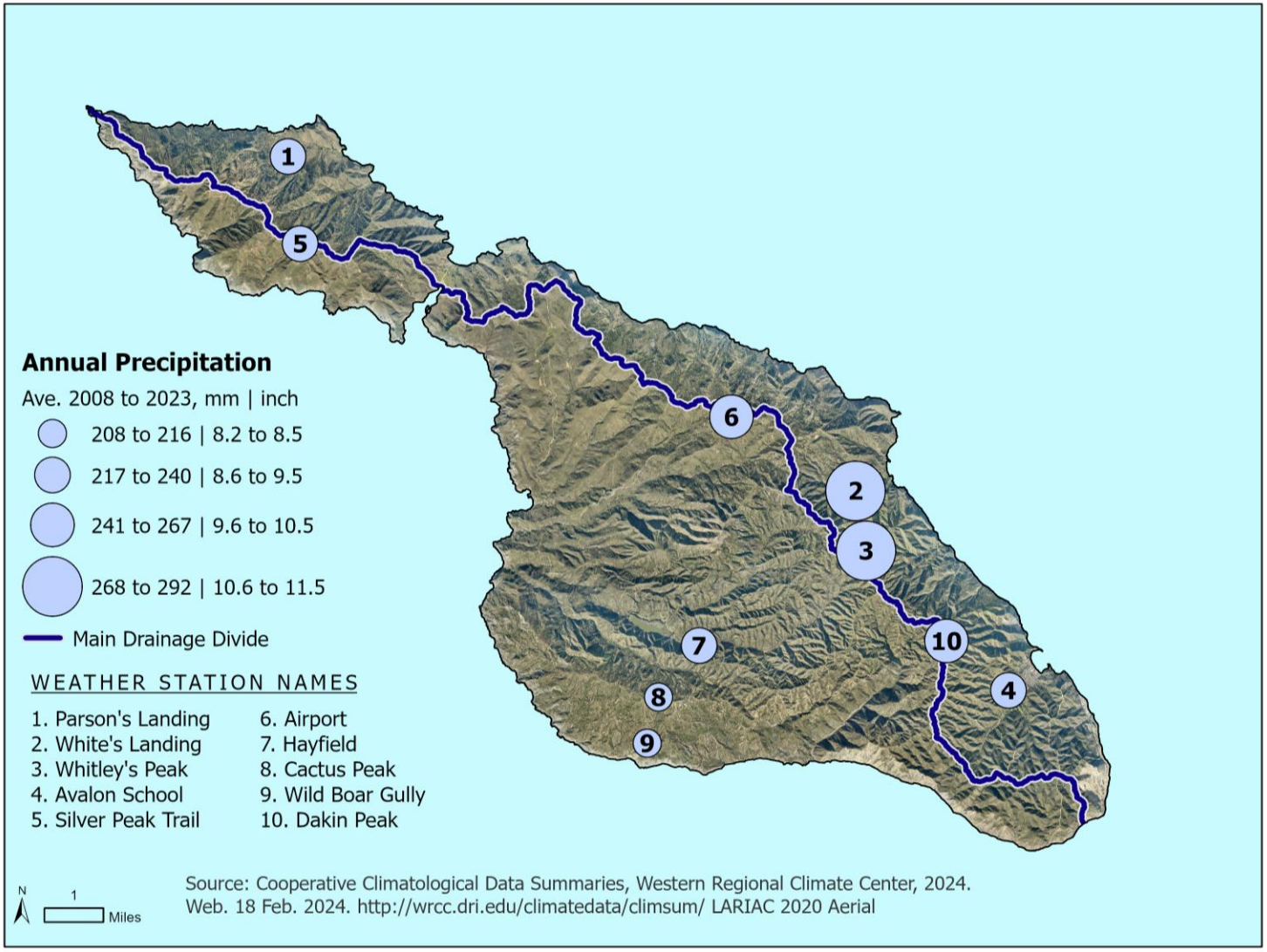


Figure 2-12 Island Weather Station Average Precipitation

Monthly average layers were provided by UCSD Scripps Institution of Oceanography (Clemesha et al. 2021). These 1-km resolution layers were derived from a time series of Geostationary Operational Environmental Satellites (GOES) imagery spanning from 1996 to 2018.

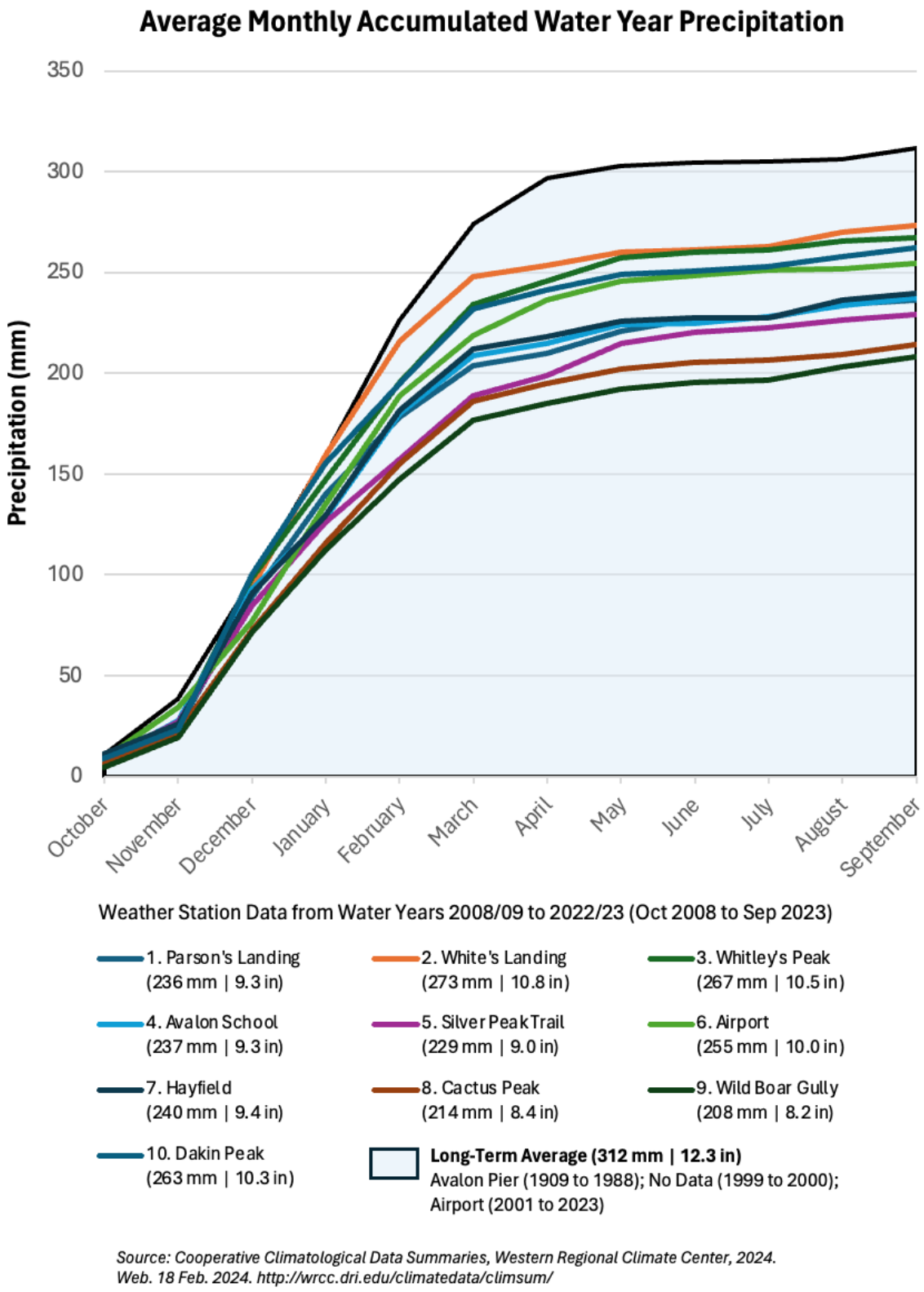


Figure 2-13 Island Weather Station Accumulation of Precipitation in a Water Year.

The island's southern coast is often shrouded in fog as prevailing fog banks sweep in from the Pacific Ocean, while the northern leeward side remains clear. Fog layers can occur at limited elevations, creating diverse weather conditions at different altitudes (Figure 2-14). The island's topography also influences the amount of solar radiation reaching the surface (Figure 2-15), resulting in notably more mesic conditions on north-facing slopes (Paudel et al. 2016). North-facing slopes receive less sunlight and solar radiation than south-facing slopes, leading to cooler air temperatures (15 to 17°C or 59 to 63°F) and isothermic soil temperature regimes. Isothermic regimes can also be found on south-facing slopes where island woodland, island scrub oak chaparral or island chaparral provide adequate shade and cooling, creating more stable temperature conditions like those found in areas with less direct sunlight exposure. Remaining areas of the island experience thermic temperature regimes with warmer and more variable annual air temperatures (16 to 22°C or 61 to 72°F) (USDA 2008).

The interplay of topography, coastal profile, and large atmospheric pressure gradients generates the regional "coastal eddy" phenomenon, which is more pronounced around Point Conception and the northern Channel Islands. Santa Catalina Island is affected by strong northwest winds that drive onshore airflow (Figure 2-16). Thick, low fog often accompanies periods of heating and cooling when the eddy effect weakens and stabilizes under the influence of high-pressure systems over the nearby Mojave Desert (Clemesha et al. 2021).

The Channel Islands, including Santa Catalina, are subject to offshore Santa Ana winds from the northeast. These winds arise from a relative low-pressure system over the eastern Pacific Ocean near southern California and a high-pressure system over the Great Basin (Muhs et al. 2007), producing northerly and northeasterly winds across the Mojave Desert, southern California coast, and Baja California.

Santa Catalina Island has a warmer and less windy climate compared to San Miguel Island, the coolest, windiest, and foggiest of the Channel Islands. Frost occurs on all the Channel Islands but is short lived. On Santa Catalina Island, frost occurs on a few days annually, typically during brief morning periods in interior valleys, such as Bullrush Canyon, Middle Ranch Valley, and Escondido Ranch. Each winter, freezing temperatures briefly occur in these valleys and deep drainageways. Fog, although more common along the coast, can also form in low interior valleys due to local temperature inversion layers. Frost-free periods span from 355 days in interior valleys and higher peaks to 365 days in coastal areas, making the latter less susceptible to frost (USDA 2008).

Like rainfall, wind is significantly influenced by the topography of the island. Weather stations on the leeward side had average windspeeds of 0.8 to 1.1 meters per second, m/s (1.8 to 2.5 miles per hour, mph), while those on the windward side were as high as 3.1 m/s (6.9 mph) average (Figure 2-17 and Figure 2-18). The airport location, although technically on the leeward side, is located at the exposed ridge of the island and has higher average windspeeds than typical leeward locations.

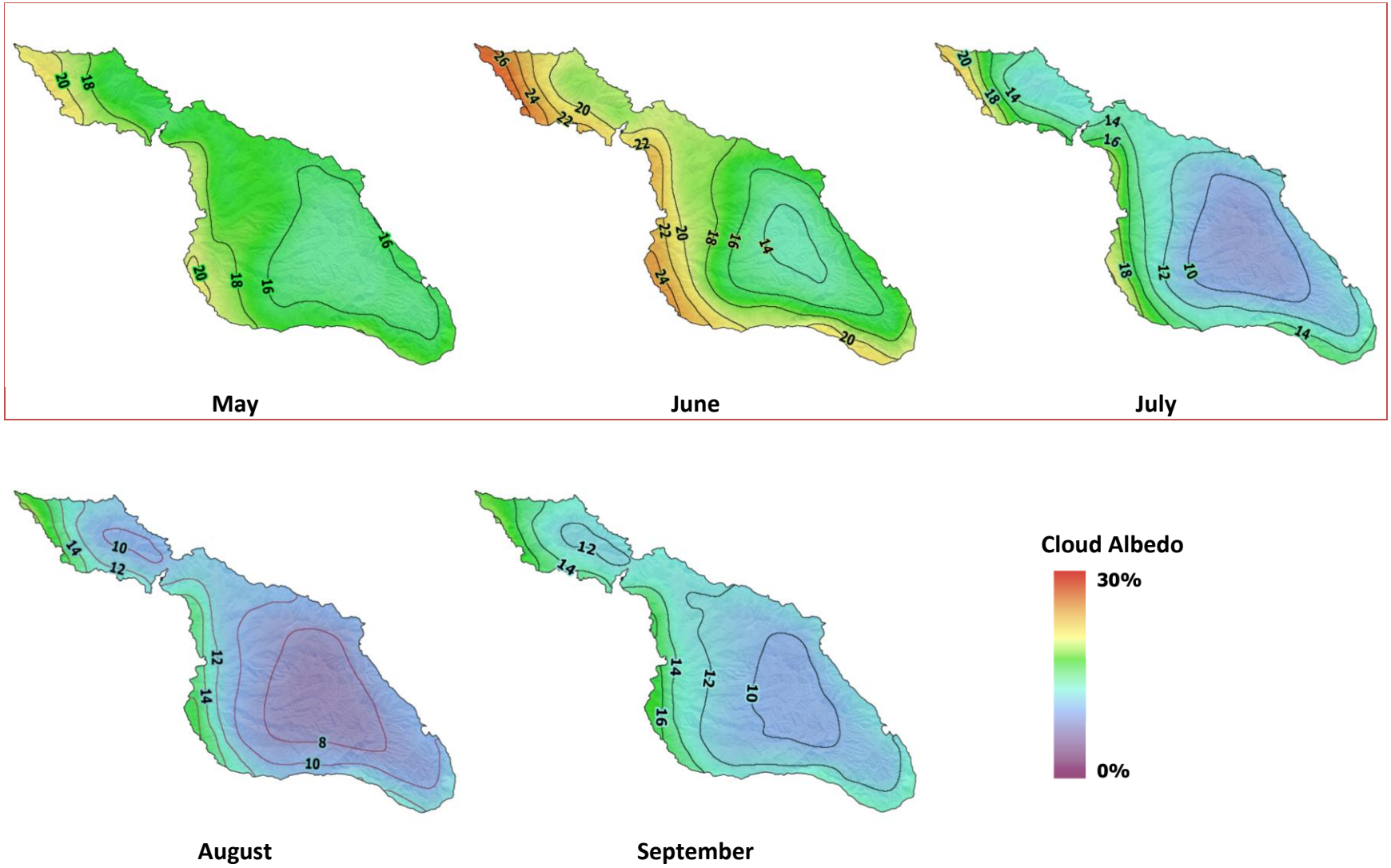


Figure 2-14 Monthly Mean Cloud Albedo (Proxy for Cloudiness) for 1996 to 2018.

Monthly average layers were provided by UCSD Scripps Institution of Oceanography (Clemesha et al. 2021). These 1-km resolution layers were derived from a time series of Geostationary Operational Environmental Satellites (GOES) imagery spanning from 1996 to 2018.

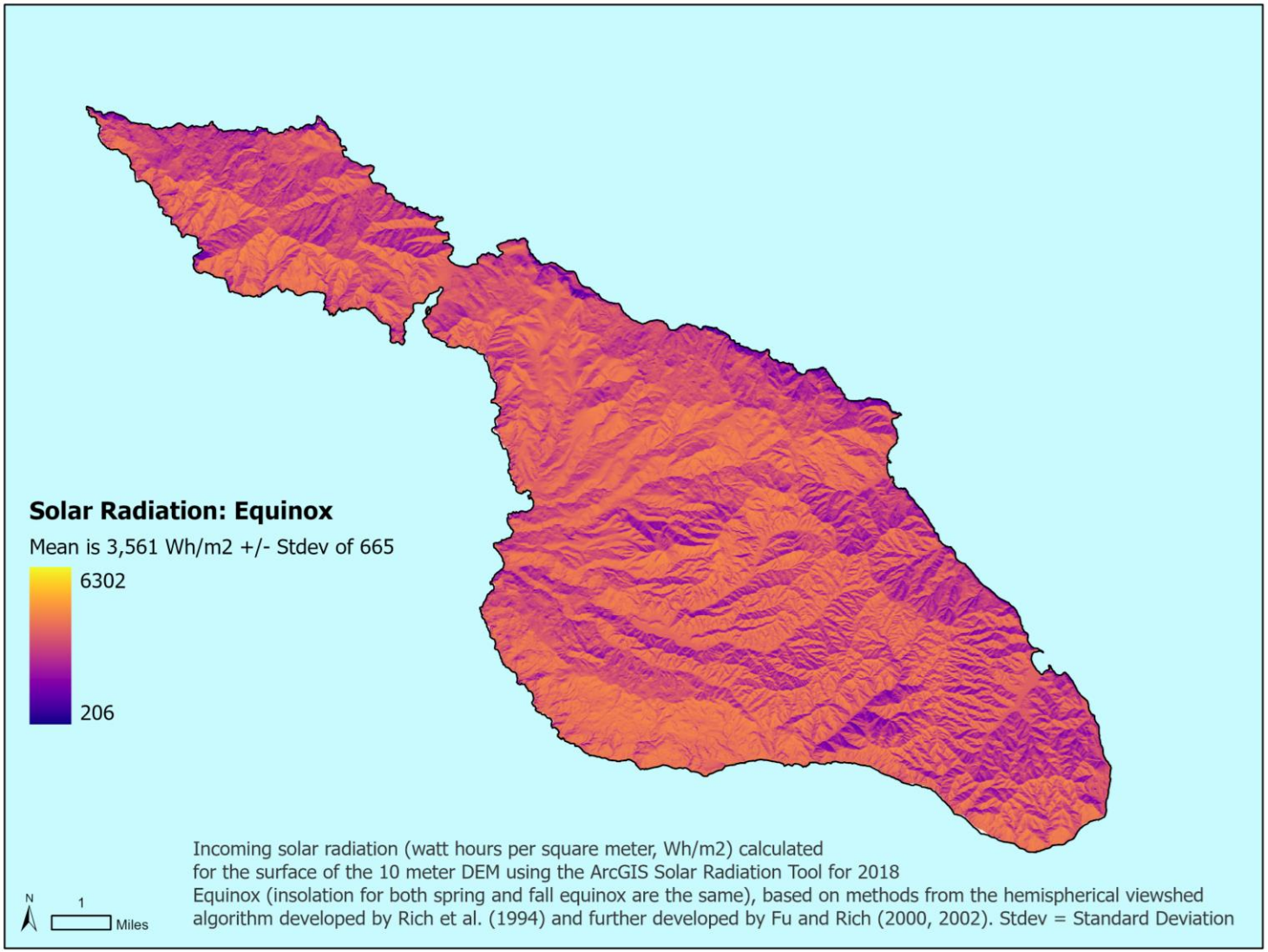


Figure 2-15 Solar Radiation Received During Equinox.

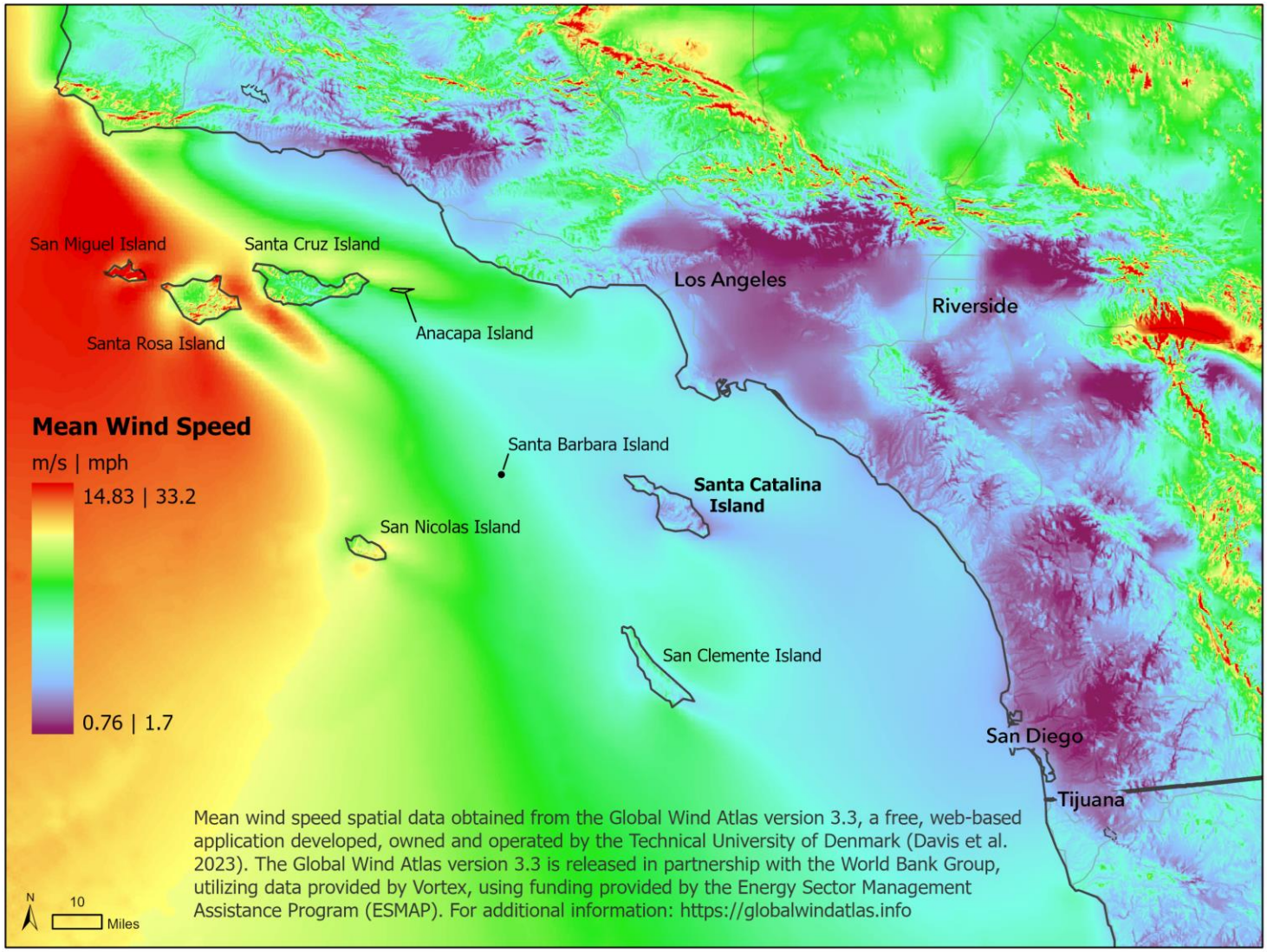


Figure 2-16 Mean Wind Speed in the Southern California Bight.

Source: Davis et al. 2023.

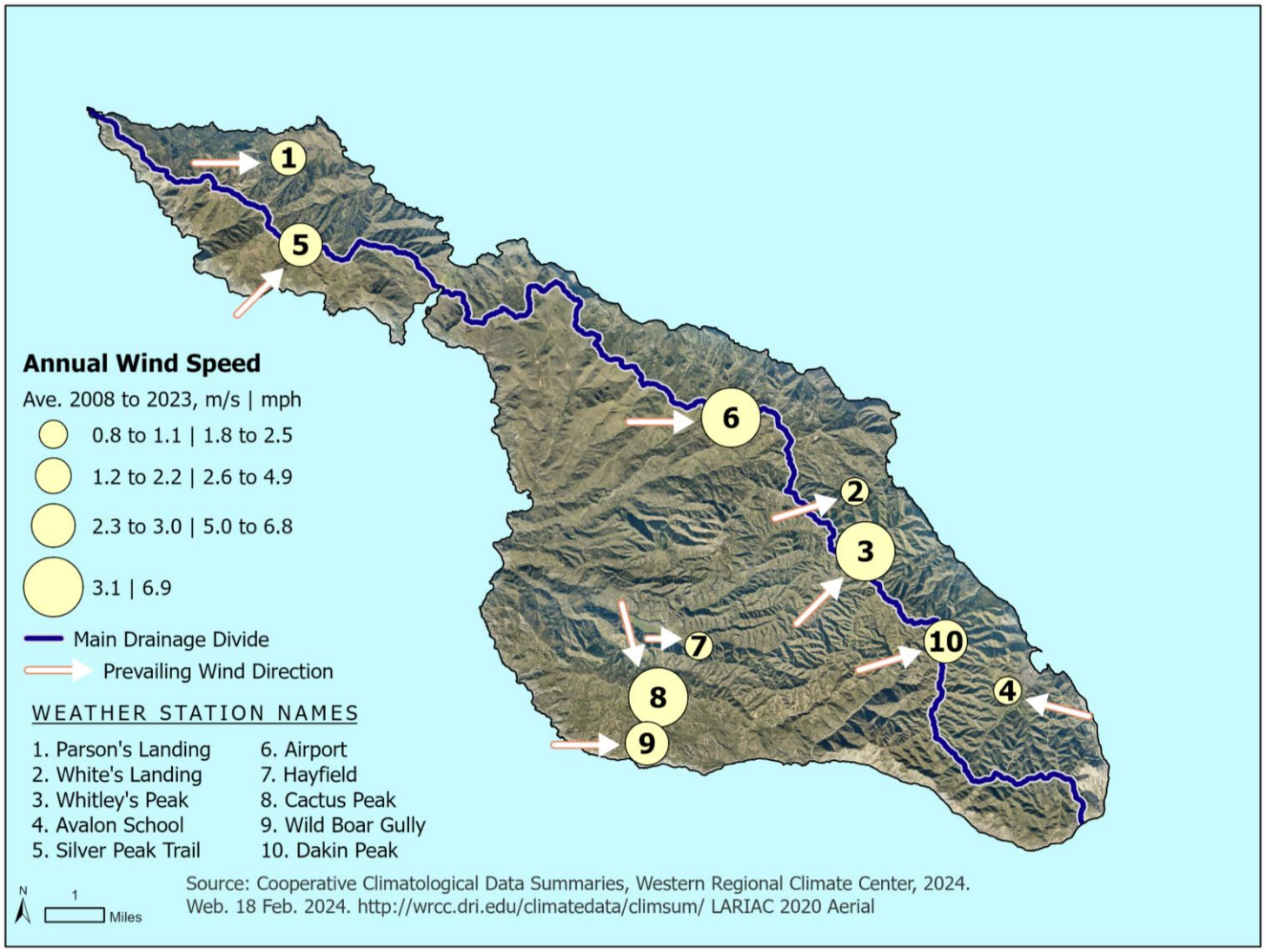
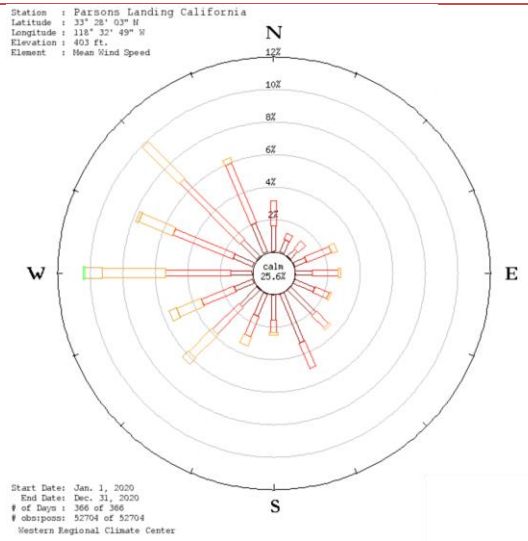
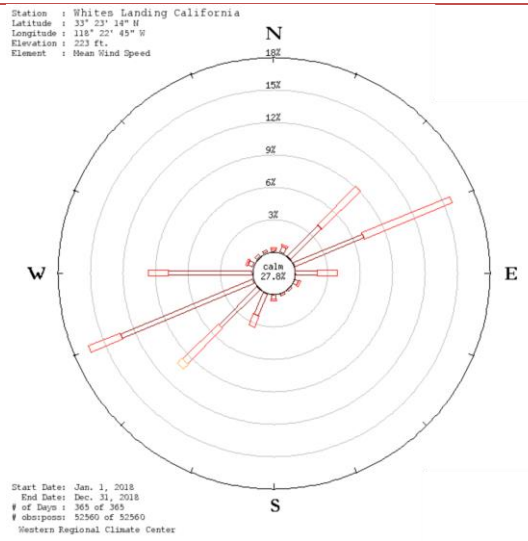


Figure 2-17 Island Weather Station Average Annual Wind Speed and Prevailing Wind Direction.

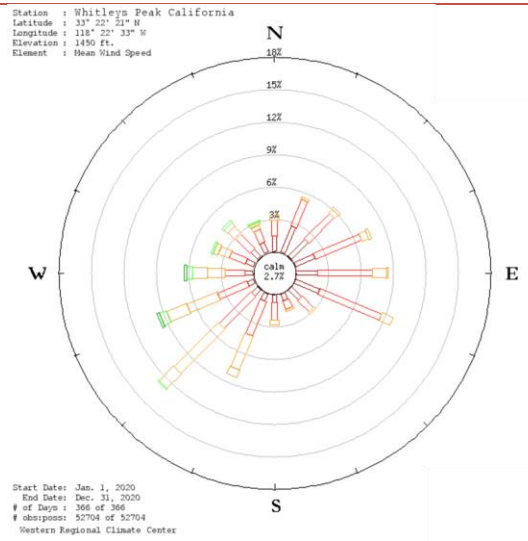
Source: Cooperative Climatological Data Summaries, Western Regional Climate Center, 2024. Web. 18 Feb. 2024. http://wrcc.dri.edu/climatedata/climsum/



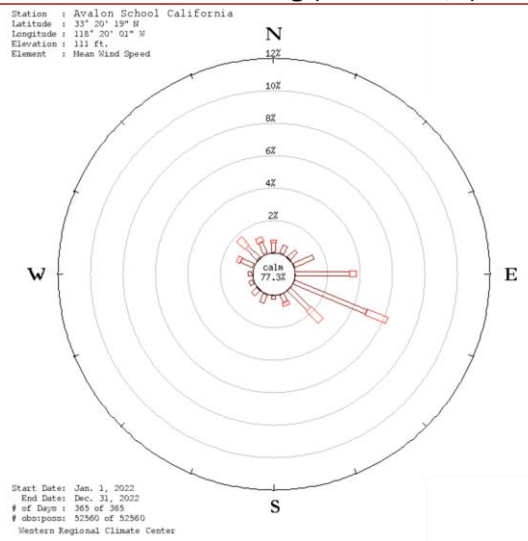
1. Parson's Landing (Ave. 1.6 m/s)



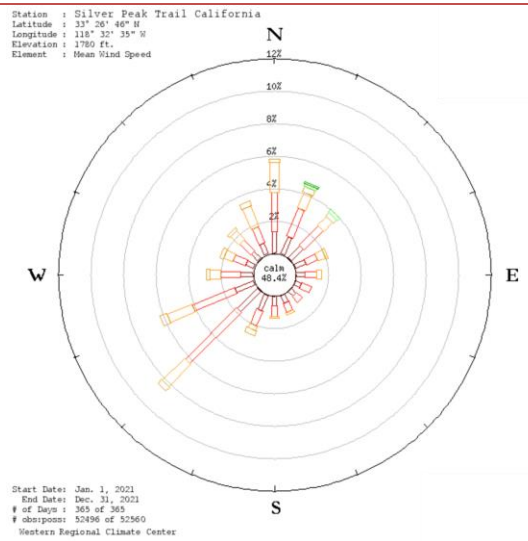
2. White's Landing (Ave. 1.1 m/s)



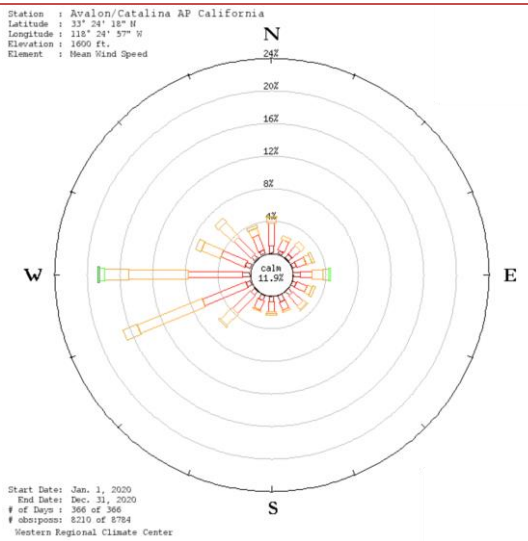
3. Whitley's Peak (Ave. 3.1 m/s)



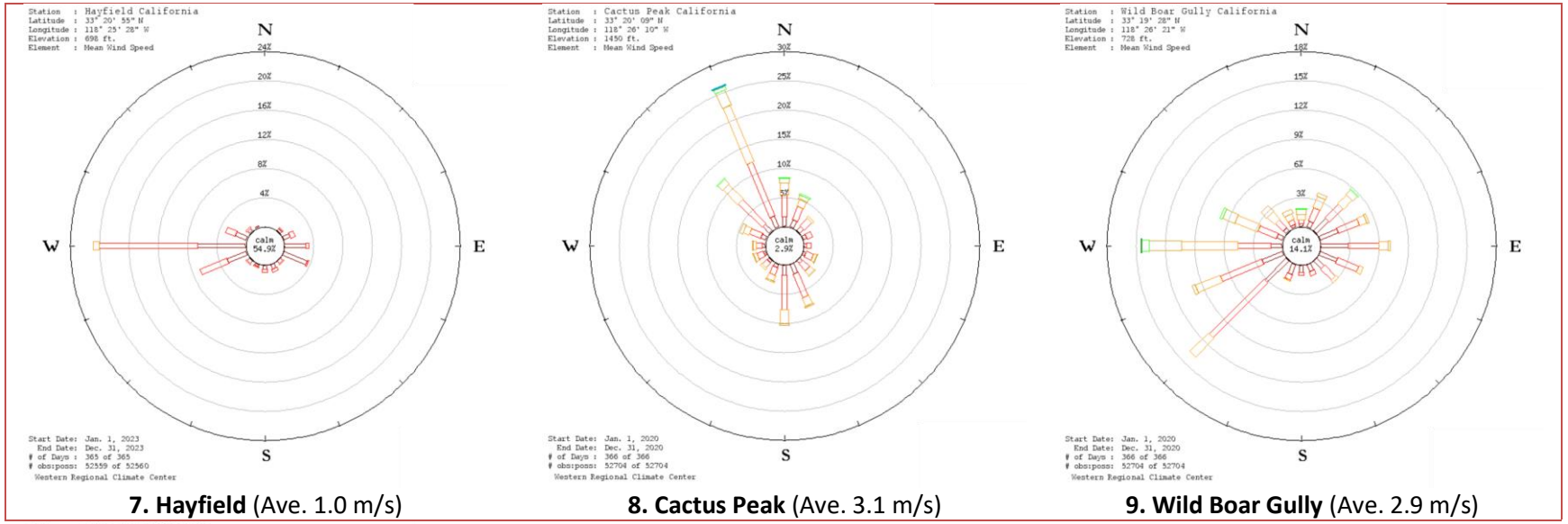
4. Avalon School (Ave. 0.8 m/s)



5. Silver Peak Trail (Ave. 2.3 m/s)



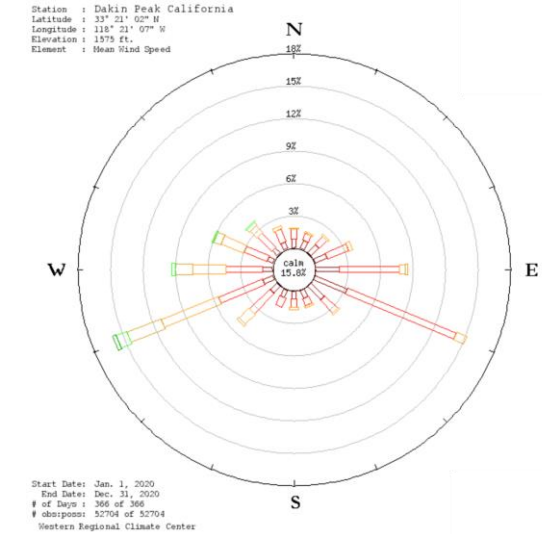
6. Airport (Ave. 3.1 m/s)



7. Hayfield (Ave. 1.0 m/s)

8. Cactus Peak (Ave. 3.1 m/s)

9. Wild Boar Gully (Ave. 2.9 m/s)



10. Dakin Peak (Ave. 2.6 m/s)

Beaufort Wind Speed Scale

	Description	Speed (m/s)
0	Calm	0 to 0.9
1	Light Air	0.9 to 1.8
2	Light Breeze	1.8 to 3.6
3	Gentle Breeze	3.6 to 5.85
4	Moderate Breeze	5.85 to 8.55
5	Fresh Breeze	8.55 to 11.25
6	Strong Breeze	11.25 to 14.4
7	Near Gale	14.4 to 17.55
8	Gale	17.55 to 21.15
9	Strong Gale+	21.15+

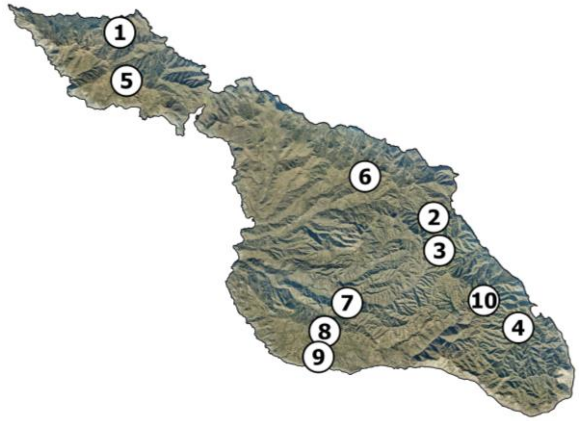


Figure 2-18 Island Weather Station Wind Rose Charts Showing Prevailing Winds from the West.

Source: Cooperative Climatological Data Summaries, Western Regional Climate Center, 2024. Web. 18 Feb. 2024. http://wrcc.dri.edu/climatedata/climsum/

2.1.4 SOIL

The soils of Santa Catalina Island are a result of the interplay between diverse geological, topographical, and climatic factors. The island's geology, which includes volcanic, metamorphic, and marine sediments, sets the stage for the formation of distinct soil types through the process of soil genesis. In combination with the island's steep topography and contrasting microclimates on its leeward and windward sides, these factors contribute to a rich mosaic of soil characteristics and properties.

Soils, coupled with geologic condition and landscape position, are critical in determining the appropriate target vegetation type and treatments for restoration especially in areas of California that have been historically disturbed and may lack clear indications of pre-European native plant communities. Soil texture is a soil characteristic that is especially valuable for understanding soil behavior and management of the land (Brady and Weil 2002).

Soil genesis is the process of soil formation and development over time, which involves the transformation of parent material into a complex and dynamic mixture of minerals, organic matter, and living organisms (Soil Survey Staff 1999). This process is driven by various soil-forming factors, including parent material, climate, topography, biological activity, and time. These factors interact in unique ways to influence the physical, chemical, and biological properties of the soil, ultimately shaping the characteristics of the resulting soil profile. The distribution and diversity of soil types found in different environments and is essential for understanding the functioning of terrestrial ecosystems and their response to environmental change.

Since 1975, the United States National Cooperative Soil Survey Program has used a systematic approach to classifying soils based on their properties and characteristics called Soil Taxonomy. This soil taxonomy framework was used to prepare the Soil Survey of Santa Catalina Island, published in 2008 (USDA 2008). There was also an unpublished Soil Survey of the island prepared by the US Soil Conservation Service in 1955, which is presented in Appendix D. The 2008 Soil Survey is a more useful document than the 1955 Soil Survey because the pre-1975 classification system could not be consistently applied by soil scientists (Ditzler and Ahrens 2006). And for the development of potential island plant species distribution models in Appendix D, the 2008 Soil Survey had more explanatory value than the 1995 Soil Survey. Out of 94 plant distribution models, the 2008 Soil Survey Map Units were a significant explanatory variable for 84 models, whereas the 1955 Soil Survey Map Units were only significant for 2 models.

Using the USDA Soil Taxonomy (Soil Survey Staff 1999), soils can be classified into several levels: order, suborder, great group, subgroup, family, and series. There are 12 soil orders, but not all occur on Catalina Island. Soil orders are frequently defined by a single dominant characteristic affecting soils in that location—for example, the prevalent vegetation (Mollisols, Histosols), the type of parent material (Andisols, Vertisols), the climate variables such as lack of precipitation (Aridisols), or the presence of permafrost (Gelisols). Also significant in several soil orders is the amount of physical and chemical weathering present (Oxisols, Ultisols, Alfisols, Inceptisols, Entisols) and/or

the relative amount of soil profile development that has taken place. These soil orders can be subdivided into suborders and great groups. Great groups are a midlevel classification point in the hierarchy of soil taxonomy.

CATALINA ISLAND SOIL ORDERS

Entisols, Inceptisols, and Mollisols are Soil Orders on Catalina Island that are weathered from igneous rocks, which include volcanic and metamorphic rocks. The exception are the soils formed by the construction of the airport, which are fill material from Catalina schist. The Alfisols on Catalina Island are primarily slope alluvium over residuum weathered from Catalina schist, which is a metamorphic rock, and/or metasedimentary rock (e.g., slate).

The evolution of the contemporary landscape occurred during the Late Pleistocene and Holocene Epochs. Highly evolved soils are typically found on landforms that have remained stable over time. The hills and mountains in the survey area contain materials that began weathering during the Late Pleistocene, resulting in the formation of characteristic soil features such as clayey argillic or cambic horizons and mollic epipedons. The depth of these soils largely depends on the weathering susceptibility of the parent material. Soils derived from volcanic materials, tend to be shallow due to the slow weathering rate of their bedrock, while those derived from metamorphic rocks (e.g., Catalina schist) typically exhibit greater depth because of their faster weathering process. The volcanic and metamorphic rock types also weather into different types of clay minerals and contain different ratios of cations (USDA 2008).

An essential aspect of soil formation on Santa Catalina Island is the contribution of eolian parent material from mainland deserts across the eastern Pacific Ocean (Muhs et al. 2007). Less than 5,000 years ago, eolian deposition of medium and finer silt particles originating from the Mojave Desert in California. These particles, measuring less than 0.5 microns, are most abundant in the atmosphere during seasonal Santa Ana winds. Once deposited, these materials can become local sources of PM-10. Disturbances to these fine soil material deposits can significantly alter the soil profile on Santa Catalina Island (USDA 2008).

Determining the relative age of soils can be a complex task, as various factors, such as climate, geology, and biological activity, influence soil development. Additionally, different regions may experience unique conditions affecting soil formation rates. However, in general, we can consider a rough chronological order of soil orders based on their degree of development, from youngest to oldest for the five soil orders represented on Catalina Island:

1. **Entisols** - poorly developed soils with minimal soil horizons (major component of 5 map units; minor component of several map units)
2. **Inceptisols** - weakly developed soils with some identifiable horizons (major component of 6 map units; minor component of 1 map unit)
3. **Vertisols** - clay-rich soils with high shrink-swell potential (minor component of 3 map units)

4. **Mollisols** – soils with dark, organic-rich surface horizons, which contain high levels of organic matter and have high cation exchange capacity and good water-holding capacity (major component of 10 map units; minor component of many map units)
5. **Alfisols** - moderately developed soils with subsurface accumulation of clay and a moderate to high base saturation (major component of 20 map units; minor component of many map units)

Keep in mind that this list serves as a general approximation, and the relative age of soil orders may vary depending on local conditions and specific site characteristics. Soil scientists consider various soil properties and environmental factors to assess the development level and age of soils.

CATALINA ISLAND SOIL SERIES AND MAP UNITS

Soil series are the fundamental units of soil classification in the soil survey, representing a group of soils with similar characteristics and formation processes. Soil series is the lowest taxonomic class and consists of soils within a family that has horizons similar in color, texture, structure, reaction, consistency, mineral composition, and arrangement in the profile.

However, for purposes of mapping the distribution of soil types, it is common for multiple soil series to be intricately connected in a landscape in topographically complex landscapes like Catalina Island, necessitating their combination into larger mapping units. These units can be classified as complexes or associations.

Complexes are formed when two or more soils or miscellaneous areas are interwoven in a complex pattern or occupy small areas that cannot be accurately represented on maps individually. Although their pattern and proportion may vary, they share similar characteristics across different locations. An example of a complex is the Masthead-Coastwise-Dewpoint Complex, which comprises 20 to 55 percent slopes.

Associations, on the other hand, consist of two or more geographically associated soils or miscellaneous areas depicted as a single unit on maps. Separate mapping of these areas may not be practical or necessary due to their present or anticipated uses within the survey area. The pattern and relative proportion of the soils or miscellaneous areas within an association are somewhat similar. The Dewpoint-Luff Association, characterized by 15 to 45 percent slopes, serves as an example of such a grouping.

In the case of Catalina Island, the soil survey map features 22 complexes and 1 association, reflecting the intricate interplay of various soil series and their relationships within the island's diverse landscape (Figure 2-19, Table 2-1). Key features of the soil survey are visualized in a series of maps based on the most prominent characteristics of each soil complex or association:

- **Soil Parent Material**, Figure 2-20

  Parent material name refers to the general composition of unconsolidated material, either mineral or organic, in which soil develops. This name often

implies the mode of deposition and/or weathering that contributed to the soil's formation.

- **Depth to Restrictive Layer**, Figure 2-21

  Depth to restrictive layer due to an abrupt soil texture change refers to the vertical distance from the soil surface to a distinct layer where a significant shift in soil texture imposes restrictions on root penetration and water movement. This layer can result from various factors such as compaction, cementation, or the presence of layers enriched in clay, silt, or coarse fragments. These changes in texture can impact soil drainage, aeration, and overall soil productivity.

- **Available Water Supply**, Figure 2-22

  Available Water Capacity (AWC) measures the amount of water a soil can store for plant use, expressed in centimeters of water per centimeter of soil on the map. AWC depends on properties like organic matter, texture, density, structure, salinity, and rock fragments. It influences vegetation growth but does not indicate the actual water available at any given time.

  Available Water Supply (AWS) is calculated by multiplying AWC with soil thickness, providing an estimate of the total water available in the soil profile.

- **Organic Soil Horizon**, Figure 2-23

  This map displays the classification of the dominant soil series in the map unit as one of the following: (1) No Organic Soil Horizon: This category is when organic matter is absent or present in negligible amounts, with no accumulation of identifiable plant residues. (2) Slightly decomposed plant material**:** This category includes plant residues that have undergone minimal decomposition, retaining most of their original form and structure. Fibers and other recognizable plant parts are still easily identifiable. (3) Moderately decomposed plant material: Organic materials in this category exhibit a more advanced stage of decomposition, where plant residues have started to break down into smaller fragments. Some original plant structures are still visible, but many have begun to degrade and lose their identity.

- **Soil Organic Matter in the Topsoil**, Figure 2-24

  Organic matter in the topsoil refers to the portion of the soil comprising various forms of carbon-based substances derived from decomposing plant and animal residues. This includes living and dead microorganisms, partially decomposed organic material (humus), and stable organic compounds like humic and fulvic acids. Topsoil organic matter plays a critical role in enhancing soil fertility, improving water retention, facilitating nutrient cycling, and supporting soil biodiversity. This value is reported as a percentage, which serves as an essential indicator of soil quality and productivity.

- **Soil Texture of A Horizon**, Figure 2-25

  Soil texture classes are groupings of soils based on the relative proportions of sand, silt, and clay particles. These classes are as follows:

  1. Sand: Soils with large, coarse particles that feel gritty and allow water to drain quickly.
  2. Silt: Soils with medium-sized particles that feel smooth and hold water moderately.
  3. Clay: Soils with tiny, fine particles that feel sticky when wet and hold water tightly.

  Each texture class influences water retention, drainage, aeration, and fertility. Additionally, soil textures are often combined to describe intermediate classes such as sandy loam or silty clay, reflecting a mix of particle sizes and properties.

- **Soil Clay Content**, Figure 2-26

  Soil clay content represents the proportion of clay particles within the soil, significantly influencing soil properties and functions. Clay particles are the smallest soil particles, less than 0.002 mm in size, and have a large surface area. In the surface layer and throughout the soil profile, clay content impacts:

  1. Water retention: High clay content enhances water-holding capacity but may reduce drainage.
  2. Nutrient availability: Clay particles have negatively charged surfaces that attract and hold positively charged nutrients, making them available for plant uptake.
  3. Soil structure: Clay particles help form stable aggregates, improving soil structure, aeration, and root penetration.

- **Cation Exchange Capacity and pH of Topsoil**, Figure 2-27

  Cation-exchange capacity (CEC-7) measures the extractable cations a soil can hold at a specific pH, typically neutrality (pH 7.0). Soils with low CEC-7 or simply, CEC, hold fewer cations, possibly requiring more frequent fertilization than high CEC soils. CEC is essential for nutrient retention.

An overview of the Catalina Island soil series, organized by Soil Odder and Suborder, is presented in Figure 2-28. And the relationship between soil series and the soil map units (complex or association) they are included in, along with taxonomic family classification, parent material, and typical vegetation type are listed in Table 2-2.

The subsequent sections provide a summary of the similarities and differences between the soil series and the presentation is organized by Soil Order and Suborder. An analysis of these soils through the perspective of the soil taxonomy and the principles of soil genesis will offer valuable insights into the intricate processes shaping Catalina Island's landscape and its potential for varying ecosystem and habitat functions, including in the preparation of site-specific habitat restoration plans.

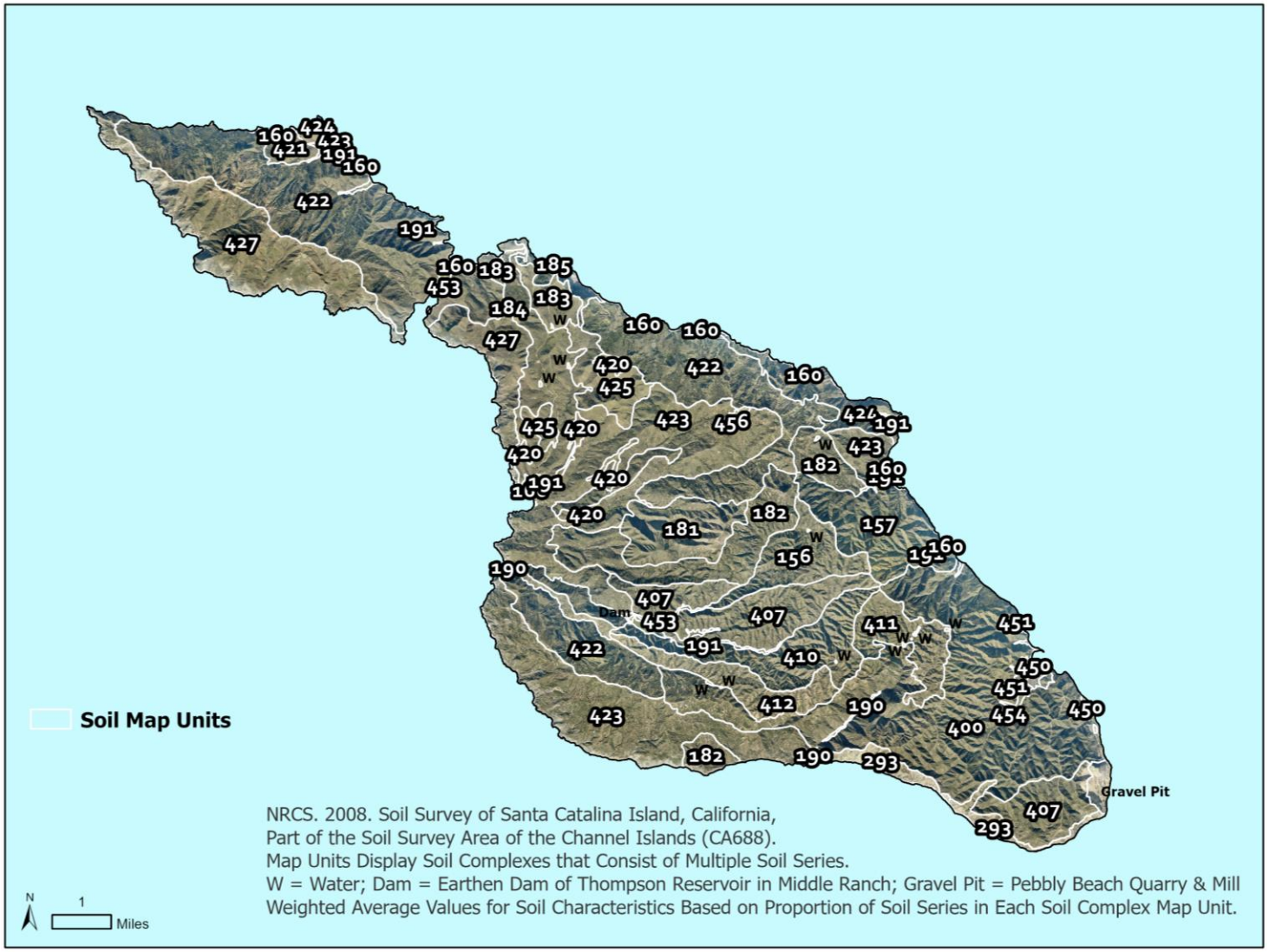


Figure 2-19 Soil Map Units for 2008 NRCS Survey.

See Table 2-1 for Soil Complex Names for the Soil Map Units.

Table 2-1 Soil Complexes with Primary Geology, Soil Series and Soil Texture (2008 Soil Map).

Map Unit Symbol	Soil Map Unit Name Soil Map Complex or Association | Slope Range	Primary Soil Series	Primary Soil Texture	Primary Generalized Geology Map Code | Geological Time Period | Rock Types
160	Beaches-Abaft complex | 0 to 5%	Beach Sand	Sand	Qb | QUARTERNARY | Beach sand
190	Typic Xerofluvents-Riverwash complex | 0 to 8%	Xerofluvents	Sandy loam	Qal | QUARTERNARY | Alluvium
191	Typic Haploxerepts-Xerofluvents-Argixerolls complex | 0 to 8%	Haploxerepts	Very gravelly sand	
184	Dewpoint-Luff association |15 to 45%	Dewpoint	Sandy loam	Qls | QUARTERNARY | Landslide deposits
293	Rock outcrop, coastal cliffs-Nauti-Haploxerepts complex | 50 to 120%	Rock Outcrop	NA	
156	Tongva-Freeboard-Starbright complex | 30 to 55%	Tongva	Loam	Tv | MIOCENE | Volcanic and volcaniclastic rocks
157	Tongva-Pachic Argixerolls-Freeboard complex | 55 to 75%			
181	Haploxerepts-Purser-Rock outcrop complex | 40 to 75%	Haploxerepts	Very gravelly sand	
182	Luff-Haploxerepts-Haploxeralfs complex | 15 to 35%	Luff	Silty loam	
183	Purser-Luff complex | 15 to 35%	Purser	Clay loam	
185	Purser-Rock outcrop complex, coastal cliffs | 45 to 75%			
400	Oboship-Nauti-Bosun complex | 50 to 75%	Oboship	Gravelly loam	Tmqd | MIOCENE | Catalina Island pluton, quartz diorite
407	Nauti-Flyer-Marpol complex | 25 to 55%	Nauti	Loam	
410	Express-Flyer-Loadline complex | 40 to 75%	Express	Sandy loam	
411	Flyer-Loadline-Nauti complex | 15 to 50%	Flyer	Gravelly loamy sand	
412	Flyer, gullied-Express, gullied-Bosun complex | 15 to 50%			
422	Dewpoint-Masthead-Coastwise complex | 20 to 55%	Dewpoint	Sandy loam	Jcs | JURASSIC | Catalina Schist
420	Masthead-Luff complex | 5 to 15%	Masthead	Gravelly silty loam	
421	Masthead-Luff complex | 8 to 30%			
423	Masthead-Coastwise-Dewpoint complex | 20 to 55%			
424	Masthead-Dewpoint-Rock Outcrop complex | 40 to 75%			
427	Masthead-Coastwise-Typic Haploxeralfs complex | 45 to 75%			
425	Coastwise-Masthead complex, cobbly | 40 to 75%	Coastwise	Gravelly sandy loam	

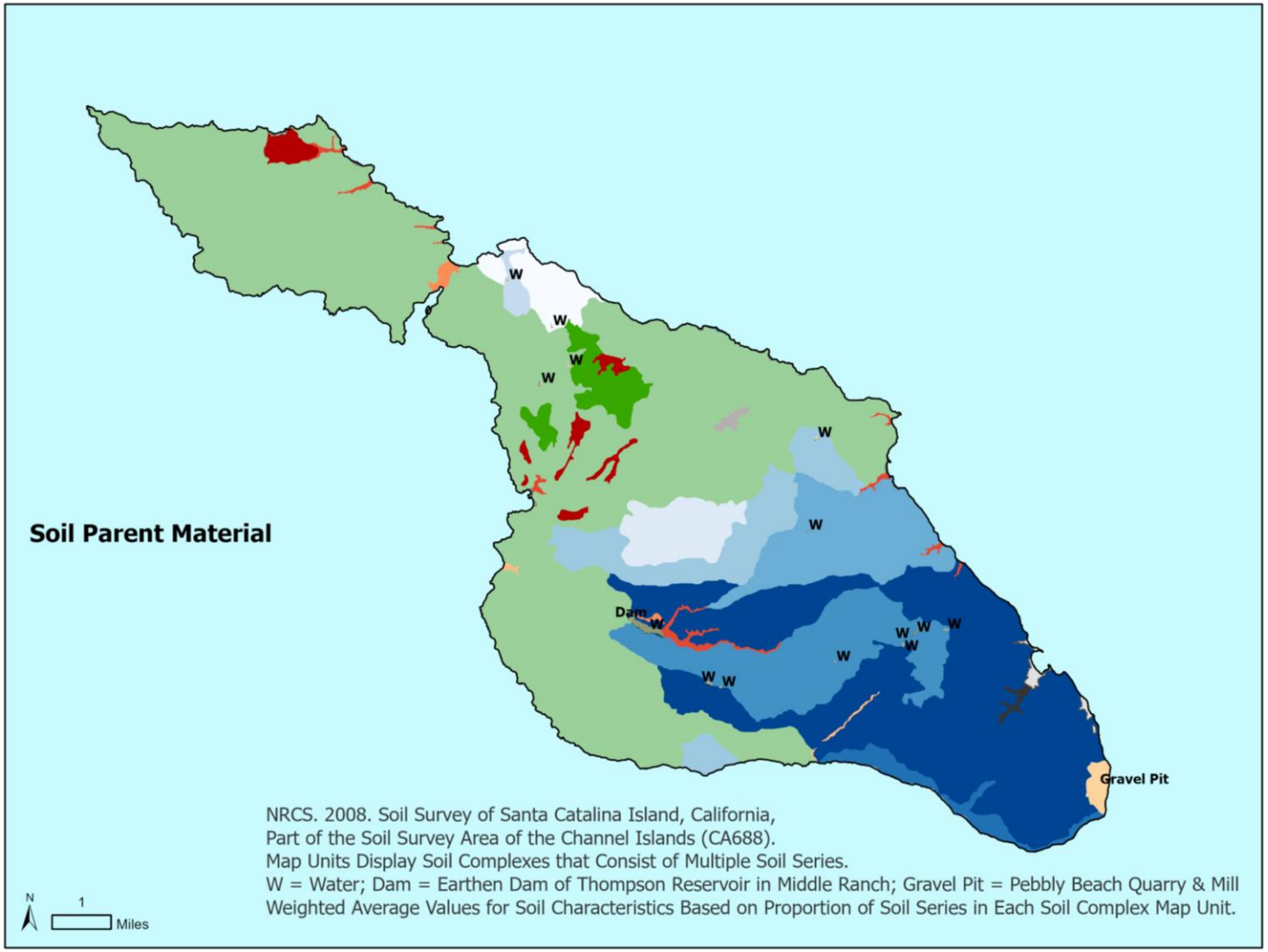


Figure 2-20 Parent Material.
2008 Soil Map

Parent Material

ANTHROPOCENE

- Pavement and buildings human transported material over alluvium derived from quartz-diorite
- Fill human transported material derived from schist
- Human transported material over alluvium derived from quartz-diorite

QUARTERNARY

- Sandy alluvium derived from sandstone
- Sandy and gravelly alluvium
- Alluvium derived from metamorphic and sedimentary rock
- Colluvium derived from metasedimentary rock over alluvium derived from metasedimentary rock
- Alluvium derived from volcanic and metamorphic rock
- Slope alluvium over residuum weathered from schist and/or metasedimentary rock

MIOCENE

- Residuum weathered from volcanic rock and/or andesite
- Residuum weathered from andesite or other volcanic rock
- Residuum weathered from volcanic breccia, andesite or basalt
- Eolian deposits over residuum weathered from volcanic and metamorphic rock
- Colluvium and/or residuum weathered from basalt and/or andesite
- Residuum weathered from quartz-diorite porphyry
- Quartz-diorite
- Slope alluvium over residuum weathered from quartz-diorite and/or quartz-diorite porphyry

JURASSIC

- Residuum weathered from metasedimentary rock
- Slope alluvium over residuum weathered from Catalina Schist and/or metasedimentary rock

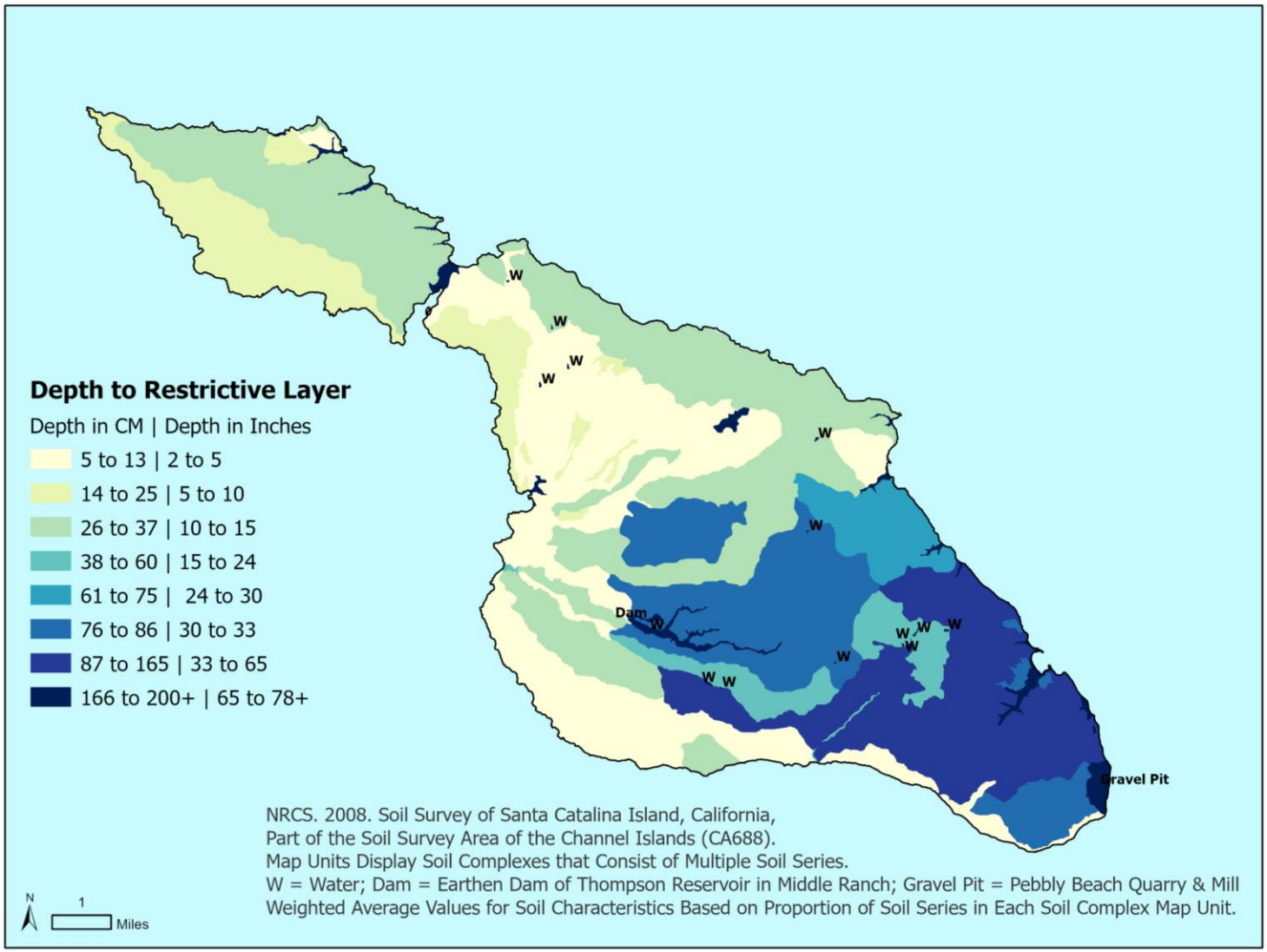


Figure 2-21 Depth to Restrictive Layer.
2008 Soil Map

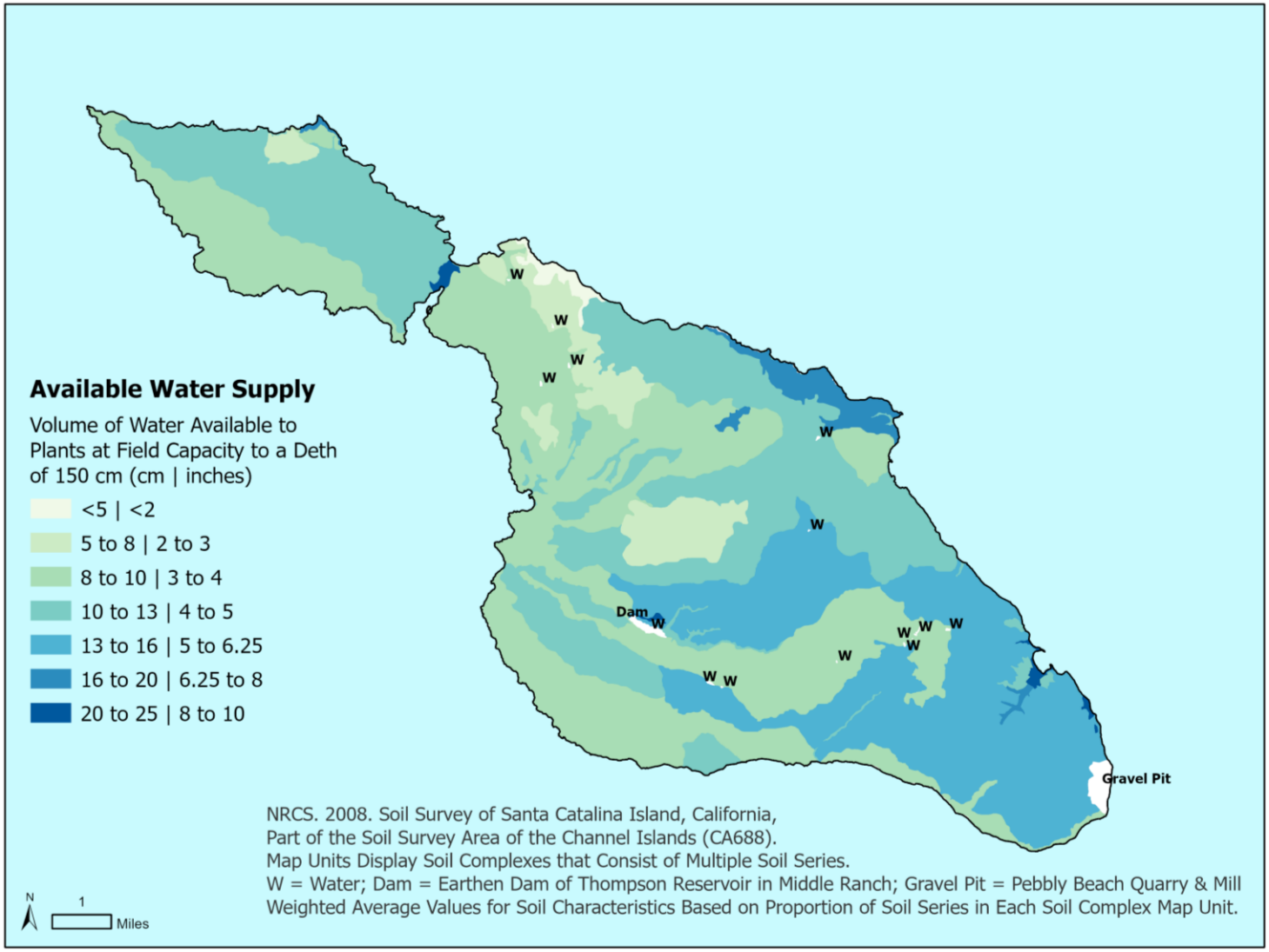


Figure 2-22 Available Water Supply to a Depth of 150 cm.
2008 Soil Map

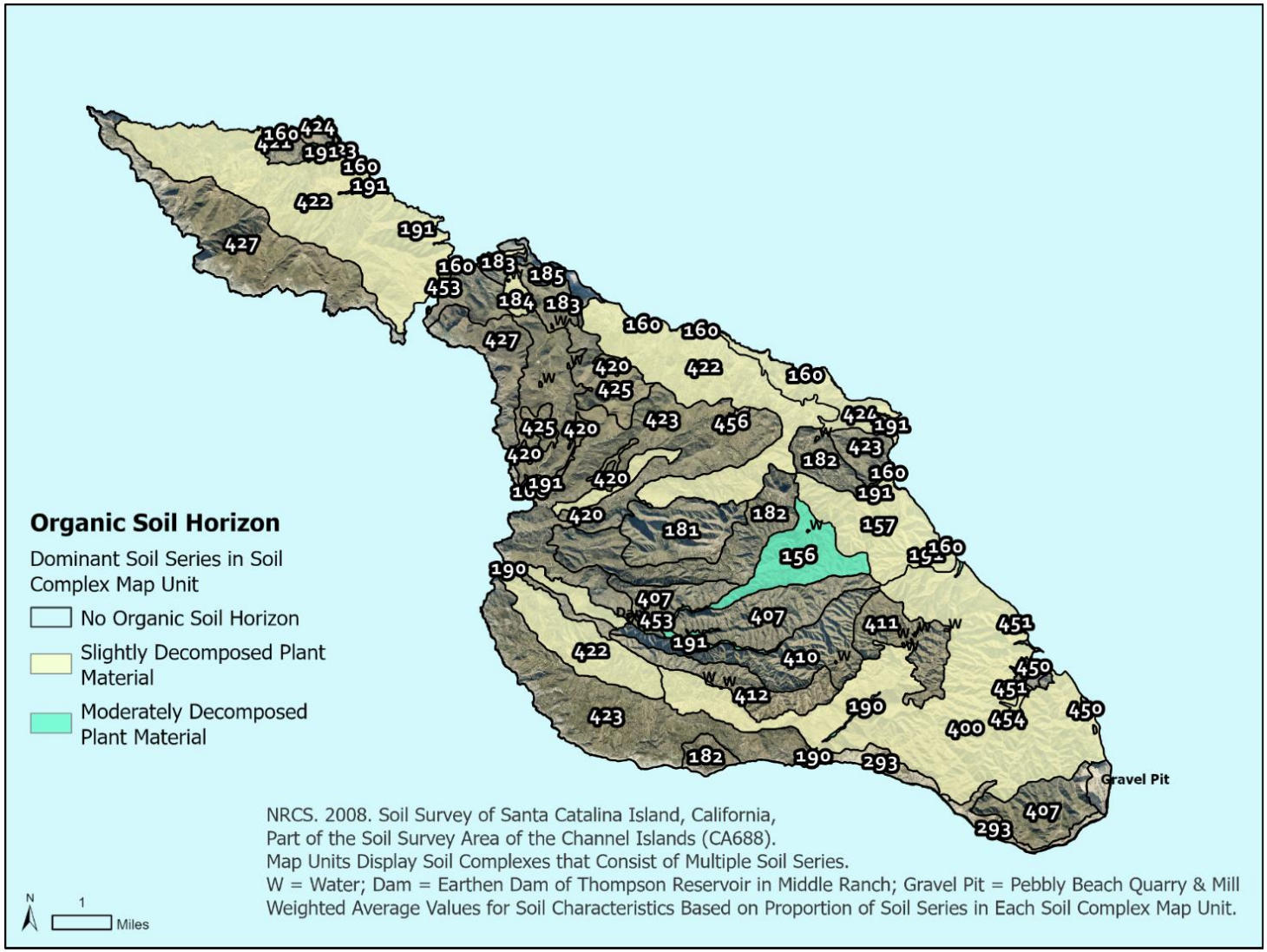


Figure 2-23 Organic Soil Horizon.

2008 Soil Map

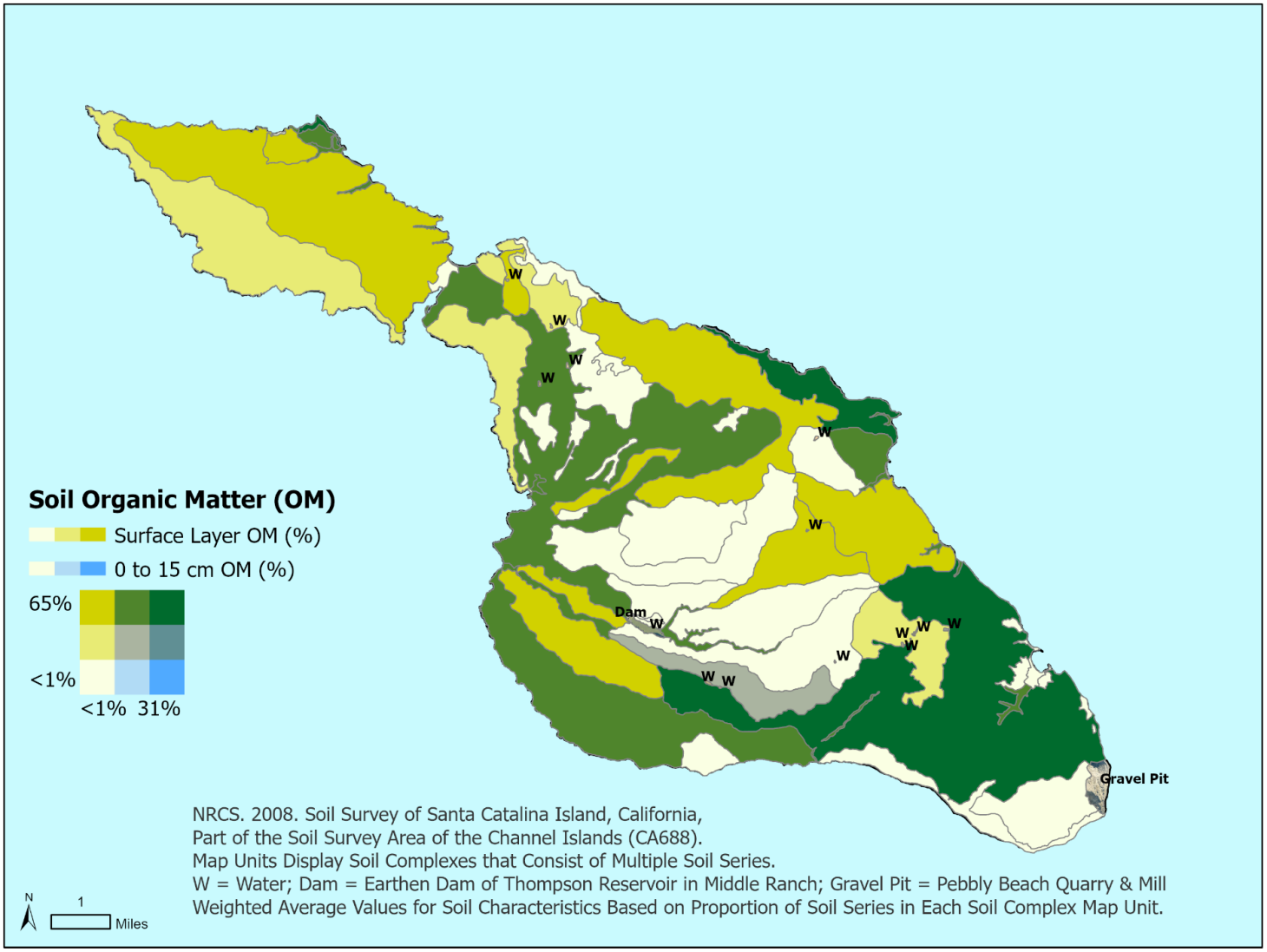


Figure 2-24 Organic Matter in the Topsoil (0 to 15 cm).
2008 Soil Map

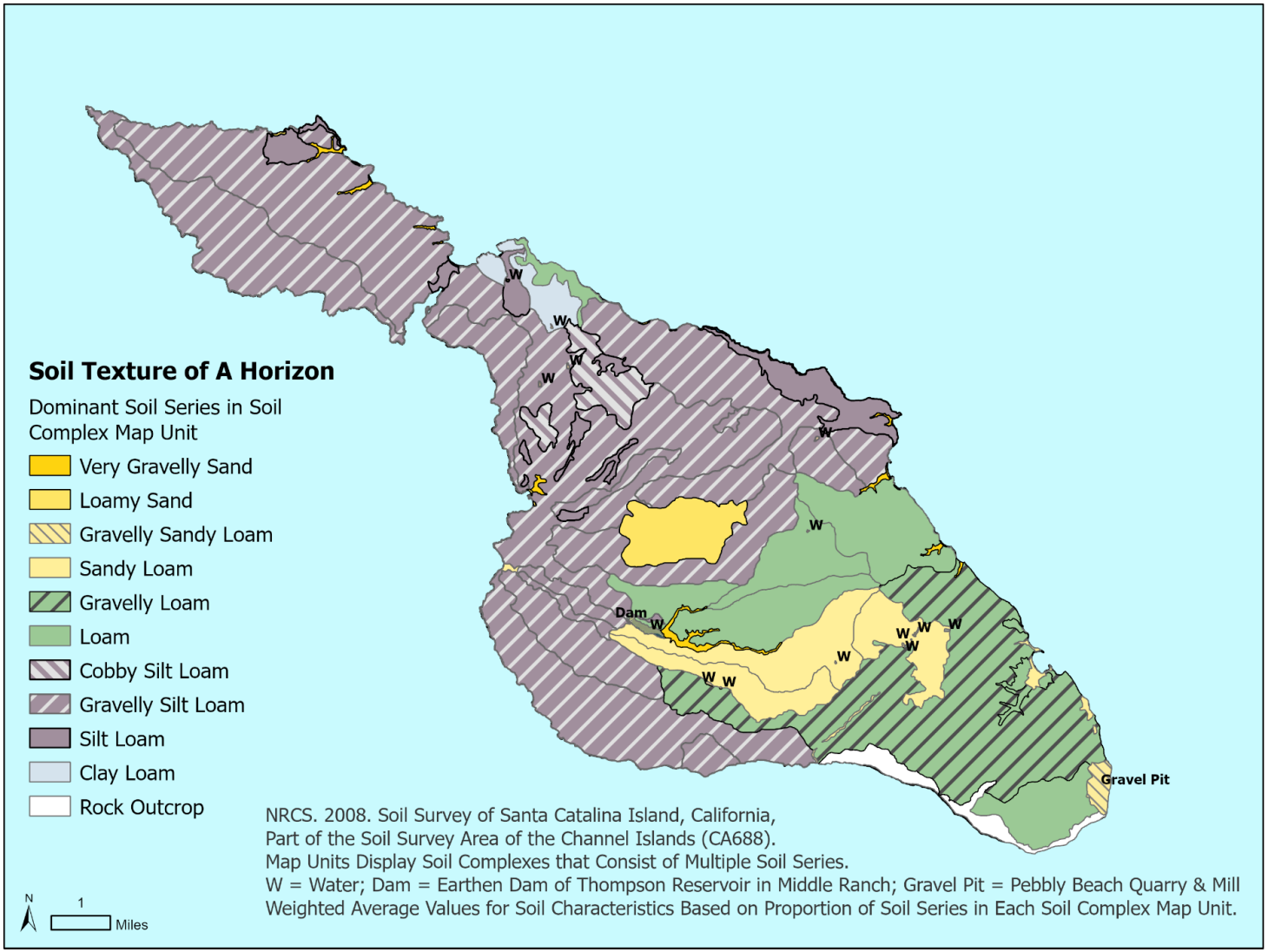


Figure 2-25 Soil Texture of the A Soil Horizon.

2008 Soil Map

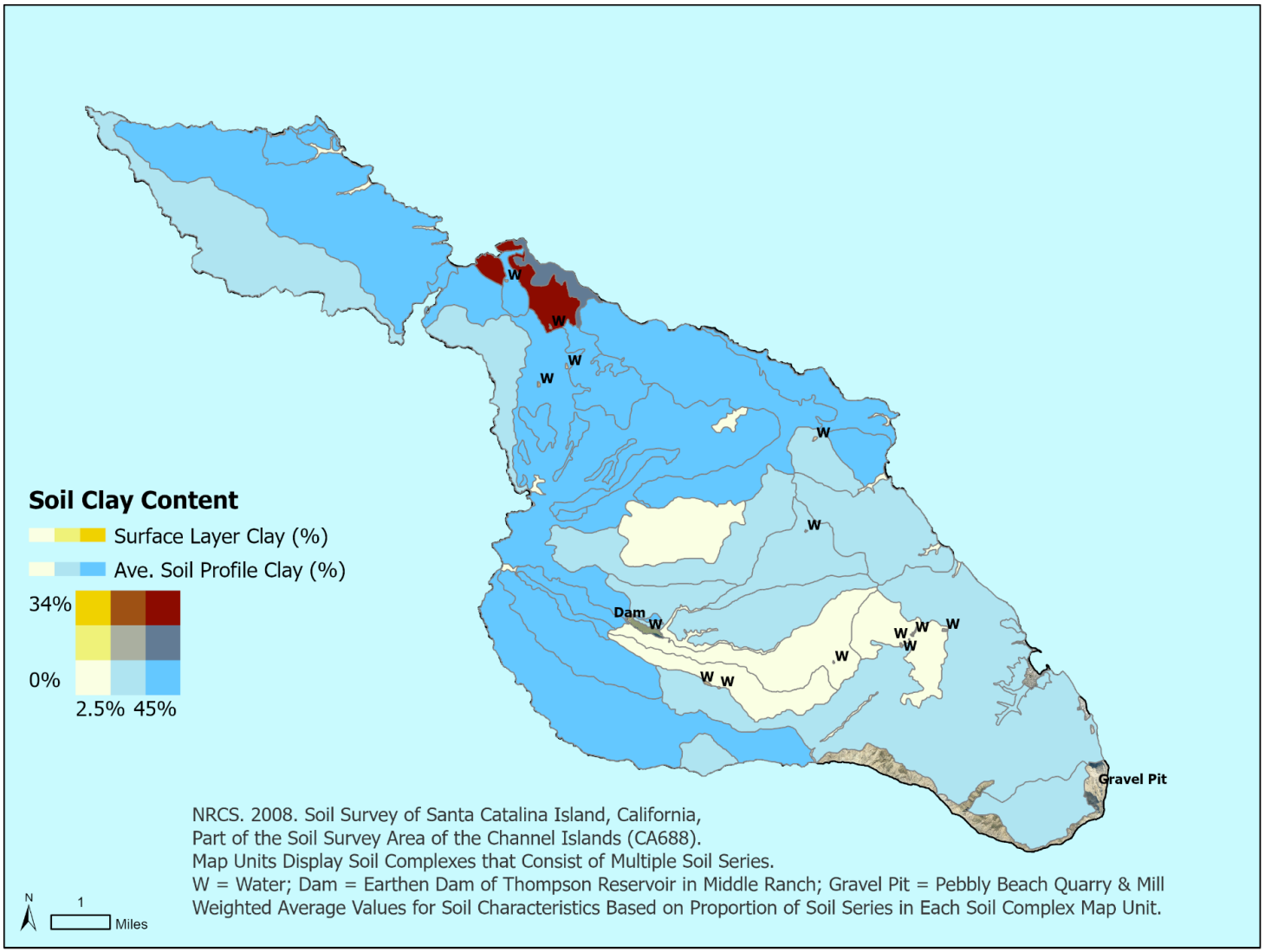


Figure 2-26 Clay Content of the Surface Layer and Average of the Full Soil Profile.

2008 Soil Map

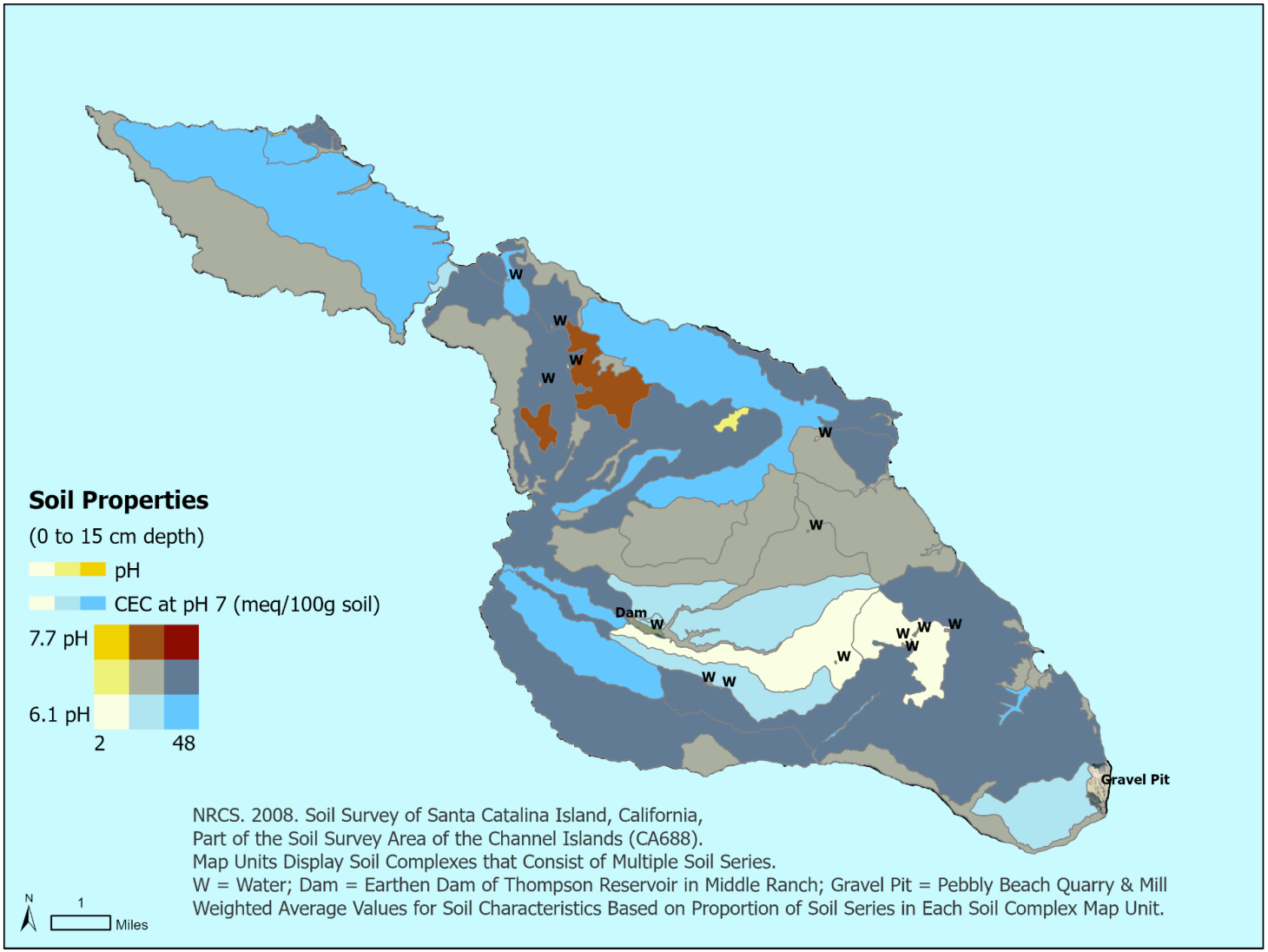


Figure 2-27 Topsoil (0 to 15 cm) pH and Cation Exchange Capacity (CEC).
2008 Soil Map

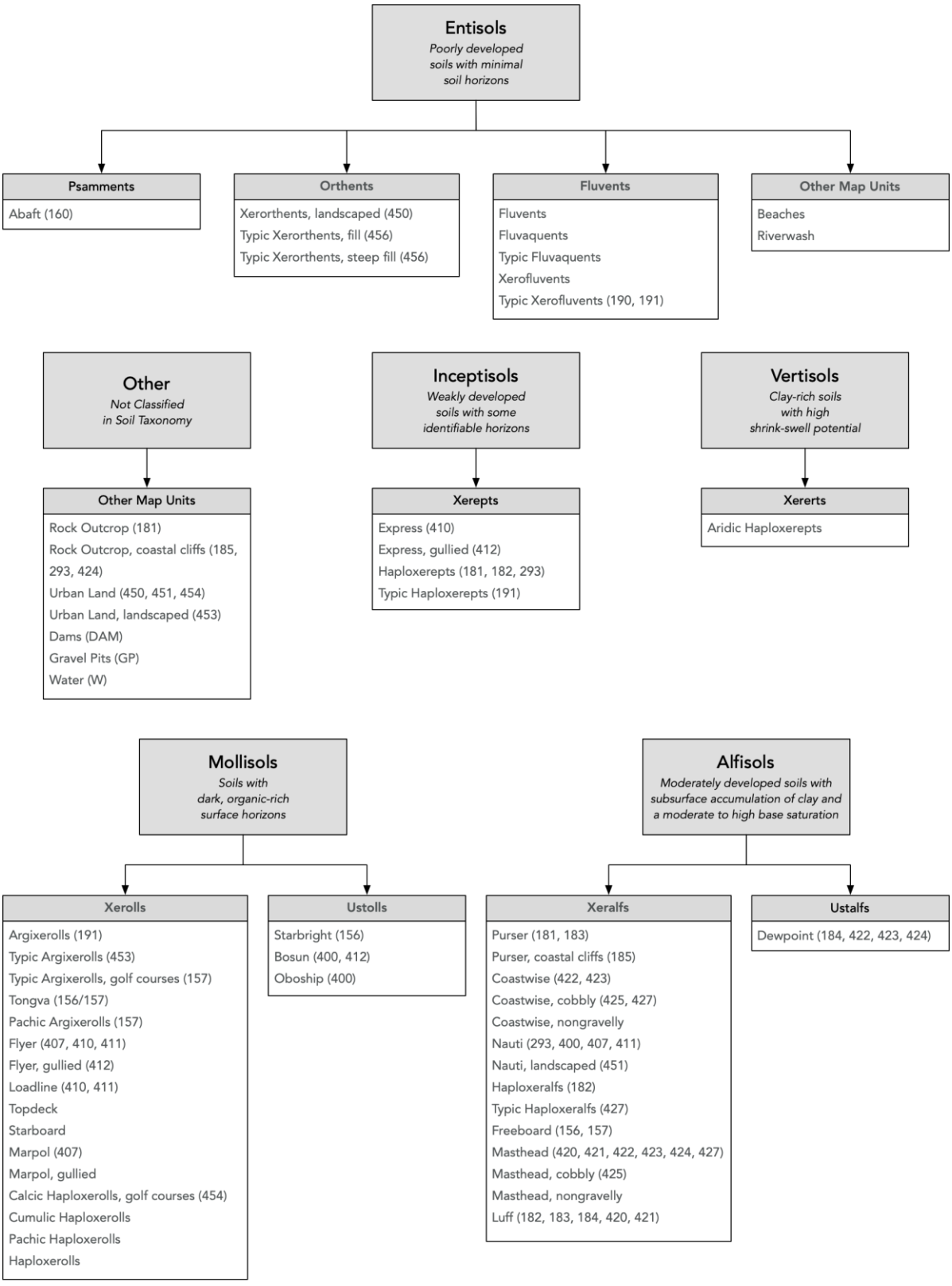


Figure 2-28 Taxonomic Relationship of Soil Map Units by Soil Order and Suborder.

Soil map units for soil types that are major constituents are listed in parentheses (USDA 2008).

Table 2-2 Soil Type, Taxonomic Family, Parent Material and Typical Vegetation.

Soil Type *Map Units Containing Soil Series as a Major or Minor (≤10% Cover) Component*	**Family**	**Parent Material**	**Typical Veg. Type**
ENTISOLS			
Typic Fluvaquents *Major: --- Minor: 191*	---	alluvium derived from volcanic and metamorphic rock	CSS
Fluvaquents *Major: --- Minor: ---*	---	alluvium derived from volcanic and metamorphic rock	CSS
Fluvents *Major: --- Minor: 421, 422, 423, 424, 425, 454*	---	alluvium derived from volcanic and metamorphic rock	CSS
Typic Xerofluvents *Major: 190, 191 Minor: 181, 182*	---	alluvium derived from volcanic and metamorphic rock	MFS, SRW, RH
Xerofluvents *Major: --- Minor: 410*	---	alluvium derived from metamorphic and sedimentary rock	CSS
Abaft *Major: 160 Minor: ---*	Mixed, thermic Typic Xeropsamments	eolian sands derived from volcanic and sedimentary rock	SBD
Typic Xerorthents, fill *Major: 456 Minor: ---*	Loamy-skeletal, thermic Typic Xerorthents	fill human transported material derived from schist	D
Typic Xerorthents, steep fill *Major: 456 Minor: ---*	Loamy-skeletal, thermic Typic Xerorthents	steep fill human transported material derived from schist	CSS, GR
Xerorthents *Major: 450 Minor: ---*	---	alluvium derived from quartz-diorite	D, NNH, GR
Beaches *Major: 160 Minor: ---*	---		SBD, B
Riverwash *Major: 190 Minor: 191*	---	alluvium derived from volcanic and metamorphic rock	MFS, CSS< B
INCEPTISOLS			
Haploxerepts *Major: 181, 182, 293 Minor: ---*	Thermic Haploxerepts	residuum weathered from andesite or other volcanic rock	GR
Express *Major: 410 Minor: ---412*	Coarse-loamy, mixed, active, thermic Typic Haploxerepts	residuum weathered from quartz-diorite porphyry	CSS, NNS, MCS, CBS, IC, ISOC

Soil Type *Map Units Containing Soil Series as a Major or Minor (≤10% Cover) Component*	**Family**	**Parent Material**	**Typical Veg. Type**
Express, gullied *Major: 412* *Minor: ---*	Coarse-loamy, mixed, active, thermic Typic Haploxerepts	residuum weathered from quartz-diorite porphyry	CSS, GR, ISOC
Typic Haploxerepts *Major: 191* *Minor: ---*	Loamy-skeletal, mixed, active, thermic Typic Haploxerepts	alluvium derived from volcanic and metamorphic rock	MFS, CSS, GR, ISOC
VERTISOLS			
Aridic Haploxererts *Major: ---* *Minor: 420, 422, 423*	---	TBD	CSS, GR
MOLLISOLS			
Starbright *Major: 156* *Minor: 157, 183, 185*	Fine, smectitic, isothermic Typic Argiustolls	residuum weathered from volcanic rock and/or andesite	IC, CSS, ISOC, IW, NNS
Bosun *Major: 400, 412* *Minor: 407, 411, 451, 454*	Loamy-skeletal, mixed, superactive, isothermic Typic Argiustolls	slope alluvium over residuum weathered from quartz-diorite and/or quartz-diorite porphyry	CSS, IC, ISOC, IW, NNS
Topdeck *Major: ---* *Minor: 156, 157, 181, 182*	Loamy, mixed, superactive, thermic Lithic Argixerolls	colluvium and/or residuum weathered from basalt, andesite and/or volcanic breccia	CSS, GR
Starboard *Major: ---* *Minor: 156, 157, 182*	Fine-loamy, mixed, superactive, mesic Pachic Argixerolls	residuum weathered from volcanic rock and/or andesite	CSS, ISOC
Pachic Argixerolls *Major: 157* *Minor: 156*	---	residuum weathered from volcanic rock and/or andesite	CSS, MCS, GR, IC, CBS
Flyer *Major: 407, 410, 411* *Minor: 400, 412, 451*	Coarse-loamy, mixed, active, thermic Typic Argixerolls	residuum weathered from quartz-diorite porphyry	CSS, MCS, GR, IC, CBS, NNS
Flyer, gullied *Major: 412* *Minor: ---*	Coarse-loamy, mixed, active, thermic Typic Argixerolls	residuum weathered from quartz-diorite porphyry	CSS, GR
Tongva *Major: 156, 157* *Minor: 181, 182*	Fine-loamy, mixed, superactive, thermic Typic Argixerolls	colluvium and/or residuum weathered from basalt and/or andesite	CSS, MCS, GR, ISOC, CBS
Typic Argixerolls *Major: 453* *Minor: ---*	Fine-loamy, mixed, superactive, thermic Typic Argixerolls	colluvium derived from metasedimentary rock over alluvium derived from metasedimentary rock	GR, CSS
Typic Argixerolls, golf courses *Major: 454* *Minor: ---*	Fine-loamy, mixed, superactive, thermic Typic Argixerolls	human transported material over alluvium derived from quartz-diorite	D
Loadline *Major: 410, 411* *Minor: 293, 400, 407, 412*	Loamy, mixed, active, thermic, shallow Typic Argixerolls	residuum weathered from quartz-diorite porphyry	CSS, MCS, GR, IC, CBS

Soil Type *Map Units Containing Soil Series as a Major or Minor (≤10% Cover) Component*	**Family**	**Parent Material**	**Typical Veg. Type**
Argixerolls *Major: 191* *Minor: ---*	---	alluvium derived from volcanic and metamorphic rock	MFS, GR
Calcic Haploxerolls, golf courses *Major: 454* *Minor: ---*	---	human transported material over alluvium derived from quartz-diorite	D
Cumulic Haploxerolls *Major: ---* *Minor: 190*	---	mixed alluvium derived from volcanic and sedimentary rock	UNK
Pachic Haploxerolls *Major: ---* *Minor: 190*	---	mixed alluvium derived from volcanic and sedimentary rock	UNK
Haploxerolls *Major: ---* *Minor: 407*	---	mixed alluvium derived from volcanic and sedimentary rock	UNK
Oboship *Major: 400* *Minor: 407, 410, 411, 412*	Coarse-loamy, mixed, superactive, isothermic Pachic Haplustolls	slope alluvium over residuum weathered from quartz-diorite and/or quartz-diorite porphyry	IW, IC, ISOC, CSS
Marpol *Major: 407* *Minor: 400, 411*	Fine, mixed, superactive, thermic Typic Palexerolls	residuum weathered from porphyry quartz-diorite	CSS, MCS, GR, IC, NNS
Marpol, gullied *Major: ---* *Minor: 412*	Fine, mixed, superactive, thermic Typic Palexerolls	residuum weathered from porphyry quartz-diorite	CSS, GR
ALFISOLS			
Purser *Major: 181, 183* *Minor: 157, 184, 453*	Clayey, smectitic, thermic Lithic Haploxeralfs	residuum weathered from volcanic rock and/or andesite	CSS, GR, NNH
Purser, coastal cliffs *Major: 185* *Minor: ---*	Clayey, smectitic, thermic Lithic Haploxeralfs	residuum weathered from volcanic rock and/or andesite	CSS, GR, B
Coastwise *Major: 422, 423* *Minor: 420, 421, 424, 427, 456*	Clayey, smectitic, thermic, shallow Mollic Haploxeralfs	slope alluvium over residuum weathered from Catalina schist and/or metasedimentary rock	CSS, MCS, NNS, GR, CBS
Coastwise, cobbly *Major: 425, 427* *Minor: ---*	Clayey, smectitic, thermic, shallow Mollic Haploxeralfs	slope alluvium over residuum weathered from Catalina schist and/or metasedimentary rock	CSS, GR
Coastwise, nongravelly *Major: ---* *Minor: 422*	Clayey, smectitic, thermic, shallow Mollic Haploxeralfs	slope alluvium over residuum weathered from Catalina schist and/or metasedimentary rock	CSS
Nauti *Major: 293, 400, 407, 411* *Minor: 412, 451, 454*	Fine-loamy, mixed, superactive, thermic Mollic Haploxeralfs	slope alluvium over residuum weathered from quartz-diorite and/or quartz-diorite porphyry	CSS, MCS, ISOC, CBS
Nauti, landscaped *Major: 451* *Minor: ---*	Fine-loamy, mixed, superactive, thermic Mollic Haploxeralfs	slope alluvium over residuum weathered from quartz-diorite and/or quartz-diorite porphyry	NNS, B

Soil Type *Map Units Containing Soil Series as a Major or Minor (≤10% Cover) Component*	**Family**	**Parent Material**	**Typical Veg. Type**
Typic Haploxeralfs *Major: 427* *Minor: 156*	Loamy-skeletal, mixed, superactive, thermic Typic Haploxeralfs	residuum weathered from Catalina schist and/or metasedimentary rock	CSS, MCS, GR, IC, CBS
Freeboard *Major: 156, 157* *Minor: 182, 183, 184, 185*	Fine, smectitic, thermic Vertic Haploxeralfs	colluvium and/or residuum weathered from andesite or other volcanic rock	GR, CSS
Haploxeralfs *Major: 182* *Minor: 183, 410*	---	residuum weathered from volcanic rock and/or andesite	CSS, GR
Dewpoint *Major: 184, 422, 423, 424* *Minor: 420, 421*	Fine, smectitic, isothermic Typic Paleustalfs	slope alluvium over residuum weathered from Catalina schist and/or metasedimentary rock	IW, ISOC, IC, SRW, RH, NNW, CSS
Masthead *Major: 420, 421, 422, 423, 424, 427* *Minor: 453, 456*	Fine, smectitic, thermic Mollic Palexeralfs	slope alluvium over residuum weathered from Catalina schist and/or metasedimentary rock	CSS, MCS, GR, IC, CBS
Masthead, cobbly *Major: 425* *Minor: ---*	Fine, smectitic, thermic Mollic Palexeralfs	slope alluvium over residuum weathered from Catalina schist and/or metasedimentary rock	CSS, MCS, GR, IC, CBS
Masthead, nongravelly *Major: ---* *Minor: 422*	Fine, smectitic, thermic Mollic Palexeralfs	slope alluvium over residuum weathered from Catalina schist and/or metasedimentary rock	CSS
Petrocalcic Palexeralfs *Major: ---* *Minor: 420, 423*	---	slope alluvium over residuum weathered from Catalina schist and/or metasedimentary rock	CSS
Luff *Major: 182, 183, 184, 420, 421* *Minor: 156, 181, 185, 407, 423, 425, 453*	Fine, smectitic, thermic Vertic Palexeralfs	eolian deposits over residuum weathered from volcanic and metamorphic rock	ISOC, SRH, CSS, MCS, GR
OTHER			
Dams *Major: DAM* *Minor: ---*	---	---	D
Gravel Pits *Major: GP* *Minor: ---*	---	---	D
Rock outcrop *Major: 181* *Minor: 156, 157, 160, 182, 183, 184, 190, 400, 407, 410, 411, 412, 422, 423, 425, 451*	---	---	B
Rock outcrop, coastal cliffs *Major: 185, 293, 424* *Minor: 427*	---	---	B
Urban Land	---	---	D

Soil Type *Map Units Containing Soil Series as a Major or Minor (≤10% Cover) Component*	**Family**	**Parent Material**	**Typical Veg. Type**
Major: 450, 451, 454 *Minor: 456*			
Urban Land, landscaped *Major: 453* *Minor: ---*	---	---	D
Water *Major: W* *Minor: ---*	---	---	VPR

Vegetation Types (after Knapp 2005a as identified in the 2008 Soil Survey with the addition of Island Scrub Oak Chaparral as distinct from Island Chaparral by Land IQ):

- ***IW*** *Island Woodland*
- ***IC*** *Island Chaparral*
- ***ISOC*** *Island Scrub Oak Chaparral*
- ***CSS*** *Coastal Sage Scrub*
- ***MCS*** *Maritime Cactus Scrub*
- ***CBS*** *Coastal Bluff Scrub*
- ***SRW*** *Southern Riparian Woodland*
- ***MFS*** *Mulefat Scrub*
- ***RH*** *Riparian Herbaceous*
- ***BSB*** *Bare Streambed*
- ***CM*** *Coastal Marsh*
- ***SBD*** *Southern Beach Dune*
- ***VPR*** *Vernal Ponds and Reservoirs*
- ***NNW*** *Nonnative Woodland*
- ***NNS*** *Nonnative Scrub*
- ***NNH*** *Nonnative Herbaceous*
- ***GR*** *Grassland*
- ***B*** *Bare*
- ***D*** *Developed*
- ***UNK*** *Unknown Vegetation Type*

ENTISOLS

The Entisols suborders Psamments, Orthents, and Fluvents occur on Catalina Island (Figure 2-29):

- **Psamments** (major component of one map unit, the soil series Abaft, 160): Psamments are sandy Entisols with a coarse texture throughout the soil profile. They often form in areas with high rates of water movement or in regions with limited soil development, such as dunes or sandy uplands. Their coarse texture leads to rapid water infiltration and limited water-holding capacity. Abaft soils are typically found on stabilized sand dunes or beaches and are excessively drained.
- **Orthents** (major component of 2 map units): Orthents are Entisols that do not exhibit significant soil development and lack horizons. They are typically shallow, rocky soils found in areas with minimal weathering and vegetation. Orthents often occur in arid regions or areas with steep slopes and high erosion rates. On Catalina they occur in areas with human transported fill to construct the airport (major component of map unit 456) and developed areas of Avalon (major component of map unit 450).
- **Fluvents** (major component of 2 map units identified as Typic Xerofluvents, component of map units 190 and 191): Fluvents are Entisols that form on recent floodplains and terraces. They have a high concentration of organic carbon in the soil and better drainage than other Entisols. Fluvents typically exhibit stratified layers due to periodic flooding and sediment deposition. The term "Xerofluvent" is a combination of "xeric," referring to a dry soil moisture regime, and "fluvent," which indicates that the soil is found on floodplains or terraces. The term "Typic" is used in soil taxonomy to indicate a subgroup within a soil order, suborder, or great group that exhibits typical characteristics of that classification. In other words, a Typic Xerofluvent would be a Xerofluvent soil that does not have any unique or unusual properties that would classify it as a different subgroup.

Areas mapped as Beaches or Riverwash are also included in the Entisols soil order.

INCEPTISOLS

The Inceptisols soil order is represented by one suborder on Catalina Island, Xerepts (Figure 2-30). These soils are characterized by their xeric soil moisture regime and moderately developed soils, exhibiting some horizon differentiation and the beginnings of clay accumulation in the subsoil. However, they are not as developed as soils in the Alfisols order, such as Xeralfs, which also have a xeric moisture regime but exhibit more pronounced clay accumulation. Xerepts are represented by one great group on Catalina Island, Haploxerepts:

- **Haploxerepts** (major component of 6 map units: soil series Express, 410; Express, gullied, 412; Haploxerepts, 181, 182, 293; Typic Haploxerepts 191): These soils are characterized by minimal horizon development (indicated by the prefix "Haplo") and a xeric soil moisture regime (indicated by "xerept"). They typically have a loamy or sandy texture, with a relatively thin, dark-colored surface horizon overlying a lighter-colored subsurface horizon. Haploxerepts may be found in regions with Mediterranean-type

climates and are often associated with undulating topography or areas of sediment deposition. These soils support California sage scrub, including California sagebrush (*Artemisia californica*), sage (*Salvia mellifera, S. apiana*) and buckwheats (*Eriogonum giganteum*). Where these soils occur on floodplain terraces (major component of map unit 191) or coastal cliffs (major component of map unit 293), the scrub may be dominated or co-dominated by California sunflower bush (*Encelia californica*).

VERTISOLS

The Vertisols soil order is represented by one great group in the suborder, Xererts, on Catalina Island, Haploxererts (Figure 2-31):

- **Haploxererts**: These soils are relatively rare and occur as minor component in three soil map units classified in the subgroup Aridic Haploxererts (minor component of map units 420, 422, and 423). Vertisols are characterized by the presence of a high content of swelling clays, such as smectites, which can cause significant changes in soil volume with changes in moisture. Aridic Haploxererts are found in arid environments and exhibit minimal horizon development, as typical of Entisols. Haploxererts typically are characterized by plants that can tolerate low moisture conditions and have drought-tolerant adaptations, such as nonnative annual grassland, native annual forblands, native perennial grassland (e.g., *Stipa* grassland), California sage scrub, and cactus scrub.

MOLLISOLS

The Mollisols suborders Ustolls and Xerolls occur on Catalina Island (Figure 2-32). The presence of deeply rooted vegetation leads to the development of the characteristic dark, organic-rich surface horizon that defines Mollisols.

- **Ustolls**: These soils typically form under semi-arid conditions with an ustic soil moisture regime (moist winters and dry summers). They often develop on relatively level or gently sloping landscapes where water can accumulate during the wetter seasons. This results in a greater availability of moisture for plant growth and contributes to the development of island chaparral or riparian woodland. Two great groups in Ustolls occur, Argiustolls and Haplustolls (soil series Bosun and Oboship):
    - **Argiustolls** have an argillic horizon (subsurface horizon with an accumulation of clay), which is facilitated by greater moisture availability. This results in higher cation exchange capacity (CEC) and water-holding capacity, making Argiustolls more productive for plant growth than Haplustolls, which lack an argillic horizon. Argiustolls are represented by the soil series Starbright (major component of map unit 156) and Bosun (major component of map units 400 and 412).

  - **Haplustolls** are represented by the soil series Oboship (major component of map unit 400).

- **Xerolls**: These soils form under Mediterranean-type climates with a xeric soil moisture regime (cool, moist winters and warm, dry summers). These soils are often found on sloping or well-drained landscapes where water drains more readily, leading to drier soil conditions during the summer months. Some examples of vegetation that can be found growing on Xerolls include CSS, xeric island chaparral (e.g., dominated by chamise), island scrub oak, and *Stipa* grassland. Three suborders occur, Agrixerolls, Palexerolls, and Haploxerolls.

  - **Agrixerolls** have an argillic horizon, similar to Argiustolls, but develop in drier conditions, and support CSS and island scrub oak. Argixerolls include the following soils described for Catalina Island: Argixerolls (major component of map unit 191), Typic Argixerolls (major component of map unit 453), Typic Argixerolls, golf courses (major component of map unit 454), Pachic Argixerolls (major component of map unit 157), Flyer (major component of map units 407, 410 and 411), Flyer, gullied (major component of map unit 412), Tongva (major component of map units 156 and 157), Loadline (major component of map unit 410, 411), Topdeck (minor component of map units 156, 157, 181, and 182), and Starboard (minor component of map units 156, 156, and 182).

  - **Palexerolls** have a calcic or petrocalcic horizon, indicating the presence of calcium carbonate or gypsum. Calcic horizons often occur where there is high evapotranspiration (ET) demand. These soils likely support CSS vegetation. There are two soil series described in the Palexerolls suborder, Marpol (major component of map unit 407) and Marpol, gullied (minor component of map unit 412).

  - **Haploxerolls** lack a diagnostic subsurface horizon, but still have a thick, dark surface horizon. Soil described include Calcic Haploxerolls, golf courses (major component of map unit 454), Cumulic Haploxerolls (minor component of map unit 190), Pachic Haploxerolls (minor component of map unit 190), and Haploxerolls (minor component of map unit 407).

ALFISOLS

Alfisols are characterized by a subsurface horizon with a significant accumulation of clay minerals, known as an argillic horizon. While this horizon is typically dominated by non-swelling clays, such as kaolinite and illite, smectite minerals can also be present in varying amounts. All the soils classified as Alfisols on Catalina Island are described as smectic. The term "smectic"

refers to a specific type of clay mineralogy that is characterized by the presence of swelling clays, also known as expansive clays or montmorillonite. Smectic clay minerals have a unique structure that allows them to swell when they encounter water and shrink as they dry out, like that observed in Vertisols. The occurrence of smectic soils within Alfisols is more common in areas with volcanic parent material rich in smectite minerals, such as occurs on Catalina Island. The Alfisols suborders Ustalfs and Xeralfs occur on Catalina Island (Figure 2-33):

- **Xeralfs** (major component of 20 map units): Xeralfs are characterized by a xeric soil moisture regime with an argillic (clay accumulation) horizon. Xeralfs in coastal southern California are often found in areas with chaparral vegetation, which is a dense, evergreen shrub community that includes species like chamise, manzanita, and ceanothus. Scrub oak woodlands are also common wtih an understory of grasses and wildflowers. There are two great groups of Xeralfs on Catalina Island, Haploxeralfs and Palexeralfs. Haploxeralfs exhibit a fine-textured (high proportion of silt and clay) surface horizon overlying a clay-rich (typically more than 40% clay content) subsurface horizon and have moderate to high base saturation (35% or more). Palexeralfs are like haploxeralfs but often display lighter-colored surface horizons compared to their underlying subsoil, a result of past erosion or leaching processes. Palexeralfs have a higher clay content than Haploxeralfs, which can lead to greater water-holding capacity, which can influence the types of plants that grow on these soils. There are four subgroups of Haploxeralfs (Lithic Haploxeralfs, Mollic Haploxeralfs, Typic Haploxeralfs and Vertic Haploxeralfs) and three subgroups of Palexarlfs (Mollic Palexeralfs, Petrocalcic Palexeralfs, and Vertic Palexeralfs) described for Catalina Island:
    - **Lithic Haploxeralfs** have a shallow profile underlain by bedrock or other hard material within 50 cm of the surface. They have a subsurface horizon with clay accumulation and moderate to high base saturation. Soil series include Purser (major component of map units 181 and 183) and Purser, coastal cliffs (major component of map unit 185). Typical vegetation communities include CSS, maritime cactus, *Stipa* grassland, and nonnative annual grassland.
    - **Mollic Haploxeralfs**: These soils have a thick, dark surface horizon rich in organic matter and minerals. Like other Haploxeralfs, they have a subsurface horizon with clay accumulation and moderate to high base saturation. There are two types of soil series in this subgroup, Coastwise and Nauti. Coastwise soils are clayey and shallow, weathered from Catalina schist, and are predominately vegetated by CSS, nonnative scrub, maritime cactus scrub and coastal bluff scrub. Soil series are Coastwise (major component of map units 422 and 423), Coastwise, cobbly (major component of map units 425 and 427), and Coastwise, nongravelly (minor component of map unit 422). Nauti soils are fine-loamy, weathered from quartz-diorite, and vegetated by island chaparral, CSS, nonnative scrub, maritime cactus scrub and coastal bluff scrub. Soil series are Nauti (major component of map units 293, 400, 407, and 411), Nauti, landscaped (major component of map unit 451).

- **Typic Haploxeralfs**: These soils (major component of map unit 427) represent the central concept of Haploxeralfs without any unique characteristics. They are loamy with a subsurface horizon with clay accumulation and moderate to high base saturation.
- **Vertic Haploxeralfs**: These soils have a significant shrinking and swelling property due to changes in moisture content, indicating the presence of smectite minerals. They also have a subsurface horizon with clay accumulation and moderate to high base saturation. These soils are represented by the Freeboard soil series (major component of map units 156 and 157).
- **Petrocalcic Palexeralfs**: These soils (minor component of map units 420 and 423) have a calcic horizon that is cemented or indurated by calcium carbonate, indicating a more arid environment compared to Haploxeralfs. They lack the argillic horizon found in Haploxeralfs.
- **Mollic Palexeralfs**: These soils have a thick, dark surface horizon rich in organic matter and minerals, like Mollic Haploxeralfs. However, they have a calcic or petrocalcic horizon, indicating a more arid environment compared to Haploxeralfs. There are three soil series described: Masthead (major component of map units 420, 421, 422, 423, 424, and 427), Masthead, cobbly (major component of map unit 425), and Masthead, nongravelly (minor component of map unit 422). Masthead soils are deep, and the vegetation is typically CSS or island scrub oak.
- **Vertic Palexeralfs**: Like Vertic Haploxeralfs, these soils exhibit vertic properties, meaning they experience significant shrinking and swelling with changes in moisture content due to the presence of smectite minerals. However, unlike Haploxeralfs, Vertic Palexeralfs do not have an argillic horizon. They typically have an abrupt textural change between the surface horizon and the underlying material. These soils are represented by the Luff soil series (major component of map units 182, 183, 184, 420, 421).

- **Ustalfs**: Ustalfs are characterized by an ustic soil moisture regime, featuring moist winters and dry summers, typical of Mediterranean-type regions, with slightly higher moisture levels during winter months compared to Xeralfs. Ustalfs also possess an argillic horizon, indicating clay accumulation in a subsurface layer. On Catalina Island, there is one great group in the Ustalfs suborder, known as Paleustalfs:
  - **Paleustalfs** are more highly developed than Haploxeralfs and have a higher base saturation (35% or more) compared to Palexeralfs. A distinctive feature of Paleustalfs is the presence of a buried soil horizon, along with a light-colored surface horizon that contrasts with the darker underlying subsoil. This results in a soil environment with higher nutrient availability and cation exchange capacity, which can support a more diverse range of plant species. These soils are in the soil series Dewpoint (major component of map units 184, 422, 423, and 424). Dewpoint soils are mesic and typically include island chaparral, island scrub oak

woodland, and other woodland groves, such as ironwood or cherry. The understory may consist of grasses and wildflowers.

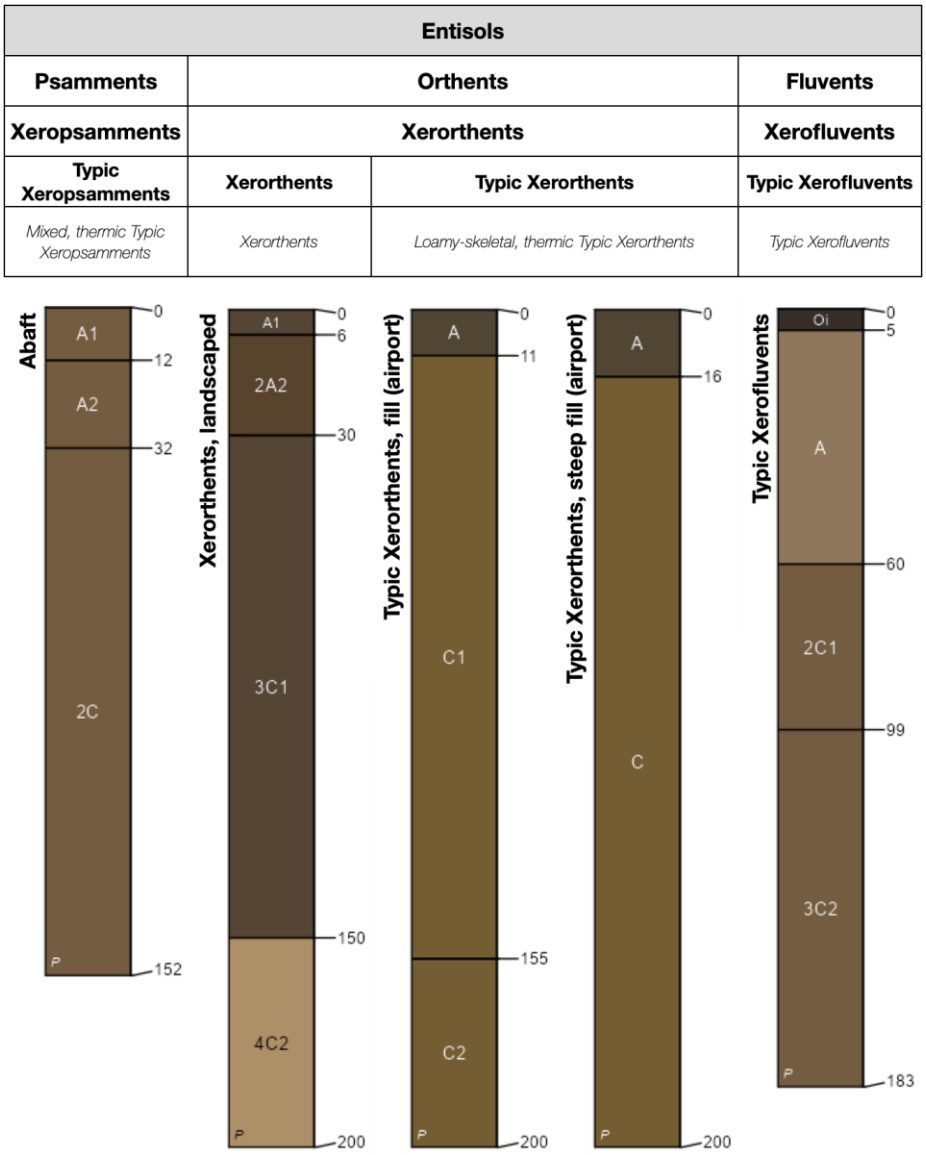


Figure 2-29 Taxonomic Relationship of Soil Map Units in the Entisols Soil Order.

USDA 2008; Typical soil profiles visualized by California Soil Resources Lab (2024); Depth in cm.

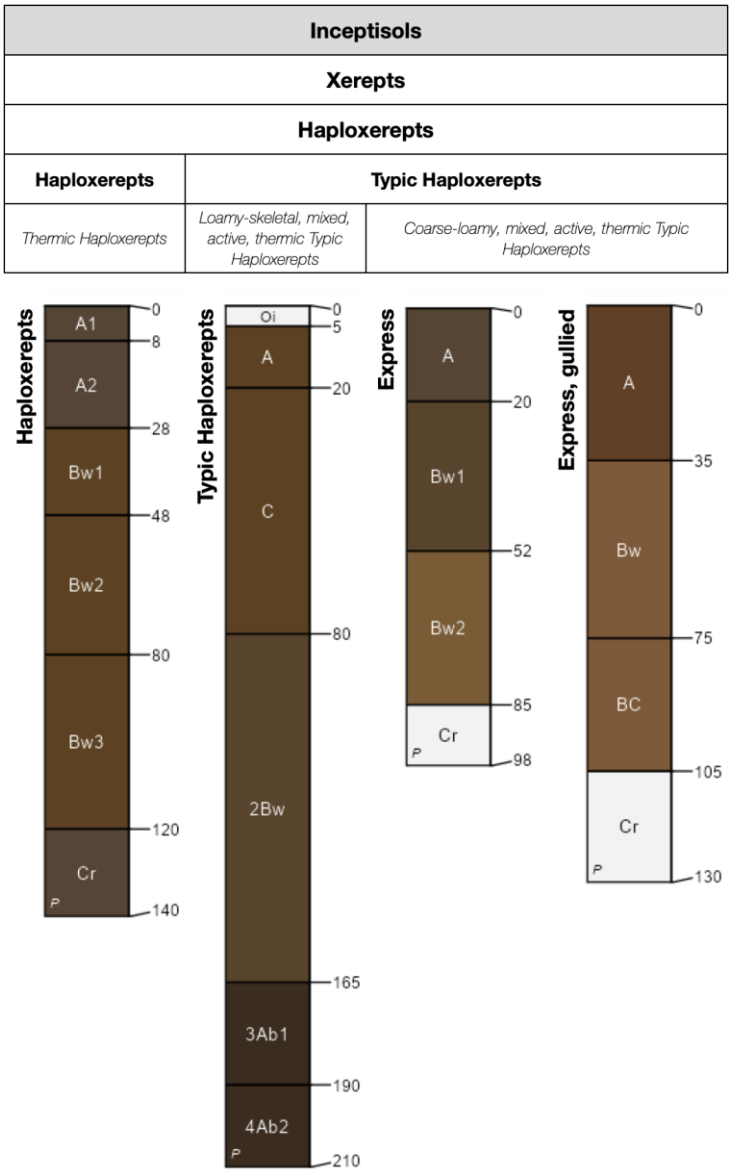


Figure 2-30 Taxonomic Relationship of Soil Map Units in the Inceptisols Soil Order.

USDA 2008; Typical soil profiles visualized by California Soil Resources Lab (2024); Depth in cm.

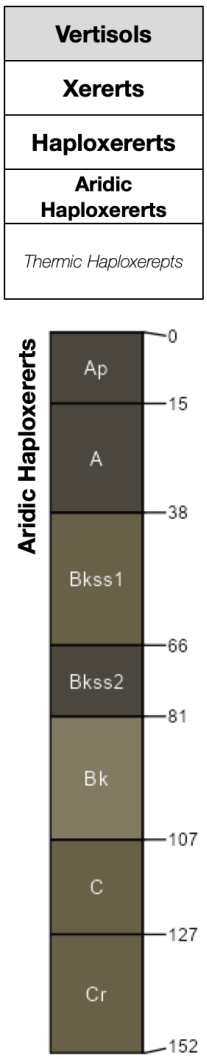


Figure 2-31 Taxonomy of the Soil Map Unit in the Vertisols Soil Order.

USDA 2008; Typical soil profiles visualized by California Soil Resources Lab (2024); Depth in cm.

Mollisols												
Xerolls											Ustolls	
Argixerolls								Palexerolls	Haploxerolls	Argiustolls		Haplustolls
Argixerolls	Typic Argixerolls			Pachic Argixerolls		Lithic Argixerolls		Typic Palexerolls	Calcic Haploxerolls	Typic Argiustolls		Pachic Haplustolls
Argixerolls	*Fine-loamy, mixed, superactive, thermic Typic Argixerolls*	*Coarse-loamy, mixed, active, thermic Typic Argixerolls*	*Loamy, mixed, active, thermic, shallow Typic Argixerolls*	*Loamy-skeletal, mixed, superactive, thermic Pachic Argixerolls*	*Fine-loamy, mixed, superactive, mesic Pachic Argixerolls*	*Loamy, mixed, superactive, thermic Lithic Argixerolls*		*Fine, mixed, superactive, thermic Typic Palexerolls*	*Mixed Calcic Haploxerolls*	*Fine, smectitic, isothermic Typic Argiustolls*	*Loamy-skeletal, mixed, superactive, isothermic Typic Argiustolls*	*Coarse-loamy, mixed, superactive, isothermic Pachic Haplustolls*

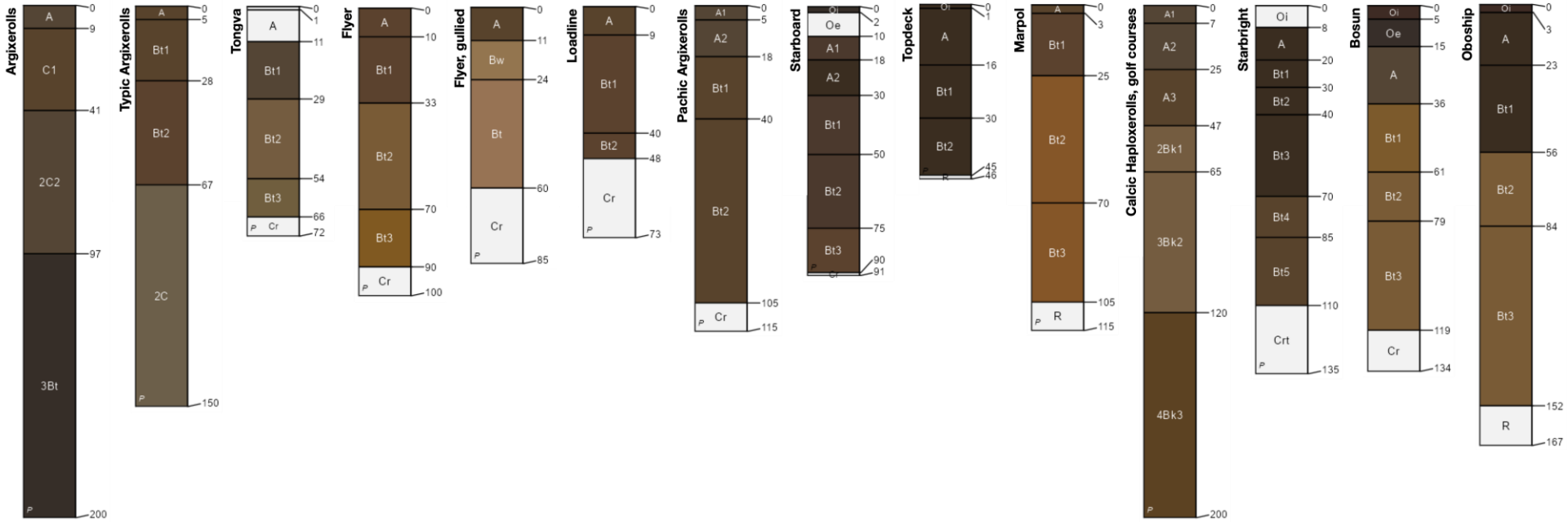


Figure 2-32 Taxonomic Relationship of Soil Map Units in the Mollisols Soil Order.

USDA 2008; Typical soil profiles visualized by California Soil Resources Lab (2024); Depth in cm.

Alfisols								
Xeralfs								Ustalfs
Haploxeralfs						Palexeralfs		Paleustalfs
Haploxeralfs	Typic Haploxeralfs	Mollic Haploxeralfs		Vertic Haploxeralfs	Lithic Haploxeralfs	Mollic Palexeralfs	Vertic Palexeralfs	Typic Paeustalfs
Haploxeralfs	*Loamy-skeletal, mixed, superactive, thermic Typic Haploxeralfs*	*Clayey, smectitic, thermic, shallow Mollic Haploxeralfs*	*Fine-loamy, mixed, superactive, thermic Mollic Haploxeralfs*	*Fine, smectitic, thermic Vertic Haploxeralfs*	*Clayey, smectitic, thermic Lithic Haploxeralfs*	*Fine, smectitic, thermic Mollic Palexeralfs*	*Fine, smectitic, thermic Vertic Palexeralfs*	*Fine, smectitic, thermic Vertic Palexeralfs*

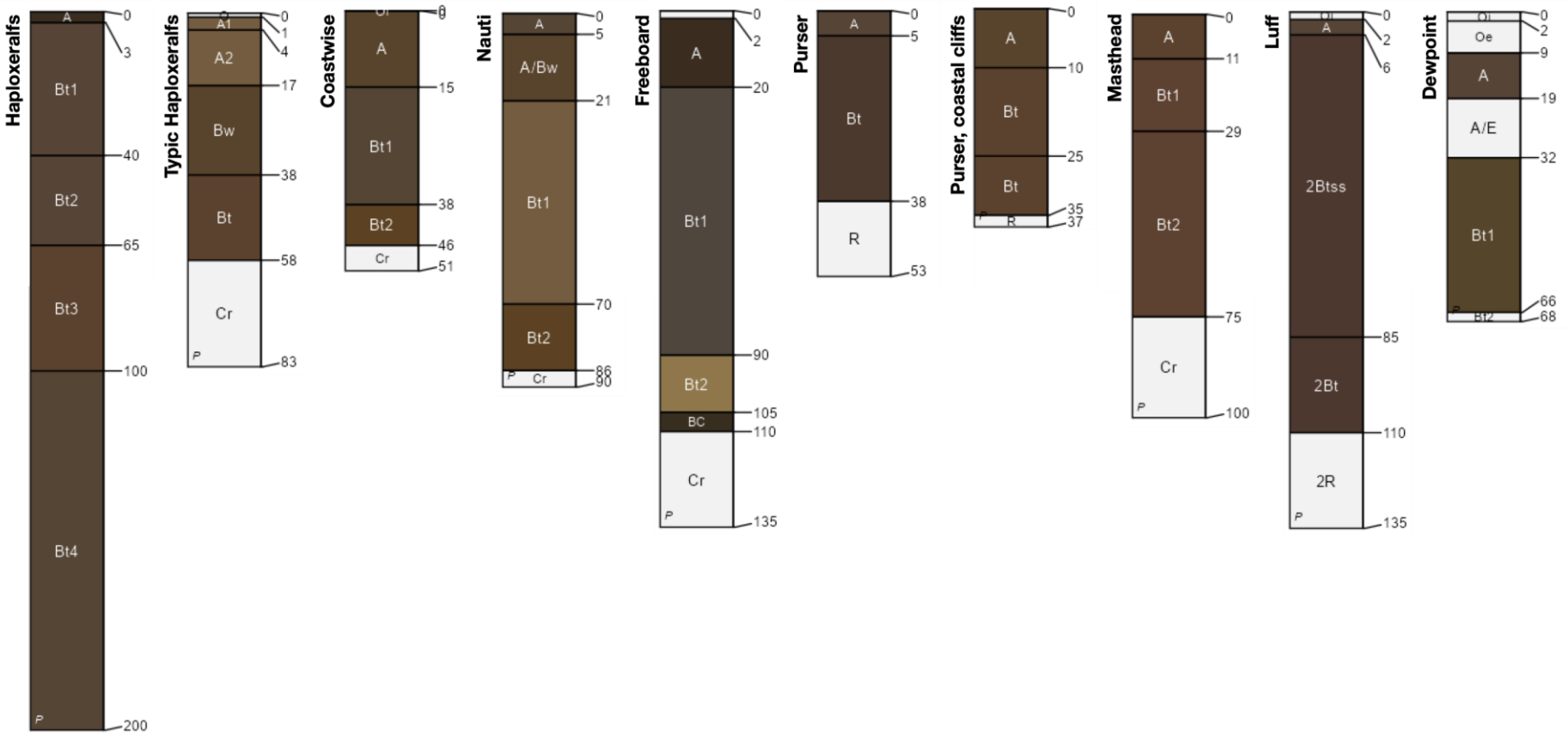


Figure 2-33 Taxonomic Relationship of Soil Map Units in the Alfisols Soil Order.

USDA 2008; Typical soil profiles visualized by California Soil Resources Lab (2024); Depth in cm.

PLANT AVAILABLE WATER

Soil types and environmental factors play a crucial role in determining plant-available water, which in turn influences the composition of plant communities within specific ecosystems. Key soil characteristics, such as organic matter content, restrictive layers (e.g., bedrock, calcic horizon, or argillic horizon), soil depth, texture, and porosity, interact with various environmental factors to shape the distribution and composition of vegetation communities. Organic matter content affects water retention and nutrient availability, while restrictive layers can impede water infiltration and root growth. Soil depth and texture influence water storage capacity, and porosity affects water movement and drainage. These factors together determine the overall water availability for plants. Environmental factors also play a significant role in shaping plant communities. Solar radiation affects evapotranspiration rates, while slope steepness influences water runoff and erosion. Position in the watershed impacts water accumulation from stormwater runoff, horizontal water movement, or upwelling from the vadose zone due to fractured rock holding water. Fog and wind contribute to water input and moisture redistribution, while orographic influences on rainfall result in spatial variations in precipitation patterns. All these factors, in conjunction with soil characteristics, create a complex and interconnected system that defines the plant communities found in different landscapes. Understanding these relationships is essential for the effective management and conservation of ecosystems and their associated plant communities.

For example, using water balance models developed by the California Soil Resources Lab (2024), we can compare the amount of available water in two different Catalina Island soil series, Coastwise and Dewpoint (Figure 2-34). The soil moisture state can be roughly interpreted as “dry” when storage is depleted, “moist” when storage is between 0mm and available water capacity (AWC) (i.e., the amount of water that a soil can store and make accessible for plant use), and “wet” when there is a surplus.

Comparing the Coastwise and Dewpoint soil series on Catalina Island using water balance models reveals distinct differences in AWC and water availability throughout the year. The Dewpoint series, comprising moderately deep and well-drained soils formed from schist and meta-sedimentary rock, exhibits a higher AWC of 124 mm annually. This series maintains available water until September and experiences an annual net water deficit of 513 mm. In contrast, the Coastwise series consists of shallow, moderately well-drained soils formed from schist. This series has a lower AWC of 61 mm annually, with available water lasting only until August and an annual net water deficit of 534 mm. Variations in soil depth, drainage, and parent material contribute to differences in AWC and water availability, impacting plant communities. The Dewpoint series, with higher AWC, primarily supports Island Woodland and Island Chaparral, while the Coastwise series, with lower AWC, predominantly hosts Coastal Sage Scrub, Maritime Cactus Scrub, and Coastal Bluff Scrub. The geographic distribution of available water on the island is visualized in Figure 2-22.

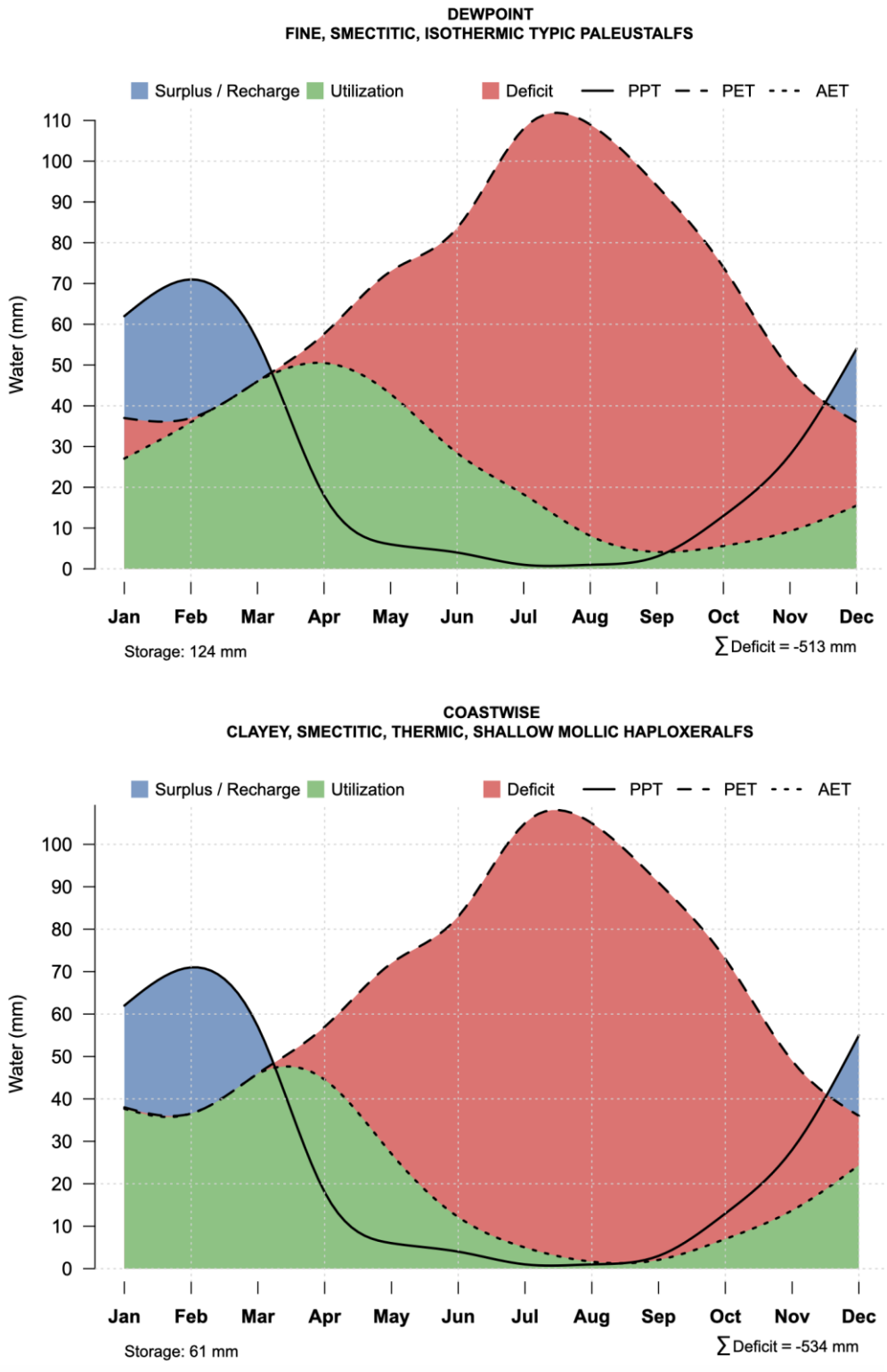


Figure 2-34 Water Balance Comparison Between Dewpoint and Coastwise Soils.

USDA 2008; Monthly water balance estimated by California Soil Resources Lab (2024) using a leaky-bucket style model.

EROSION POTENTIAL AND BARE AREAS

The erosion of potential of soils on Catalina Island is lower than those reported for Santa Rosa and San Clemente, and more typical of erosion potentials in mainland southern California woodland and rangeland (Mertes et al. 2000). A high-resolution potential annual soil loss map for Catalina Island was prepared (Figure 2-35), which is consistent with the previous calculations by Mertes et al. (2000). It was developed using a 10-meter raster digital elevation model (DEM) derived from 2002/2003 Interferometric Synthetic Aperture Radar (IfSAR) (NAVD88 vertical datum) and an empirical model (Renard et al. 1997). Additional notes on model development are provided on the figure. The potential annual soil loss map identifies areas that may be subject to greater topsoil loss from sheet or rill erosion, especially due to loss of vegetation cover from past ranching practices, the impacts of introduced ungulates (e.g., feral goats and pigs that have been removed, mule deer that are a source of current browsing pressure on woody vegetation, and bison that are largely grass consumers), and the effects of vegetation cover loss from the interactive effects of recent large fires (e.g., 2006 Empire Fire and the 2007 Island Fire) that temporarily removed vegetation cover and the loss of post-fire vegetation recovery due to mule deer browse.

While erosion potential is lower on Catalina Island than some of the northern Channel Islands (e.g. Chaney and McEachern 2000), there is evidence of localized erosion impacts, including topsoil loss and highly incised drainages reported by Knapp (2010) that have been attributed to impacts from road construction and intensive browsing by introduced ungulates. As noted by Knapp (2010) and further illustrated in the Soil Survey (USDA 2008), the presence of soil series, such as Masthead, Dewpoint and Luff with prominent argillic horizons, suggest the stability of older soil profiles that take a long time to develop. An argillic horizon is a subsurface soil layer characterized by the accumulation of clay particles, indicating the translocation of fine-textured materials through the soil profile. These soil series are represented by several soil complexes, such as 420, 421, and 422, which currently are generally dominated by CSS, island scrub oak woodland, and island chaparral. This indicates that these areas have retained most of their soil profile, however, certainly there may have been a loss of organic matter from the O and A horizons that have changed the biological conditions for native scrub and woodland recruitment in these areas.

In areas with younger soils, such as Express or Express, gullied (Inceptisols that are major components of map units 410 and 412, respectively) and Flyer and Flyer, gullied (Mollisols that are major components of map units 410 and 412), material is lost downslope faster than weathered clays can migrate down through the soil profile (USDA 2008). As a result, these soils have few distinctive characteristics and few or no diagnostic subsurface horizons. Because argillic horizons can take hundreds if not thousands of years to develop depending on weathering conditions, it is likely that these subsoils would have been relatively similar in composition prior to introduction of invasive ungulates in the early 1800s.

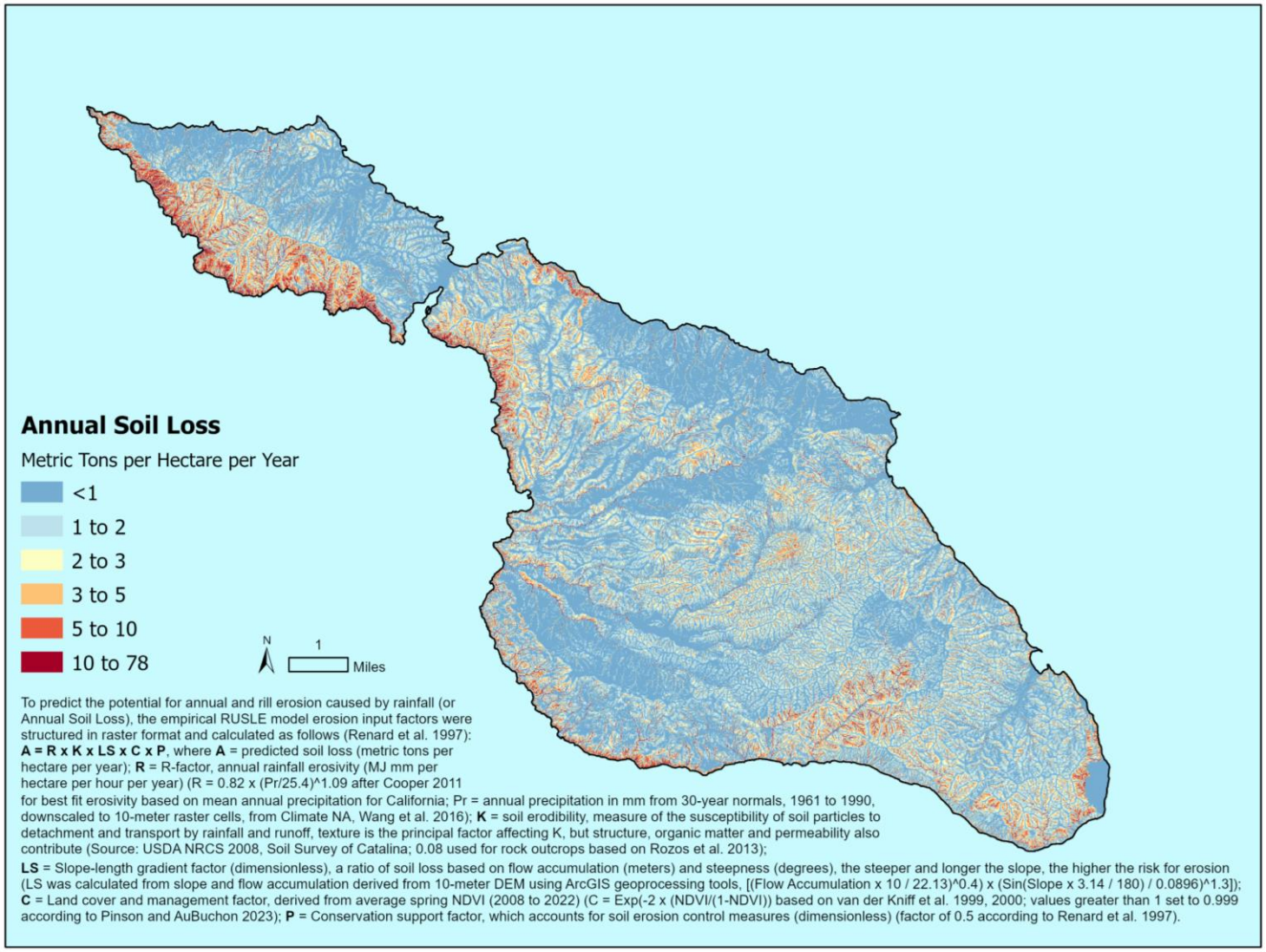


Figure 2-35 Annual Soil Loss Potential.

However, the extensive gulling and the infestation of invasive annual grasses in areas like map unit 412 (Flyer-gullied-Express, gullied-Bosun complex, 15 to 50% slope) indicate that natural vegetative cover has been lost, which is likely to have at least impacted the topsoil, including organic matter content.

To identify areas on Catalina Island with high-levels of bare soil, the Dry Bare-Soil Index (DBSI) was calculated (Figure 2-36). The DBSI is an indicator derived from Landsat imagery that allows for the identification of areas with bare soil or minimal vegetation (Rasul et al. 2018). This index can be used to study various aspects of land cover, such as land conversion, impervious surfaces, and their relation to surface temperature.

2.1.5 Indigenous People and Cultural Land Management

For thousands of years, indigenous peoples inhabited coastal southern California, establishing a complex network of groups and villages, including on Catalina Island. Their settlements were strategically situated near freshwater sources and ecosystems that provided essential resources, such as food and fuel (Anderson 2007). By the time Spanish explorers arrived, the region was already home to a well-established and thriving indigenous society. Evidence of human settlements on the island can be traced back to 6,165 to 5,745 years before present through radiocarbon dating (Radde et al. 2024). Indigenous settlements are found along the island's coasts and terraces, with some sites now submerged due to the island's gradual sinking and rising sea levels (Porcasi et al. 1999). The indigenous people who lived here at the time the Spanish explorers found them called Catalina Island “Pimu” or “Pemú’nga” (Maxwell et al. 2014).

Catalina Island is part of the traditional territory of the Gabrieliño-Tongva which included most of modern-day Los Angeles County, part of Orange County (to Aliso Creek), and the southern Channel Islands, including San Clemente and Santa Catalina (McCawley 1996). The Gabrieliño-Tongva were a semi-nomadic coastal hunter-gatherer tribe that traveled by foot and by canoe, called ti’ats. They speak a language called Takic that belongs to the Cupan group of the Takic subfamily of the UtoAztecan language family, a language family that includes the Shoshonean groups of the Great Basin (Golla 2011). The total Gabrieliño-Tongva population (mainland and islands) at about 1770 AD was roughly 5,000 people, based on an estimate of 100 small villages of 50 to 200 people (Bean and Smith 1978, McCawley 1996).

The Gabrieliño-Tongva people had sophisticated political systems capable of governing sizeable villages comprising diverse clans and lineages. Although the exact nature of their government remains a subject of debate among anthropologists, it is evident that their political structures were intricate and effective in maintaining order and cohesion within their communities (Cherny et al. 2021).

The staple foods of the indigenous people of Catalina Island consisted of marine resources (Salls 1988, Raab et al. 1994, Porcasi and Fujita 2000). The Gabrieliño-Tongva would supplement the resources gathered near them with resources from other ecological zones by obtaining them either directly or through trade (Bean and Smith 1978).

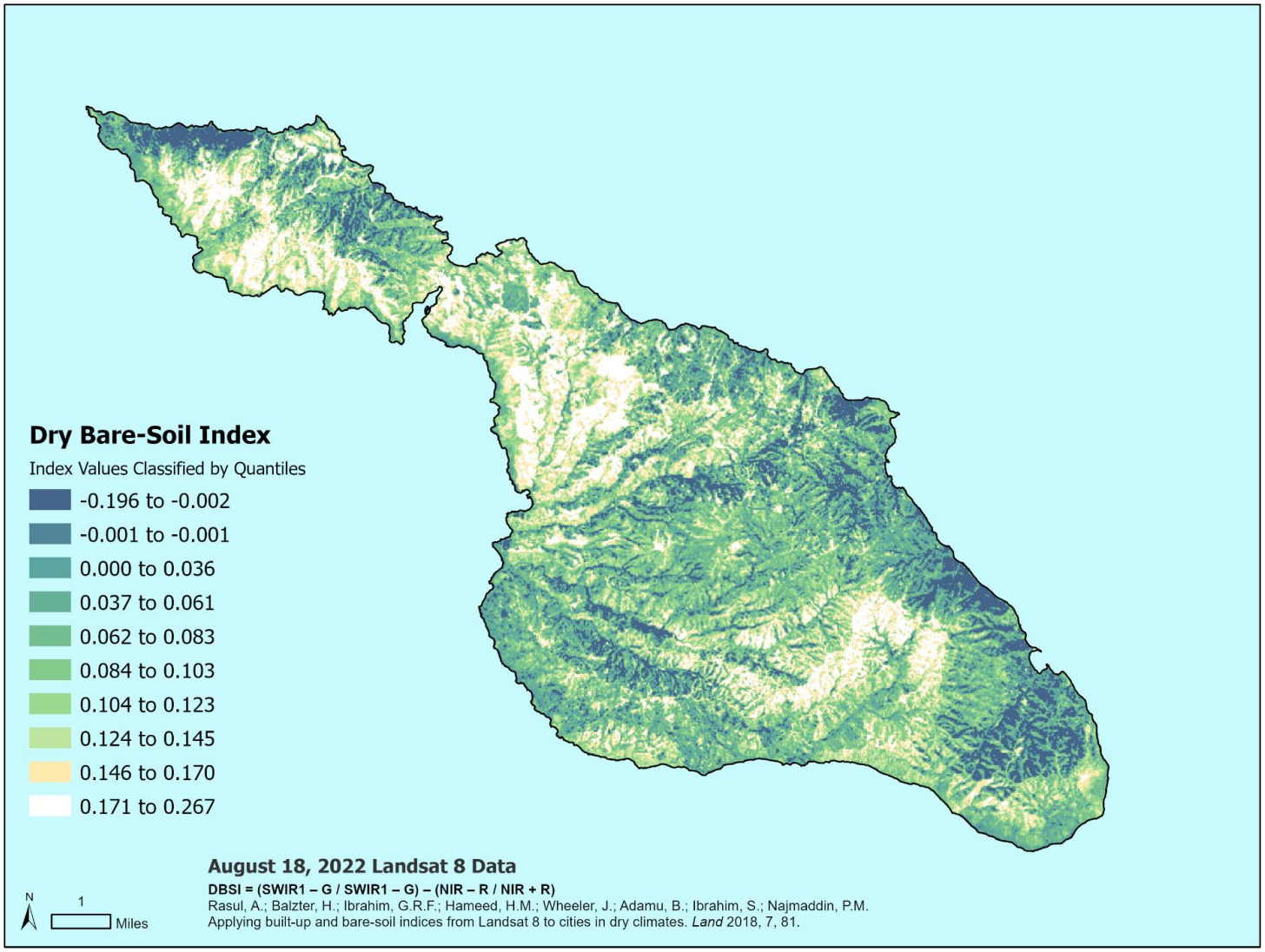


Figure 2-36 Dry Bare-Soil Index.

The Gabrieliño-Tongva were part of an extensive trade network among indigenous people from southern California to Arizona and New Mexico (Bean et al. 1978, Longcore and Ethington 2023). The main export item for the indigenous people of Catalina was steatite (commonly referred to as soapstone), a kind of rock found on the island used to make carvings of sacred animals and vessels (Howard 2000). They also exchanged salt, shellfish, dried fish, marine mammal meat, and sea otter pelts for acorns, obsidian, and deerskins from the inland territories (Bean et al. 1978, McCawley 1996, 2002, Cherny et al. 2021).

Indigenous peoples actively managed the island's vegetation through fire (Hardiman et al. 2016) but the extent and the purposes of cultural burning practices are not well understood. Pacific Coast tribes have a long history of using fire to manage the land, with their practices varying depending on the season and local environmental conditions (Anderson 2007, Vinyeta 2022). In southern California, indigenous people would likely burn the mainland coastal prairie annually to increase plant food yield for seed collection of plants such as red maids (*Calandrinia* spp.), Chia (*Salvia columbariae*), and tarplant (*Deinandra* spp.), and for bulb plants such as blue dicks (*Dichelostemma spp.*) (Timbrook et al. 1982). Burning may have also been used to improve hunting for small mammals, such as rabbits or rodents. There is limited evidence of these types of cultural burning practices to increase food yield on Catalina Island. Instead, there is more direct evidence that there was a marine-based diet supplemented with terrestrial plant food resources, either collected on the island or traded for from the mainland.

Referring to the pre-colonial setting as the “Indigenous Landscape,” Longcore and Ethington (2023) emphasize the role of humans in manipulating the region’s natural communities during the long period that predated large-scale introduction of nonnative plants and animals from Europe and elsewhere. This historical context serves as a reminder of the region's ecological diversity and the importance of human-environment interactions in shaping the landscape of Catalina Island.

2.1.6 Impact of Invasive Species Introductions

Nonnative Ungulate Introductions

European ranchers and small-lot farmers settled, and an era of extensive and eventually uncontrolled grazing and browsing by introduced ungulates began (Figure 2-37). Sheep, cattle, and goats were introduced in the 1820s and persisted for a century. Sheep were removed in the 1920s and were replaced by pigs (*Sus scrofa*). Bison (*Bison bison*) were added in the 1920s as well, followed by mule deer in 1928 (Landis 2000). Goats and pigs were controlled in the 1990s through the early 2000s, and bison kept in check through fertility management starting in 2009 (Duncan et al. 2017). Pigs were fully eradicated by 2004 and goats by 2005.

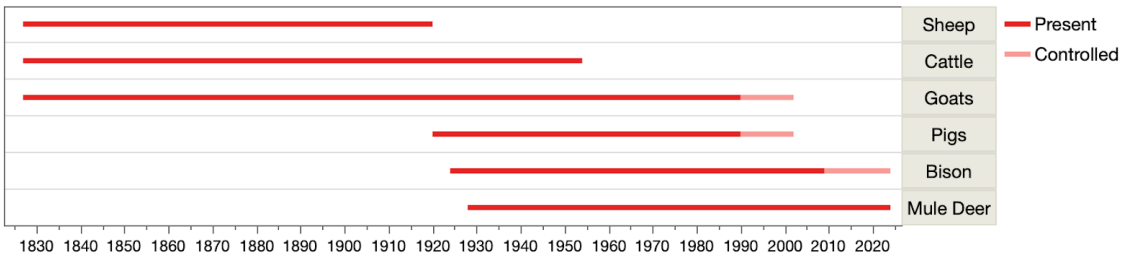


Figure 2-37 Timeline of Presence of Invasive Ungulates on Catalina Island.

Spanish missionaries are believed to have brought goats to the island as food for the indigenous people in 1827 (Preston 1997). Goats introduced by the Spanish multiplied so greatly that they drove more than 48 animal and plant species to extinction (Cherny et al. 2021). A census in 1864 by the military determined that between 8 ranchers on the island there were approximately 620 cattle and 22,000 sheep. Feral goats were estimated at 15,000. Ranching operations on the Island were sometimes intermittent and managed primarily by what is now the Island Company. Cattle were barged on and off the Island from the Isthmus and sometimes White's Landing. Sheep ranching was common in the 1800s and some of the harbors, such as Ben Weston, were named after these ranchers. Most of the historic livestock fences have been mapped by the Conservancy but are no longer maintained and some sections have been removed (Figure 2-38). By the early 1900s, it became apparent that there was not enough vegetation for so many herbivores and sheep were removed from the Island in 1920 by William Wrigley, Jr. who purchased the island in 1919. Subsequently, invasive mule deer and feral pigs were introduced by the early 1930s (Sweitzer et al. 2005).

The historical presence of these introduced herbivores has significantly altered the vegetation communities on Catalina Island, as well as the other California Channel Islands (Junak et al. 2012). Native plant cover, diversity, and natural recruitment has been significantly reduced due to the legacy of the introduction of ungulates, including browsers that primarily consume woody vegetation (e.g., feral goat, sheep, pigs, and mule deer) and grazers that primarily consume grasses and other herbaceous plants (e.g., cattle and bison) (Landis 2000, Laughrin et al. 1994, Knapp 2005b, Knapp 2009, Minnich 1982, Manuwal and Sweitzer 2007). The legacy impact of invasive ungulates is the loss of the extent and diversity of native habitat, especially Coastal Sage Scrub and Island Chaparral on Catalina Island (Minnich 1980, 1982). Similar impacts from the introduction of sheep have been documented on Santa Cruz Island (Brumbaugh 1980, Van Vuren and Bowen 1987).

Channel Island and Catalina Island endemic plants are especially vulnerable to invasive ungulates. Because of the long-term isolation of island vegetation from the mainland, endemic island plants evolved in the absence of ungulates, leading to a reduction in defenses to herbivores (Bowen and Ban Vuren 1997, Orians and Ward 2010).

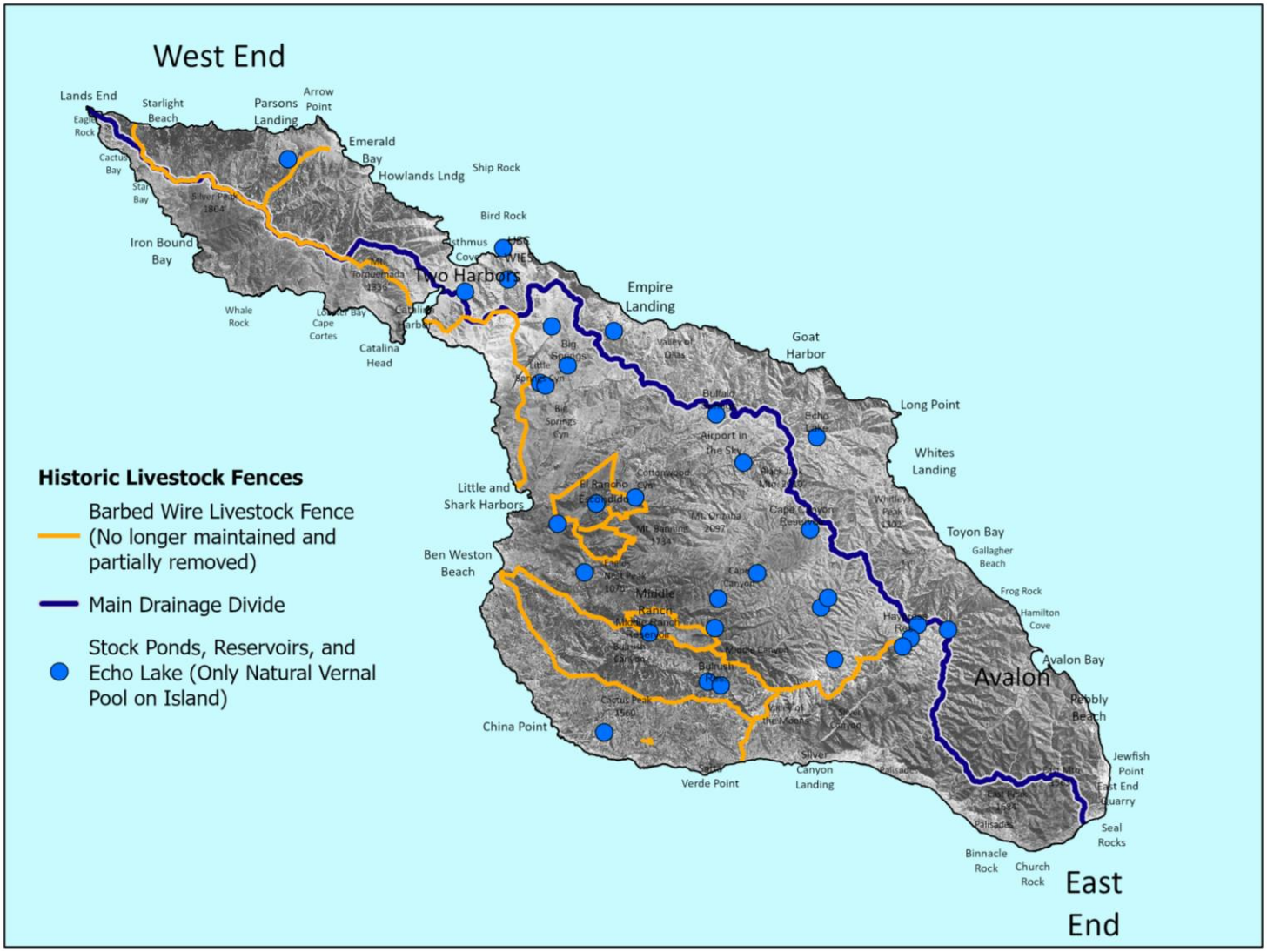


Figure 2-38 Location of Historic Livestock Fences.

Many endemic island plants are preferentially consumed by invasive herbivores, thereby restricting their distribution from their natural habitat to difficult-to-access locations, such as sea bluffs, cliff faces in the interior of the island, and within thorny cactus patches (Junak et al. 2012). This selective browsing decreases island biodiversity and increases the frequency of other native plants that retained their herbivore defenses, such as lemonadeberry (*Rhus integrifolia*), toyon (*Heteromeles arbutifolia*), white sage (*Salvia apiana*), black sage (*Salvia mellifera*), and prickly pear cactus (*Opuntia littoralis*). Many of these browse resistant plants are now more frequent in many areas of the island. Coastal Bluff Scrub, because of its inaccessibility to invasive ungulates is one of the best-preserved vegetation communities on Catalina Island (Thorne 1967).

Island vegetation lifeform (e.g., tree, shrub, herb) is responsive to long-term climatic trends (i.e., wetter, or drier periods of time) and impacts from invasive ungulate browsing, and to a lesser extent grazing and trampling from the small managed herd of bison. The introduced bison population is currently managed by the Conservancy through an immunocontraception program, with about 90 individuals currently living on Catalina. Browsing pressure from invasive ungulates is magnified during periods of drought, as the animals are driven to consume less nutritious forage to survive, which impacts the limited island vegetation resources that grow below the browse line (e.g., green leaves and small stems within reach of mule deer to a height of about 4 to 5 feet).

Recent large fires, coupled with the impacts of drought and mule deer browsing, have significantly altered the vegetation structure on Catalina Island (Appendix C). The human-caused Empire Fire in 2006 and the Island Fire in 2007 collectively burned 12% of the island, with the latter being the largest recorded fire since 1915 (Figure 2-39). The Island Fire alone scorched 4,723 acres, surpassing the previous record set by the Goat Fire, which burned 285 acres. From 1985 to 2022, unburned watersheds saw a 5.2% decrease in barren soil cover and an 8.1% increase in shrub cover, which coincides with successful removal of feral goats and pigs between 1990 and 2005 (Figure 2-40). Tree cover increased from 40.2% to 48.7% in 1998 but then declined to 40.1% in 2022 following successive drought years from 2011 to 2016 and 2020 to 2022. While in watersheds that burned in the 2006 and 2007 fires, tree cover had increased from 52.0% in 1985 to 63.2% in 2005 (before the Empire Fire). However, 15 years after the fires tree cover has not recovered and is at 54% in 2022, 9.2% below pre-fire levels. Following fire, newly germinated plants from the native soil seed bank and basal resprouting shrubs and trees are subject to intense browsing pressure from mule deer (e.g., see Figure 2-41), even for plants that deer wouldn't find palatable after they have grown to a mature size (e.g., chamise, *Adenostoma fasciculatum*) (Minnich 1982, Ramirez et al. 2012). The browsing pressure from mule deer on the island is intensified during drought when forage is limited.

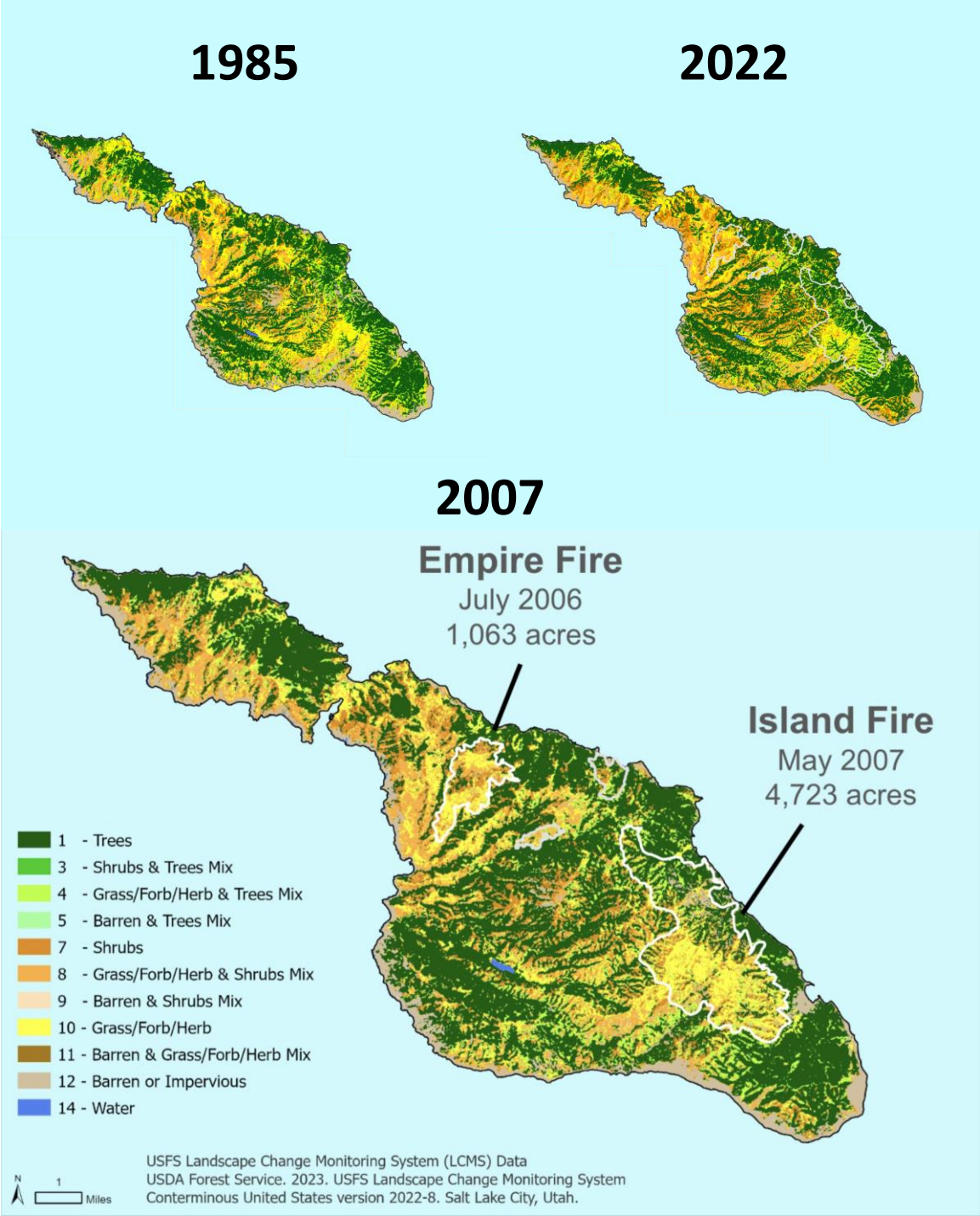


Figure 2-39 Vegetation Cover in 1985, 2007 after two large fires, and 2022.

Tree Cover Increased and Barren Cover Decreased Between 1985 and 2022 Following Feral Goat and Pig Removal beginning in the 1990s. However, Tree Cover Has Not Fully Recovered in the 15 Years Since the 2006 and 2007 Due to Drought and Mule Deer Browsing Impacts. See Appendix C for more detail.

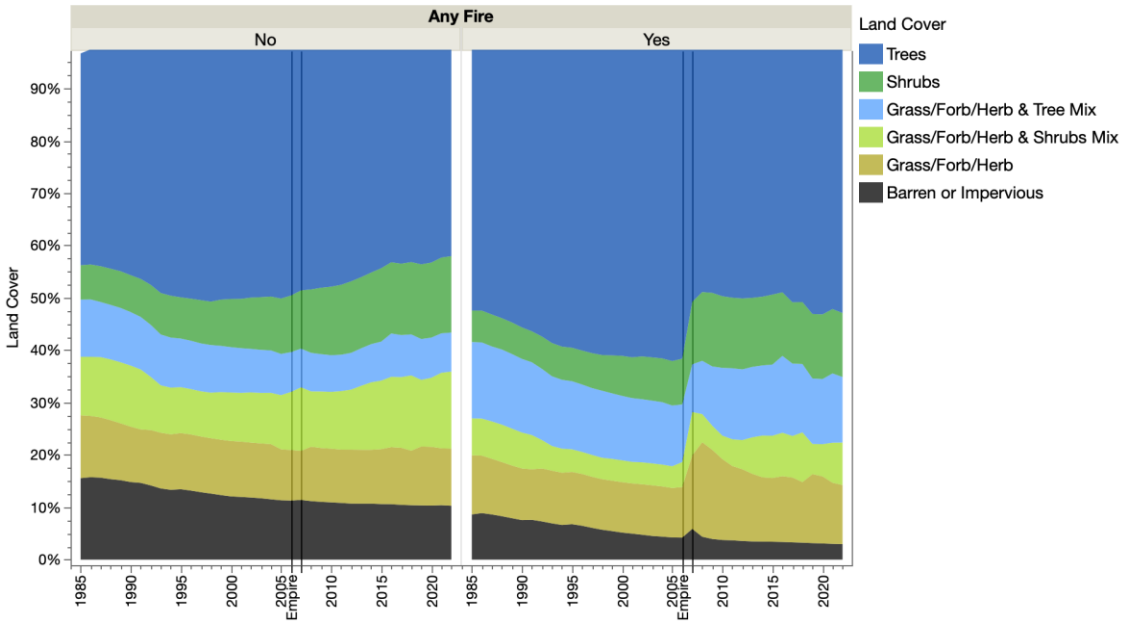


Figure 2-40 Tree Cover has not recovered in Watersheds that Burned in the 2006 Empire and 2007 Island Fires.

See Appendix C for more detail.

Figure 2-41 An Island Scrub Oak plant is unable to recover after the 2003 Airport Fire because of mule deer browsing basal resprouts.

Photo taken May 19, 2003, by the Conservancy after the January 6, 2023, Airport Fire.

IMPACTS OF INTRODUCED FLORA

Predating the introduction of nonnative ungulates to Catalina Island, nonnative plants from Eurasia where first introduced to California by European explorers, including Juan Rodríguez Cabrillo in 1542. Spanish colonizers further introduced Eurasian plants to California in the late 1700s. On Catalina, the introduction of ungulates and colonial agricultural practices, created the disturbances that allowed for extensive invasion by the introduced flora. The Eurasian vegetation, having evolved alongside agricultural practices for millennia in a similar Mediterranean-type climate, was already well-adapted to the ecosystem upon its introduction to California. The concurrent introduction of agriculture created additional landscape disturbances, which further facilitated the spread and establishment of naturalized plant populations. This combination of factors contributed to the successful integration and persistence of these nonnative species in their new environment (Jackson 1985).

Invasive annual grasses and forbs have become a significant component of Catalina Island's flora, constituting approximately one-third of its species (see Table 2-4 and Appendix B). These nonnative plants compete with native vegetation for resources, often hindering the recruitment and growth of native species. For instance, a study by Knapp (2007a) documented a 30% reduction in island scrub oak cover between 1943 and 2005, potentially linked to the aggressive spread of invasive annual grasses. Research suggests that the presence of nonnative annual grasses can impede oak recruitment by outcompeting oak seedlings for water resources (Griffin, 1973; Bernhardt & Swiecki, 1991; Danielson & Halvorson, 1991). This competition may have contributed to inadequate regeneration of valley oaks in California during the 20th century. Given these findings, managing and controlling invasive plant species on Catalina Island is essential for preserving native plant communities and fostering the successful recruitment of key species such as island scrub oak.

Other common invasive plants on the island that impact ecosystem health include Italian thistle (*Carduus pycnocephalus*), sweet fennel (*Foeniculum vulgare*), Harding grass (*Phalaris aquatica*), and Mediterranean broom (*Genista linifolia*). Mediterranean broom is particularly aggressive and has the potential to establish on most of the island (see Appendix D). First introduced in 1920 as a horticultural landscaping plant at the Saint Catherine Hotel at Descanso Beach that replaced the Banning home burned down in the 1915 Avalon Fire, Mediterranean broom has naturalized in the Avalon watershed, and as of 2015, has infested at least 9 percent of the island (Dion 2018).

2.1.7 INVASIVE MULE DEER IMPACTS

Following the successful removal of feral goats and pigs by the Conservancy from 1990 to 2003, mule deer have become the most significant remaining invasive browser on Catalina Island, threatening the island's biodiversity and ecosystem health (Ramirez et al., 2012). Although native vegetation cover has recovered since the removal of feral pigs and goats by 2005 (see Appendix C), there is a disproportionate representation of deer-resistant plants such as laurel sumac (*Malosma laurina*), lemonade berry (*Rhus*

integrifolia), and invasive annual grasses and forbs. This recovery also lacks a significant presence of island endemic and rare plant species.

Concurrently, bison remain as the other invasive ungulate on the island, primarily impacting the ecosystem through trampling and soil compaction. However, their population is currently managed via an immunocontraception program, which has successfully maintained the population at less than 100 individuals in recent years.

The detrimental effects of mule deer overpopulation and introduction to novel habitats on biodiversity are well-documented in scientific literature (e.g., Anderson 2003, Anthony 2019, Côté 2004). Moreover, the impact of the introduction of mule deer to the ecological health of Catalina Island has been extensively studied (Appendix C, Dvorak and Catalano 2016, Jacobsen, et al. 2018, Knapp 2005b, Knapp 2007a, Landis 1997, Manuwal and Sweitzer 2007, Ramirez, et al. 2012, Salladay and Ramirez 2018, Stapp et al. 2022).

The diet of mule deer varies seasonally depending on the availability of different plant resources throughout the year. Most of their diet consists of leaf and twig browse of woody shrubs (Collins and Urness 1983), supplemented with forbs in spring and summer (Longhurst et al. 1952), and acorns in fall and early winter when nutritional stress is highest (Cronemiller and Bartholomew 1950, Harlow et. al 1975, Ashcraft 1979, Pine and Mansfield 1980, Pavlik et al. 1991). In California Chaparral, mule deer heavily rely on oak leaves in the summer months and acorns in the fall (Urness 1981, Kucera and Mayer 1999).

Native woody plants on Catalina Island, particularly endemic species, are more vulnerable to deer browsing due to their lack of evolutionary defenses against large herbivores. Since these plants evolved in the absence of such herbivores, they did not develop or retain the necessary chemical and mechanical traits to protect themselves from browsing (Orians and Ward 2010). A forage palatability study comparing plants from ten matched taxonomic groups, consisting of samples from both the mainland and Catalina Island, revealed that ungulates showed a clear preference for island plants (Salladay and Ramirez 2018).

Mule deer have a significant impact on vegetation during post-fire successional periods when germinated seedlings are present in the landscape. The increased vulnerability of these seedlings to deer browsing can significantly influence plant community composition and hinder the recovery of native species. As observed in recent years following the 2007 Island Fire in the White's exclosure and as reported by Knapp (2005b) in exclosures erected following the 1999 Goat Fire, rare and endemic plants germinate and resprout when protected from mule deer browse but cannot establish in the presence of mule deer browsing (e.g., see Figure 2-42). Examples are the Channel Islands tree poppy (*Dendromecon harfordii*) and Catalina ironwood (*Lyonothamnus floribundus* subsp. *floribundus*). In the Goat Fire exclosures numerous rare herbaceous species were observed, including fire poppy (*Papaver californicum*), which had not been previously recorded (Knapp 2005b).

Figure 2-42 Exclosure (Outlined in Red) Protecting Island Chaparral Vegetation from the Impacts of Mule Deer Browsing Following the 1999 Goat Fire.
Photo Provided by the Conservancy, Taken in 2002.

Post-fire regeneration is a critical stage in a plant's life history, as limited stored resources are mobilized to establish stable growth. Herbivory during this fragile period can have a disproportionate impact on plant survivorship. A study by Ramirez et al. (2012) on post-fire regeneration in three woody re-sprouters (*Heteromeles arbutifolia, Rhus integrifolia*, and *Rhamnus pirifolia*) following the 2006 Empire Fire revealed that exposure to mule deer resulted in an eight-fold increase in plant mortality. In protected plots, 11% of resprouts died, compared to 88% in deer-exposed plots. Deer browsing also led to a more than 93% reduction in canopy coverage among dominant shrub species, paving the way for exotic species invasion and vegetation type conversion.

The effects of excess browsing after wildfires can be even more pronounced among taxa that rely solely on re-seeding for regeneration. After the 2007 Island Fire, Jacobsen et al. (2018) established long-term monitoring stations at four sites within the fire footprint, consisting of monitoring plots both within a protective exclosure and unprotected plots immediately outside the exclosure. They monitored seedling survival, density, browse damage, and water relations in three re-seeding taxa: *Arctostaphylos catalinae, Ceanothus arboreus*, and *C. megacarpus*. All three species produced dense fields of new plants after the fire, which gradually thinned over subsequent years. A clear effect on seedling height was observed within the first two years for *C. arboreus*, with protected individuals reaching four times the size of those outside the exclosures. Over a span of fourteen years, the differences in growth and survival rates within the protective exclosures led to substantial demographic changes. The exclosure plots with mature

stands of *Ceanothus arboreus* and *C. megacarpus* contributed to the soil seed bank, ensuring the population's potential for recovery following future fire events. In contrast, plants exposed to mule deer did not survive long enough to produce a seed bank, resulting in their effective extirpation from those locations.

The disruptive effect of mule deer following fire events can also be seen in legally protected plants. The island rush-rose (*Crocanthemum greenei*) is a federally listed as threatened species found exclusively on the Channel Islands. The California Native Plant Society ranks it CRPR 1B.2—a high threat level—and it's one of twelve top-priority native plant taxa identified by the Catalina Island Conservancy (Rare Plant Conservation Plan). The plant occurs in small, widely scattered populations, and its germination appears to be fire dependent. Following the 2007 Island Fire, the growth and reproductive success of *C. greenei* was assessed at nearly half of the species' known occurrences on the island, both within and outside protective exclosures. Populations exposed to mule deer browsing showed markedly lower reproductive success, with 58% of those populations failing to produce any seeds. Populations protected by exclosures contained significantly larger plants, and all the plants in exclosure populations successfully fruited, regenerating the soil seed bank (Dvorak and Catalano 2016). Any effective conservation strategy for this federally listed species must address the mitigation of deer impacts.

Mule deer not only impact plant diversity but also degrade habitat quality for the federally threatened Catalina Island Fox. Mule deer preferentially browse species such as island redberry (*Rhamnus pirifolia*) and Santa Catalina Island manzanita (*Arctostaphylos catalinae*), which are important berry sources for the fox. By reducing deer populations, these native plant species can recover, providing essential food resources for the Catalina Island Fox and other wildlife species.

Mule deer have been subject to nearly annual harvesting on the island since 1949, with recent management efforts conducted under the Private Lands Management Program of the California Department of Fish and Wildlife (Knapp 2014). Despite these ongoing management actions, research suggests that recreational hunting alone is insufficient to effectively mitigate the negative effects of mule deer on habitat and biodiversity (Mack et al. 2000).

2.1.8 FIRE

The fire frequency of mainland chaparral and CSS communities is higher than on the Channel Islands. However, recent human-caused large fires (2006 Empire and 2007 Island) on Catalina Island have resulted in a dramatic loss of chaparral habitat due to the combination of post-fire browsing by mule deer and drought (years 2011 to 2016 and 2020 to 2022) (Appendix C, Ramirez et al. 2012).

Historically, fire frequency in mainland chaparral ecosystems ranged from 25 to 65 years, allowing sufficient time for native species to recover in the fire-free period (Keeley 1982, Lombardo et al. 2009). However, if fires occur too frequently, generally less than 20-year fire return intervals, obligate-seeding chaparral species may struggle

to replenish seed banks, reducing post-fire reestablishment (Zedler et al. 1983, Keeley et al. 2005). Similarly, obligate resprouting species can experience diminished recovery following short-interval fires, as their carbohydrate storage may be insufficient to support vegetative regrowth, particularly under extreme climatic conditions (Pratt et al. 2014). As native shrub recovery falters, gaps in the closed-canopy chaparral open opportunities for invasive grasses or sage scrub species to colonize. This invasion leads to varying degrees of "type-conversion," resulting in a regional continuum of canopy openness and altered plant community composition (Keeley et al. 2005, Jacobsen and Pratt 2018).

Chaparral and many CSS vegetation communities are typically resilience to invasion by nonnative plants when there is not a disturbance. These shrublands typically maintain a closed canopy, which provides resistance to invasive species. However, changes in fire regimes can lead to increased susceptibility to invasions (Zedler et al. 1983, Keeley et al. 2005). Land management practices, such as grazing and mechanical disturbances, can further exacerbate the susceptibility of these ecosystems to invasion (Stylinski and Allen 1999). Jackson (1985) proposed that the invasion of Eurasian annual grasses into California's grasslands in the late 1700s was a combination of intensive year-round livestock grazing and conversion to crop agriculture followed by land abandonment. Keeley (2002) hypothesized that frequent use of fire by indigenous people increased the susceptibility of the landscape to invasion by nonnative of Eurasian annual grasses.

On the Channel Islands, there are fewer fire events than on the mainland because ignition sources are much less common, and the foggy maritime climate generally limits fire spread. Fire caused by lightning rather than by human ignition is extremely uncommon (Minnich 1982, Carroll et al. 1993), likely a result of the maritime conditions (although 3 lightning fires were recorded between 2001 and 2005 in Catalina Island Conservancy records). There are 22 fires in the contemporary record since 1915 (Table 2-3). A fire perimeter has been mapped for the 18 most recent fires (Table 2-3 and Figure 2-43). Less than 15% of the island (about 7,000 acres) has burned since 1915. Except for a small portion of the 1982 Isthmus Fire and the 2011 Banning Fire, none of the fire perimeters overlap, meaning that the fire return interval for the burn areas is at least 100 years. Minnich (1982) observed that the loss of Island Chaparral on the island from the impact of invasive ungulates beginning in circa 1820 reduced fuel loads and may have reduced the likelihood of significant fire events in the last two hundred years. The two largest recorded fires (2006 Empire and 2007 Island) occurred in the last 20 years and were both ignited by human activity. Although similar plant communities on the mainland experience regular fire, fire on the islands would have been much less frequent during the evolutionary history of island plant communities until evidence of human occupation on Catalina Island 6,165 to 5,745 years ago (Radde et al. 2024).

Periodic fire has likely played a role in shaping the evolution of Catalina Island's flora, as suggested by studies such as Carroll et al. (1993), Landis (1997), and Knapp (2005b). Some plant species with traits favoring post-fire regeneration, like felt-leaf ceanothus (*Ceanothus arborus*) and Santa Catalina Island manzanita (*Arctostaphylos catalinae*), have become less common due to invasive ungulate browsing. Landis (1997) also

suggested that they may be less common in part because of a reduction in fire frequency. However, while periodic fire may be important recruitment events, these plants can also reproduce by seed. The occurrence of fire-adaptive traits in native plants might not be solely attributed to fire as a primary selective pressure in their evolution. Instead, these traits could have been retained from ancestral populations on the mainland and proven advantageous in the face of periodic fires on the island.

Table 2-3 Catalina Island Fire History, 1915 to Present.

Fire Name	Month-Year	Size (Acres)	Fire Perimeter Mapped	Watershed Management Units Impacted
Avalon	1915	>20	no	Not mapped
Isthmus Quarry	1920	4 to 6	no	Not mapped
Forester's Inn, Avalon	1920	>100 acres	no	Not mapped
White Rock Springs	1921	400 to 500	no	Not mapped
Middle Ranch Shop	1975	6.5	yes	61j
Isthmus	Jul-1982	184.2	yes	70, 11
Little Harbor	Sep-1998	1.2	yes	66a
Goat	Jul-1999	285.4	yes	27, 28
Airport	Jan-2003	142.8	yes	63c
Middle Ranch Junction	Jul-2006	2.6	yes	35, 61e
Empire	Jul-2006	1,063.2	yes	19, 20, 21, 65, 66c
Bulrush	Jul-2006	1.4	yes	61h
Island	May-2007	4,723	yes	32a, 32b, 32c, 33, 34, 35, 36, 37, 38, 39, 40a, 40b, 50a, 50b, 50c, 61e, 61f
Plane Crash	Oct-2008	0.4	yes	64
Echo Lake	Jul-2010	24.1	yes	29
Plane Crash	Oct-2010	0.7	yes	63d
Banning	May-2011	118	yes	11, 12, 70
Castle Rock	Jan-2012	0.6	yes	61d
Howlands	2014	0.1	yes	7, 74
Banning	2019	1.5	yes	11
Banning	Dec-2020	1.5	yes	13
Middle	Nov-2021	17.1	yes	61d

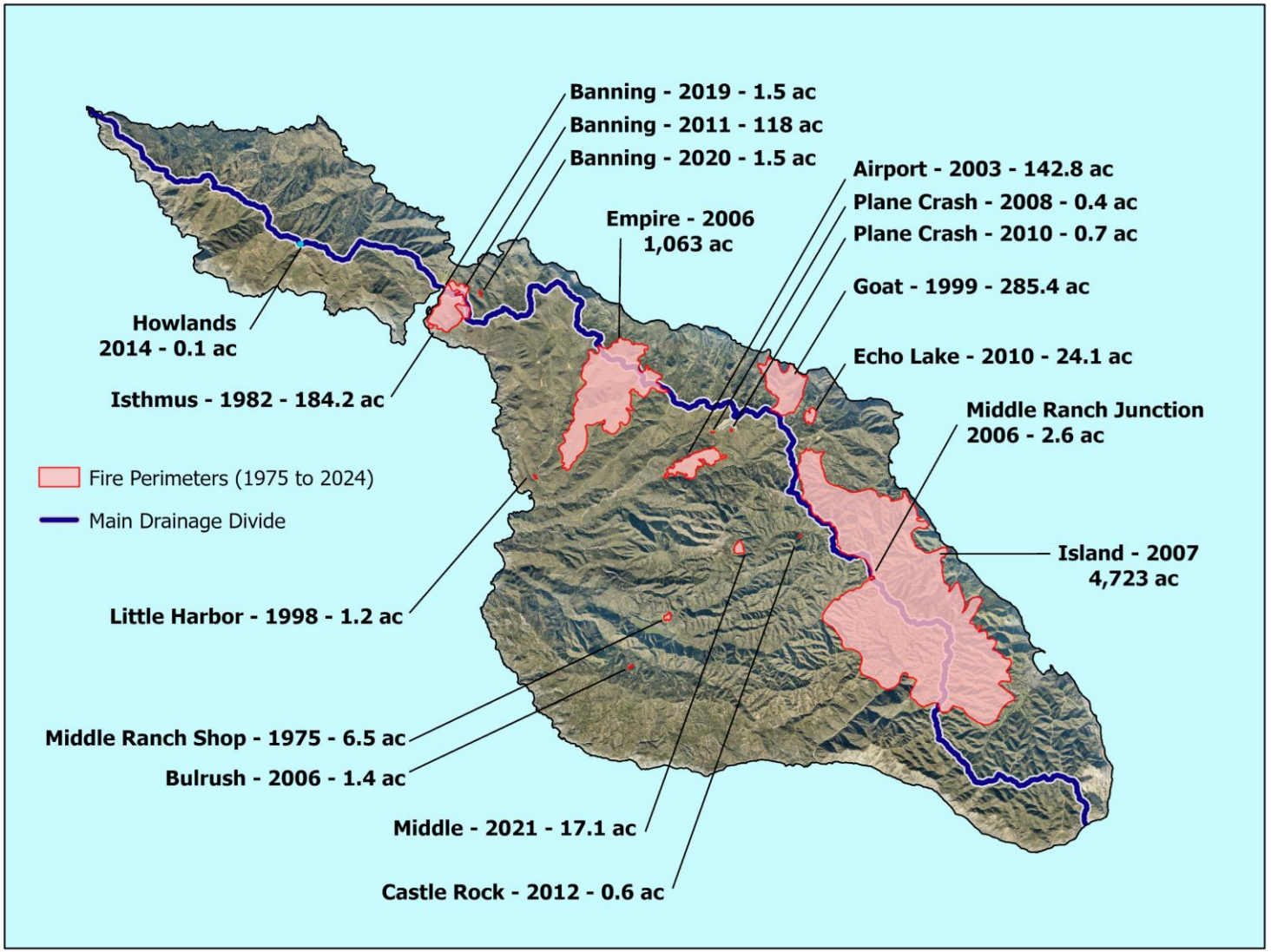


Figure 2-43 Catalina Island Fire Perimeter History, 1975 to Present.

Data provided by the Conservancy.

Thus, while fire may have influenced the evolution of Catalina Island's flora in geological time, it is essential to consider the interplay of various factors, such as ungulate browsing and historical events, in shaping the current distribution of vegetation on the island.

2.2 CATALINA ISLAND CONSERVANCY HABITAT RESTORATION EFFORTS

The Catalina Island Conservancy was established in 1972, and in 1975, 88% of the island was transferred from the Island Company to the Conservancy. Over the years, the Conservancy has implemented several habitat restoration and conservation initiatives, including:

- Eradication of feral pigs and goats
- Management of the introduced bison herd
- Founding a native plant nursery
- Conducting restoration plantings
- Establishing exclosures to shield native habitats from invasive herbivores
- Facilitating the recovery of the Catalina Island Fox
- Controlling invasive plant species

Building upon the Conservancy's experience with habitat restoration, this Habitat Restoration and Management Plan (HRMP) updates and aligns existing restoration strategies with current habitat restoration goals and principles outlined in Section 1.5. Relevant past planning efforts and research that inform this HRMP include:

- Whole island restoration strategies and prioritization (Knapp & Knapp, 2005; Knapp, 2010b, 2014; Olson & Farley, 2013)
- Island Scrub Oak restoration research and planning (Knapp, 2009, 2010; Stratton, 2005, 2007)
- Vegetation Map identifying the distribution of vegetation types in the year 2000 (Knapp, 2005a)
- Potential Natural Vegetation Map (Longcore et al., 2018)

The HRMP aims to integrate this wealth of knowledge and experience to guide future restoration efforts on Catalina Island, promoting the long-term health and resilience of its unique and diverse ecosystems.

2.2.1 INVASIVE UNGULATE CONTROL

Between 1990 and 2005, the Conservancy successfully removed all feral goats and pigs from the island and reduced the introduced bison herd to 150 individuals.

Since 1969, the bison herd has been managed to minimize negative ecological impacts. Periodic captures and shipments to the mainland aimed to maintain a relatively small

herd (150 to 200 individuals) and reduce effects on native plants and animals (Duncan et al. 2013, Sweitzer et al. 2005). However, the costs of transporting animals became unsustainable due to high expenses, concerns about animal stress during transport, and herd expansion between shipments (Duncan et al. 2013). Moreover, genetic testing revealed a high prevalence of cattle gene introgression in the Catalina herd, raising concerns about shipping bison to mainland herds with no historical or genetic evidence of hybridization with cattle (Vogel et al., 2007).

In late 2009, the Conservancy shifted to using fertility control to replace periodic removals for herd management (Duncan et al., 2017). As of 2024, the bison population is approximately 90 individuals. This approach has allowed for a more sustainable and cost-effective management strategy while addressing concerns related to animal welfare and genetic integrity.

2.2.2 CATALINA ISLAND FOX RECOVERY

The Catalina Island Fox was federally listed as endangered in 2004 due to a 90% population decline in 1998 (from about 1,300 to 103 individuals), primarily caused by the canine distemper virus (Timms et al. 2009). Concurrently, three other Channel Island subspecies experienced crashes, likely resulting from increased predation by golden eagles. These eagles were uncommon in the Channel Islands before the 1990s but may have proliferated following the decline of bald eagles, which were affected by DDT pollution in the food chain starting in the 1950s (Roemer et al. 2002).

To address the Catalina Island Fox's population crisis, the Conservancy partnered with the Institute for Wildlife Studies to establish the Catalina Island Fox Recovery Program. This multifaceted plan combined vaccination, relocation, and captive breeding efforts. By 2012, the Conservancy estimated that there were 1,500 Catalina Island Foxes, and the population had stabilized. Consequently, in 2016, the Catalina Island Fox was downlisted to threatened (USFWS 2016).

While the fox population size has recovered, ongoing research continues to examine the genetic health of the population because of potential risks associated with genetic diseases that may become more prevalent due to the significant reduction in population size and subsequent genetic bottleneck (Hendricks et al. 2022. Adams and Edmands 2023). Monitoring the genetic health of the Catalina Island Fox population is crucial to ensuring its long-term survival and adaptability.

2.2.3 RESTORATION PLANTINGS

The Conservancy opened the Ackerman Native Plant Nursery in 1987 in Middle Ranch to support the habitat restoration. The nursery's primary mission is to cultivate plants native to Catalina Island from seeds or cuttings, with a special focus on rare plants and endangered species. Because of the damage caused by invasive ungulates, nursery grown transplants needed to be placed in protective cages for them to survive herbivory pressure (e.g., Figure 2-44).

Figure 2-44 Example of a Felt-Leaf Ceanothus Restoration Planting in an Herbivory Protection Cage.
Photo Taken February 28, 2023.

Mature plants can grow outside the protective cage above the mule deer browse line, but the deer keep the plants pruned at the perimeter of the cage, creating unnatural looking plantings sometimes referred to as “Catalina dis-topiary”. Caged restoration planting locations since 2008 are shown in Figure 2-45.

Beginning in 1998, the Middle Ranch hayfields were the focus of a restoration project to control invasive plants, such as Harding grass, and to revegetate with island natives. Restoration plantings needed to be caged and given supplemental water for up to three years. These efforts were labor intensive and relied on volunteer support.

By 2002, the Catalina Island Conservancy had successfully removed 99% of feral pigs and 100% of goats from Santa Catalina Island (Schuyler et al., 2002a, b). However, the anticipated significant increase in natural oak regeneration did not materialize as expected. Simultaneously, patches of dying mature oaks, referred to as "dieback" areas, were observed on the channel side of the island, and a 30% island-wide loss in island scrub oak chaparral was documented between 1943 and 2005 (Knapp, 2007a).

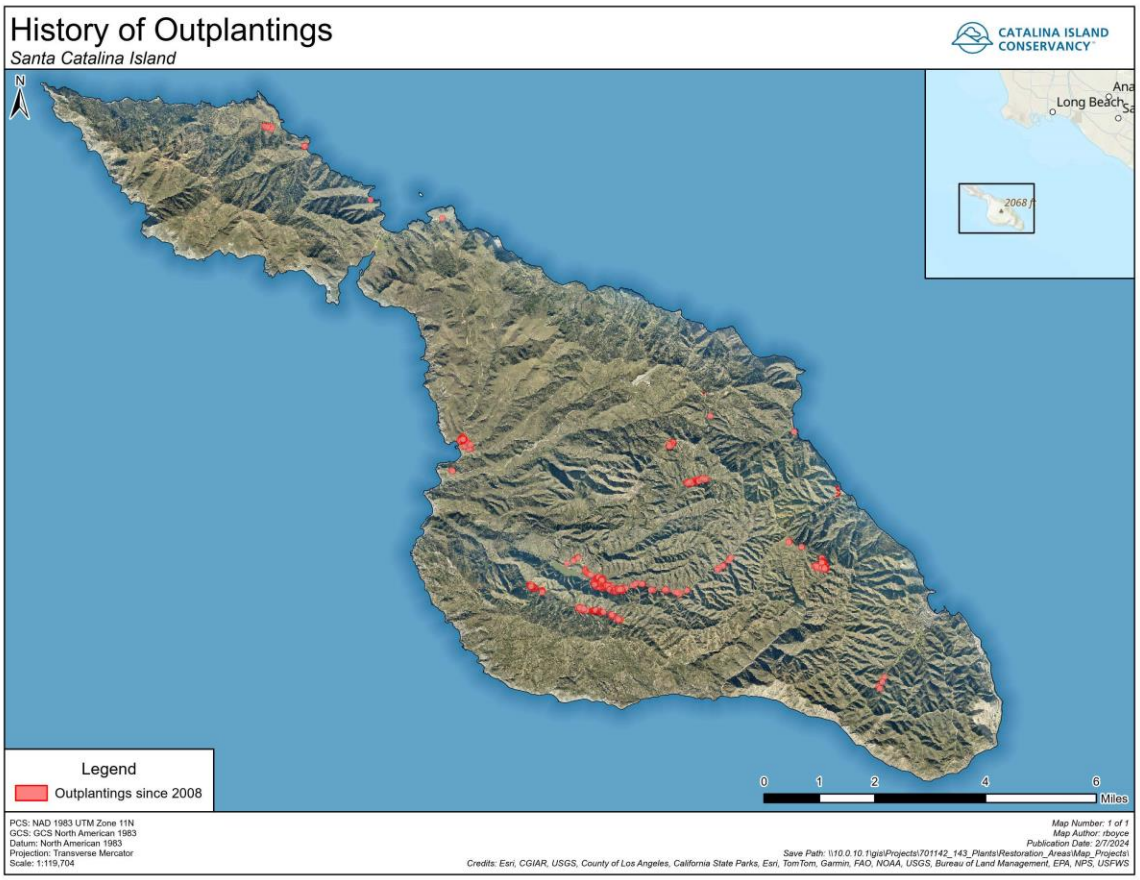


Figure 2-45 Location of Caged Restoration Plantings Since 2008.

Stratton (2009) conducted experiments with acorn plantings of island scrub oak (e.g., Figure 1-4) and discovered that establishment rates were higher within openings between existing trees rather than at the edge of the tree canopy. This finding led to speculation that the lack of natural regeneration in oak dieback areas might be attributed to a scarcity of acorn dispersers, such as scrub jays. The impact of herbivory by mule deer and bison on acorn germination and seedlings was found to be minimal (Stratton 2009), although other studies have demonstrated adverse herbivory effects on oak regeneration (Tyler et al. 2008). The presence of non-native annual grasses was also found to impede germination.

2.2.4 EXCLOSURES

Presently, the Conservancy employs a two-fold strategy to conserve and restore native plant taxa and communities amidst the ongoing impacts of mule deer:

1. Caged restoration plantings (Section 2.2.3) in select areas that are accessible by roadways for regular maintenance.
2. Herbivore exclosures in regions containing relatively intact native vegetation or sensitive species.

After successfully removing feral pigs and goats from parts of the island in the late 1990s (with complete eradication achieved by 2005), the Conservancy began constructing deer exclosure fences to shield ecosystems from deer browsing. Currently, the Conservancy maintains 39 exclosures, ranging in size from 0.02 to 45.44 hectares, covering about 0.4% of the island's total land area (78.3 hectares or 193.5 acres) (Figure 2-46).

The largest investment in exclosures occurred following the 2007 Island Fire, which affected 10% of the island. Funded by the Seaver Institute, the Conservancy erected eight miles of 8-foot deer fencing in 2008. Notable exclosures constructed post-fire include the White's Exclosure and the Farnsworth Exclosure (Figure 2-47).

The 7.99-hectare exclosure at White's Landing safeguards a diverse ecosystem, including at least five Catalina endemic plants (Catalina Manzanita, Trask's Yerba Santa, Catalina Ironwood, Catalina Bedstraw, and Catalina Bush Mallow) and all three California Lilac (*Ceanothus*) taxa found on Catalina in high abundance. This protected area offers vital habitat for rare plants and wildlife, such as the Catalina California Quail, Catalina Hutton's Vireo, and the Catalina Island Fox.

Despite these efforts, only 29.71 hectares of the 2,582.9 hectares (6,382.4 acres) affected by fires since 1999 have been protected from mule deer herbivory by exclosures—less than 1.5% of the fire-impacted land area. Safeguarding even this small portion of regenerating habitat incurs significant costs, and maintaining these exclosures remains an ongoing challenge for the Conservancy.

2.2.5 Invasive Plant Management

The Catalina Invasive Plant Program (CIPP) was established by the Catalina Island Conservancy in 2003 to address the escalating threat and spread of invasive plants following the removal of invasive herbivores.

Invasive plant surveys in the early 2000s indicated that the abundance and distribution of invasive plants on Catalina Island were more severe than initially anticipated. The Conservancy observed a significant population expansion of several highly ranked invasive plant species, including Italian thistle (*Carduus pycnocephalus*), sweet fennel (*Foeniculum vulgare*), and Harding grass (*Phalaris aquatica*). This rapid growth occurred predominantly on the island's West End, where bison had been excluded for over 15 years and the Feral Animal Removal Program had been active for over a decade. These circumstances highlighted the potential consequences of eradicating and reducing feral herbivores from the East End of Catalina Island without proper invasive plant management strategies in place. Habitat suitability modeling for common invasive plants currently under management by the Conservancy show the potential risk of uncontrolled spread on the island, especially by sweet fennel (Figure 2-48), Harding grass (Figure 2-49), and Mediterranean broom (Figure 2-50) (Appendix D).

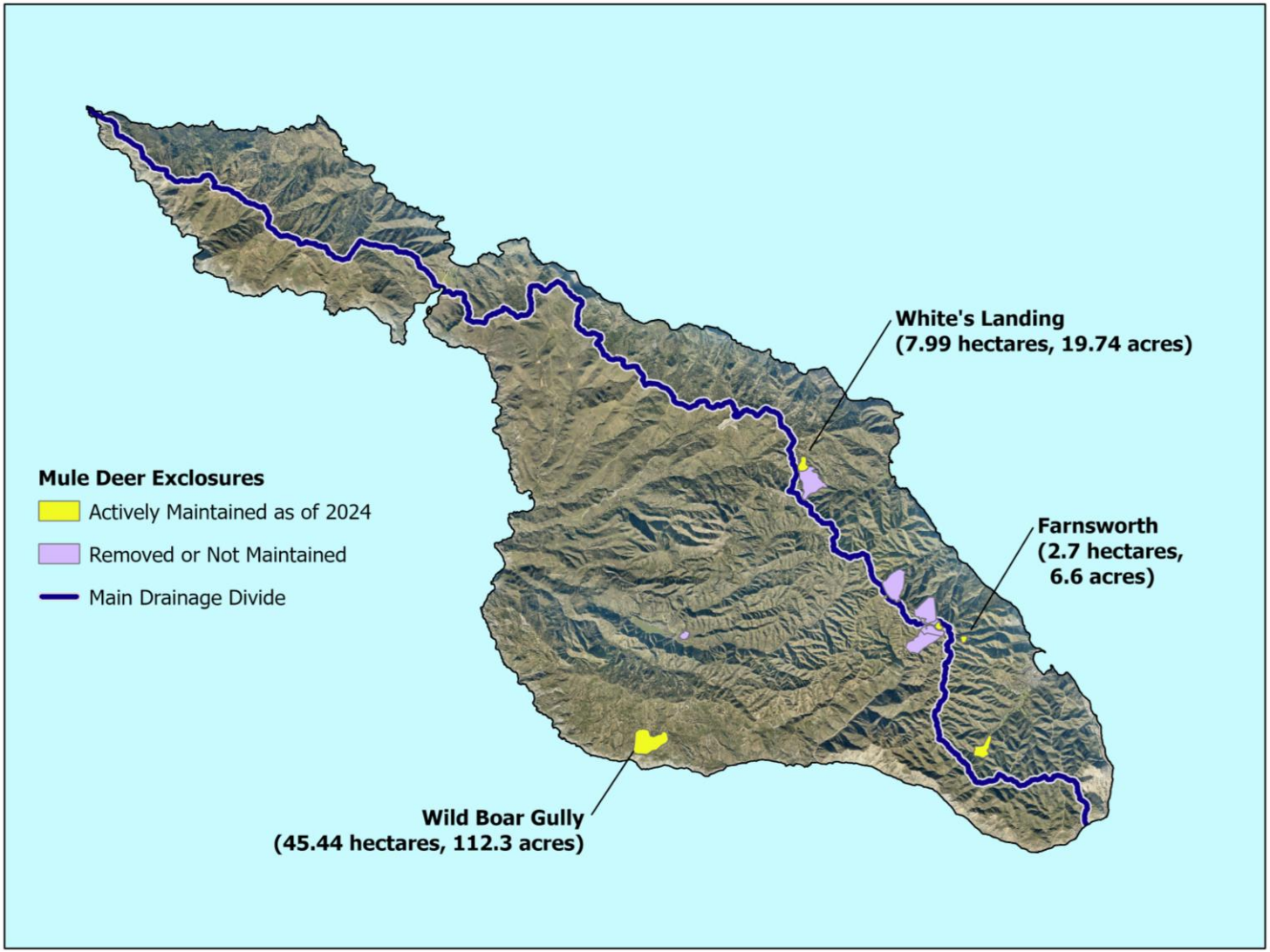


Figure 2-46 Mule Deer Exclosures.

Selected exclosures are Labeled.

Figure 2-47 Farnsworth Exclosure within 2007 Island Fire Footprint, Protecting Felt-Leaf Ceanothus Regeneration from Mule Deer Herbivory.

Photo Taken 2021 by the Conservancy. The protected felt-leaf ceanothus plants in the exclosure (top of photo) are reproductively mature and produce seed, while the few surviving individuals outside the exclosure (bottom of photo) remain just a few centimeters tall and have yet to flower.

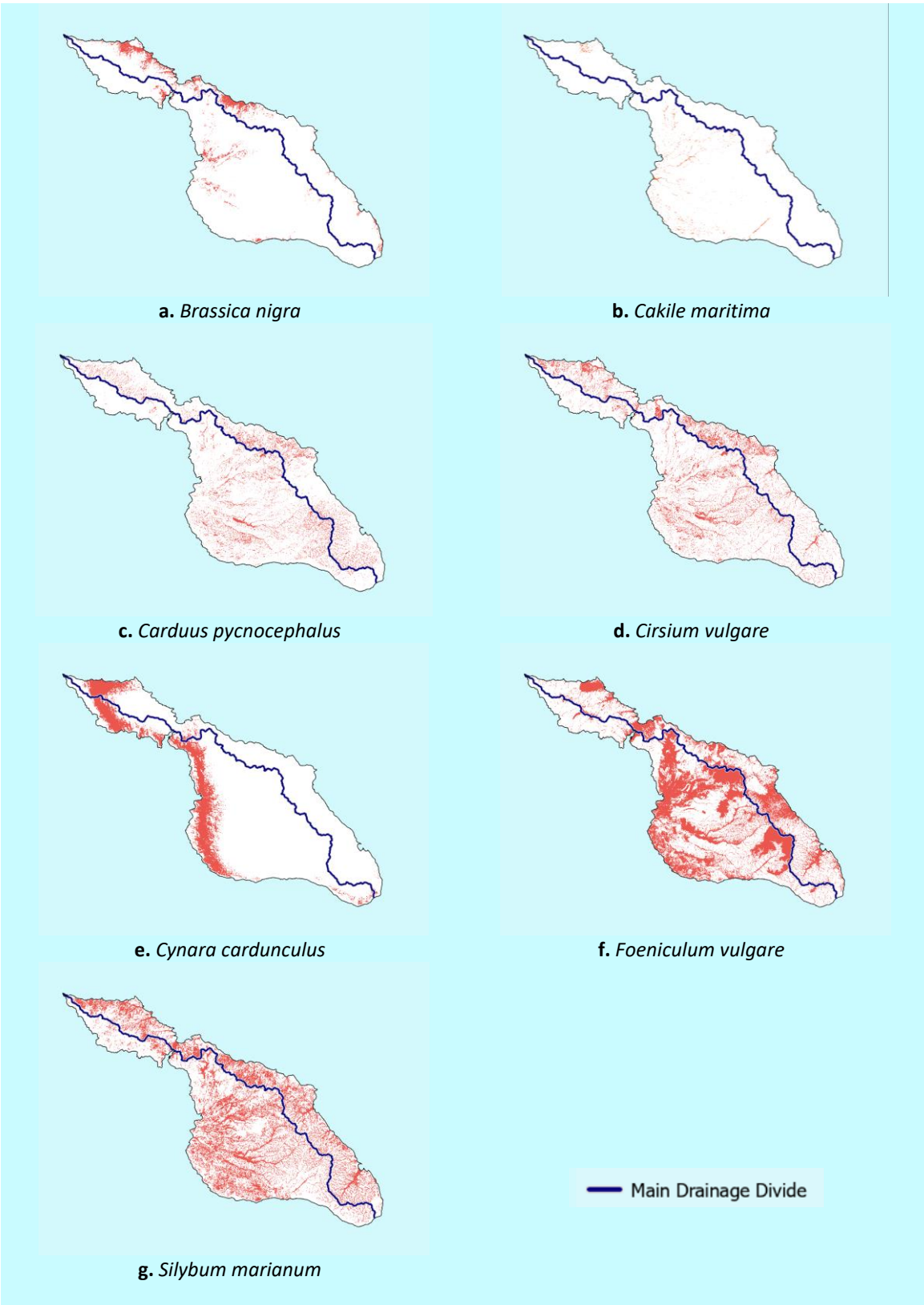


Figure 2-48 Potential Distribution of Seven Invasive Herbaceous Flowering Plants (excluding Grasses).

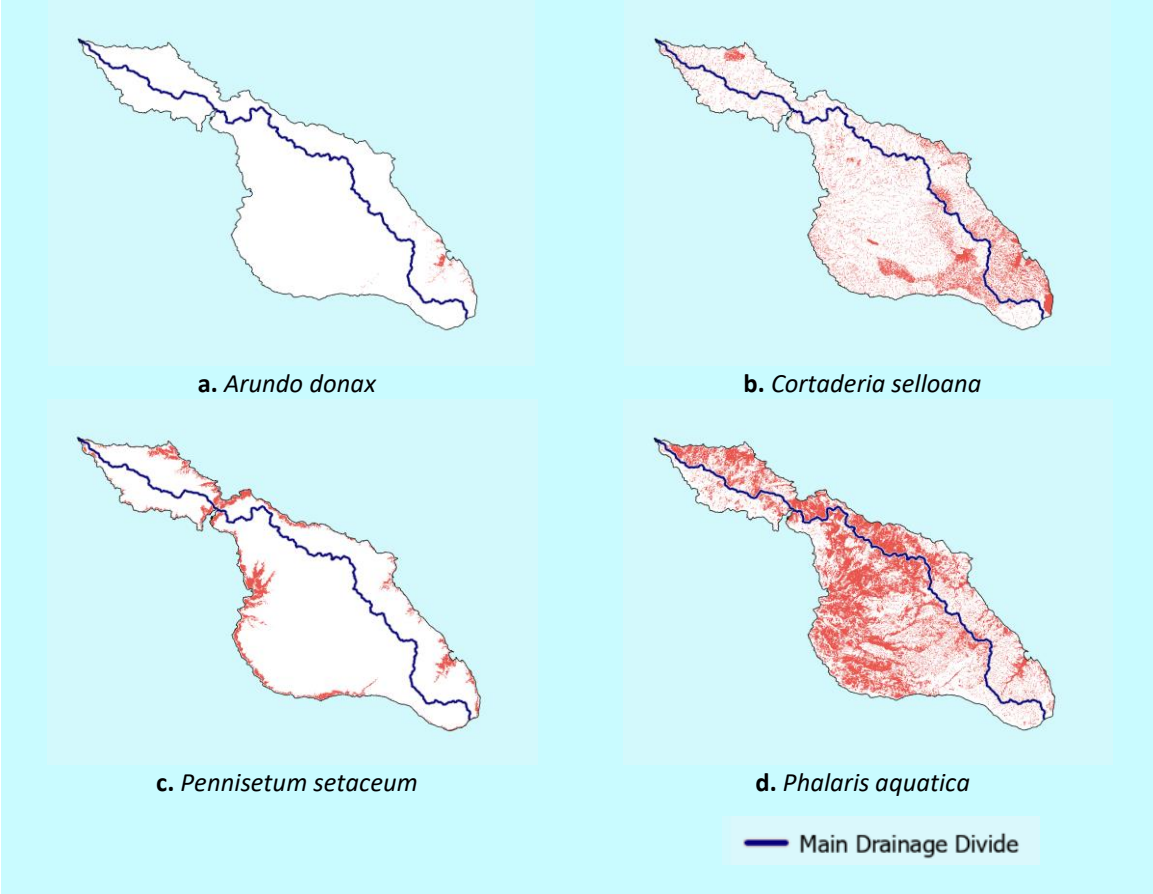


Figure 2-49 Potential Distribution of Four Invasive Grasses.

Drawing from the experiences on Santa Cruz Island, where the removal of cattle in the 1990s led to a dramatic increase in fennel populations (Knapp 2007b), the Conservancy recognized the urgency to prevent a similar outcome on Catalina Island. Consequently, the CIPP program was developed to tackle the invasive plant issue before it became unmanageable.

The goals of the CIPP invasive plant management project are (Knapp, 2007b):

1. Prevent the reduction or loss of native Catalina Island flora and fauna due to the direct or indirect impact(s) caused by invasive plants by actively controlling invasives with the safest, most effective, and economical methods available.
2. Increase the Conservancy's and partner agencies' knowledge regarding invasive plant distribution, impacts, and management strategies.
3. Stop invasive plant introductions, establishment, and spread on Catalina Island by increasing invasive plant awareness among staff, contractors, local residents, and visitors through education programs and improving cultural practices and partnerships.

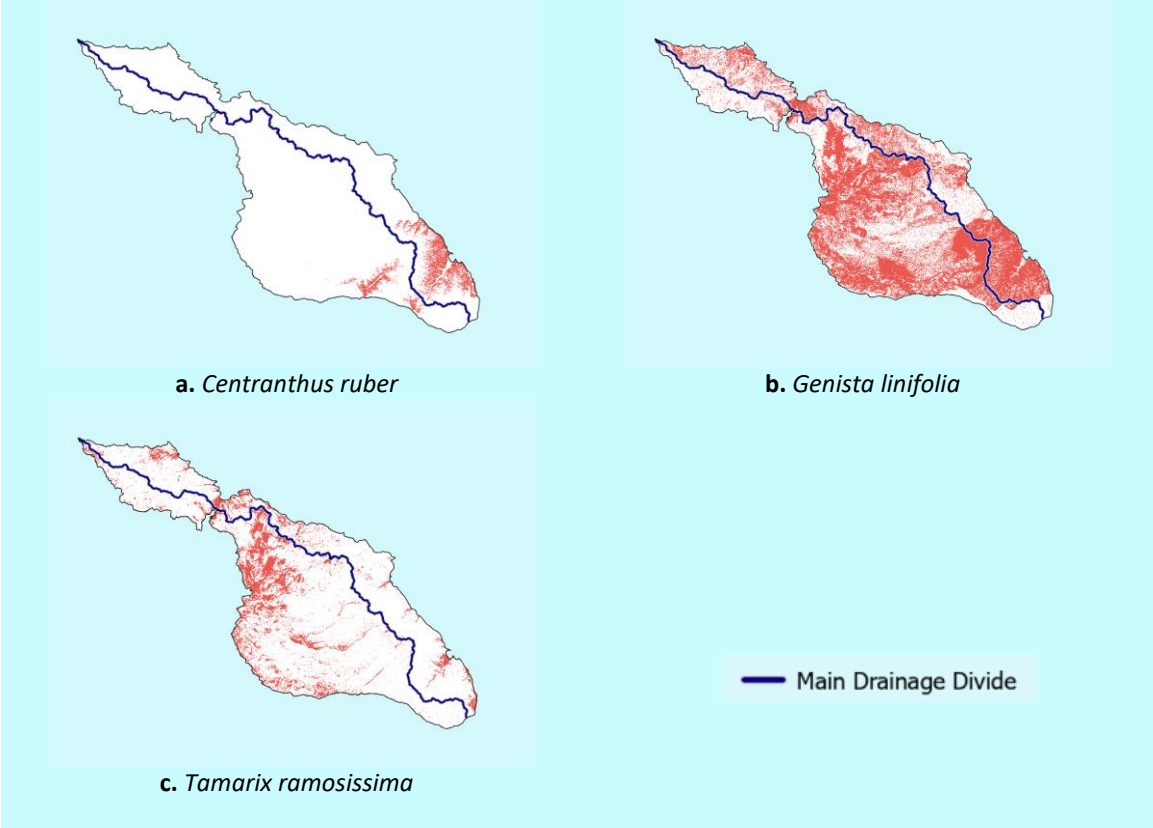


Figure 2-50 Potential Distribution of Three Invasive Shrubs.

The Conservancy controls invasive plant populations in high priority areas with a strategic top-down approach. Starting at the top of watersheds, at the highest elevation, and working downwards reduces source populations and reintroduction.

To achieve successful invasive plant management, the Conservancy emphasizes consistent treatment of infestations, building upon lessons learned from eradicating feral animals. Consistency and follow-through are essential for achieving management objectives and maintaining the benefits derived from previous efforts.

Since the beginning of CIPP over 1.4 million individual plants have been treated, nearly 30,000 acres have been surveyed, over 3,000 acres have been treated, over 200 species have been treated, and over 68,000 management hours have been invested (e.g., see Figure 2-51) (Appendix A).

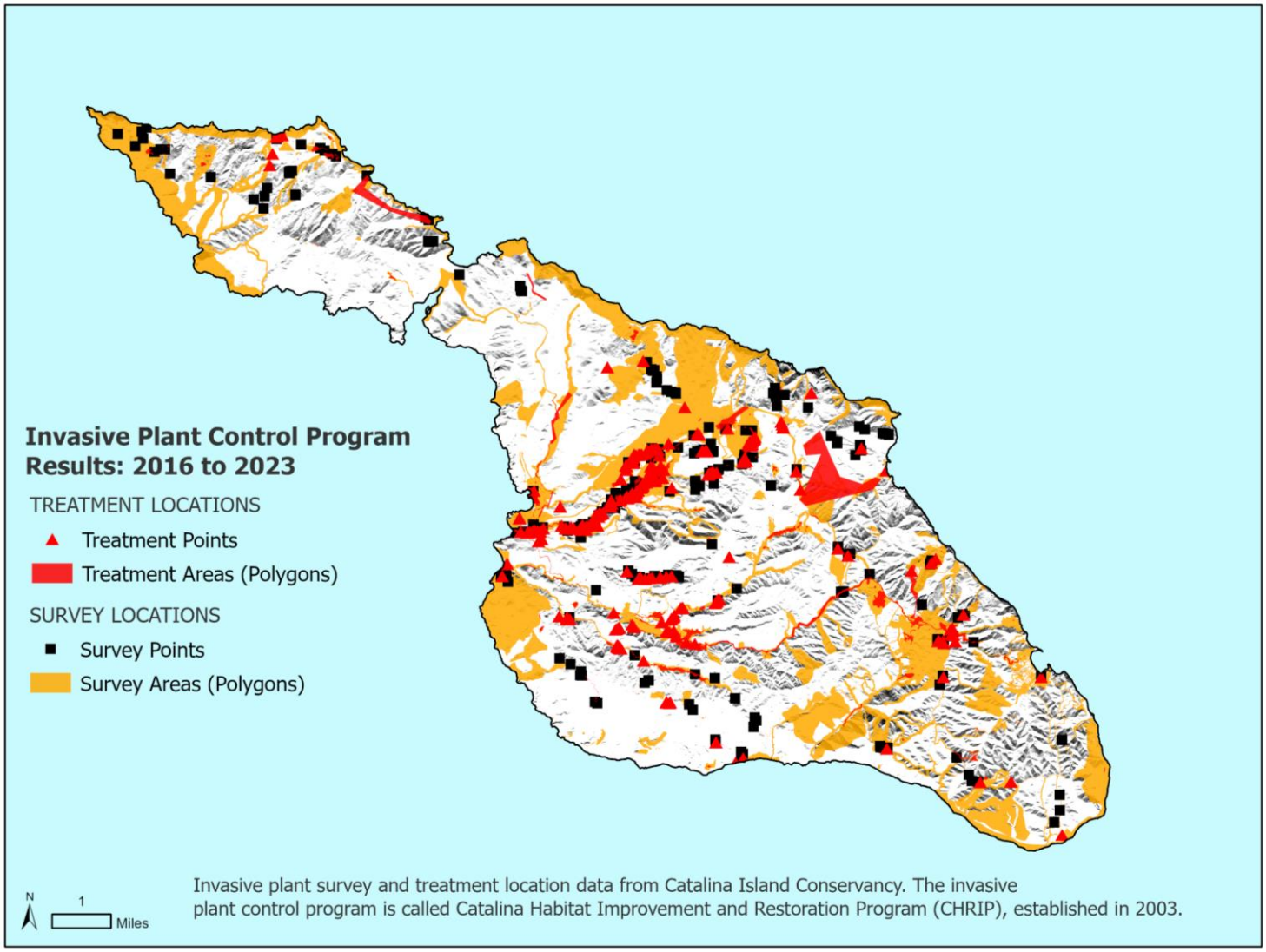


Figure 2-51 Invasive Plant Control Survey and Treatment Locations from 2016 to 2023.

Data provided by the Conservancy.

2.3 CONTEMPORARY ISLAND HABITAT

2.3.1 PLANT DIVERSITY

The diversity of plant life on Catalina Island can be summarized by the major taxonomic groups that occur on the island (Table 2-4): ferns and fern allies, gymnosperms, and angiosperms, which include magnoliids, monocots, and eudicots. There are more than 700 plant species, subspecies, or varieties on the island, a third of which have been introduced. See Appendix B for a list of plants recorded by the Conservancy.

1. **Ferns and Fern Allies:** These ancient plants reproduce via spores instead of seeds. They typically thrive in moist environments, with ferns producing large, feathery fronds, while fern allies (such as club mosses and horsetails) may have more specialized structures. Their unique reproductive strategies make them distinct from other plant groups on islands.
2. **Gymnosperms:** Also known as "naked seed" plants, gymnosperms bear exposed seeds within cones or cone-like structures. They include conifers (e.g., pine trees), cycads, and ginkgos. Their wind-pollinated reproductive structures and unique seed-bearing adaptations set them apart from plant groups. There are no native gymnosperms on the island.
3. **Angiosperms:** The most diverse group of plants, angiosperms, or flowering plants are characterized by their production of flowers and fruits. There are three groups of angiosperms that occur on the island:
    - **Magnoliids:** Representing the earliest branch of flowering plants, magnoliids display diverse characteristics, making them challenging to categorize. Magnoliids include magnolias, tulip trees, and black pepper plants, among others. There is one Magnoliid that occurs on the island, and it is native, yerba mansa *(Anemopsis californica*). Yerba mansa is commonly found in moist, alkaline, and saline habitats such as marshy areas, creek edges, and salt grass flats.
    - **Monocots:** These angiosperms have seeds with one embryonic leaf, or cotyledon. They typically exhibit parallel leaf veins, scattered vascular bundles in stems, and flower parts in multiples of three. Almost half of the monocots on the island are introduced species.
    - **Eudicots:** Also known as "true dicots," eudicots have seeds with two embryonic leaves or cotyledons. They generally feature net-like leaf veins, vascular bundles arranged in a ring in stems, and flower parts in multiples of four or five. Examples of eudicots include oak trees and sunflowers.

In island ecosystems like Catalina Island, understanding the distinction between native and introduced plant species is crucial for preserving the unique ecological balance. Native plants naturally occur within the island, having evolved and adapted to the specific environmental conditions over time. These plants form the foundation of island ecosystems, playing essential roles in supporting native wildlife and maintaining biodiversity.

Table 2-4 Summary of the Number of Santa Catalina Island Plants, including all Species, Subspecies, or Varieties, by Taxonomic Group.

	Native	Introduced	Total
PLANTS	**473**	**236**	**709**
FERNS AND FERN ALLIES	**18**	**1**	**19**
GYMNOSPERMS	**0**	**12**	**12**
ANGIOSPERMS	**455**	**223**	**678**
Magnoliids	1	0	1
Monocots	68	60	128
Eudicots	386	163	549

Plant Species: A group of individual plants with similar characteristics, such as appearance, reproductive traits, and genetic makeup, that are capable of interbreeding and producing fertile offspring. Species represent the basic taxonomic unit of biological classification, sharing a common ancestry and occupying specific ecological niches.

Subspecies: A geographic or ecological subdivision of a species that exhibits distinct characteristics from other individuals of the same species but is still capable of interbreeding. Subspecies are often isolated from other populations, allowing them to develop unique traits while maintaining their connection to the broader species.

Varieties: A taxonomic category within a species or subspecies that displays minor differences in morphological or physiological features from the more typical members. Varieties often result from genetic mutations or environmental factors, and they can be naturally occurring or selectively bred by humans for desired traits, such as increased pest resistance or improved taste.

On the other hand, introduced plant species are those that have been brought to the island by humans, either intentionally or accidentally. The impact of these nonnative plants on island ecosystems can vary significantly. Some introduced plants may be planted in the landscape but do not spread beyond their designated areas. These plants typically pose minimal threat to native species and habitats, as their growth and reproduction are controlled.

Other introduced plants may naturalize, meaning they can establish self-sustaining populations and spread outside the areas where they were initially planted. While some naturalized plants can coexist with native species without causing harm, others may pose a threat to native biodiversity by outcompeting native plants for resources and altering ecosystem processes.

A subset of introduced plants is considered invasive due to their aggressive growth, rapid reproduction, and ability to thrive in both disturbed and undisturbed native habitats. Invasive species can significantly disrupt island ecosystems by displacing native plants, reducing habitat quality for native wildlife, and changing natural processes such as fire regimes, water availability, and nutrient cycling. These negative impacts on the

native ecology or ecosystem make invasive plants a major concern for conservation efforts on Catalina Island.

RARE AND PROTECTED PLANTS

Islands often exhibit a higher degree of species endemism, extinction, and vulnerability compared to mainland areas (Keir et al. 2009). Catalina Island exemplifies this phenomenon, with an elevated occurrence of rare and endemic plant species.

The island's flora includes over sixty species with a California Rare Plant Ranking (CRPR) status (see Section 2.4.1), three species with federal endangered status (*Cercocarpus traskiae, Pentacheta lyonii,* and *Sibara filifolia*), one with federally threatened status (*Crocanthemum greenei*), three with California endangered status (*C. traskiae, P. lyonia,* and *Acmispon dendroideus* var*. traskiae*), and one with California threatened status (*Dithyrea maritima*). The Catalina Island rush rose (*Crocanthemum greenei*) is an example of a rare, federally listed species directly impacted by nonnative browsing pressure.

The Project aims to aid in the recovery of various sensitive plant species, including felt-leaf ceanothus (*Ceanothus arboreus*), Catalina grass (*Dissanthelum californicum*), southern island mallow (*Lavatera assurgentiflora* subsp. *glabra*), Catalina ironwood (*Lyonothamnus floribundus* subsp. *floribundus*), Santa Catalina Island bush-mallow (*Malacothamnus fasciculatus* var. *catalinensis*), the federally and state endangered Lyon's pygmydaisy (*Pentacheta lyonii*), the federally endangered Santa Cruz Island rockcress (*Sibara filifolia*), and Catalina nightshade (*Solanum wallacei*). Many of these species are recognized by the California Native Plant Society with Rare Plant Ratings and are identified as Species of Greatest Conservation Need. Endemic island plant species are expected to experience the most significant recovery from the Project due to their lack of physical and chemical defenses against nonnative herbivores.

The situation is particularly critical for certain species like the Catalina ironwood and Santa Catalina Island mountain-mahogany, which currently have extremely low population counts. With only about 120 and 6 individuals, respectively, remaining for these species, action is necessary to protect and promote their recovery on Catalina Island.

2.3.2 VEGETATION COMMUNITIES

Knapp (2005a) developed a vegetation map based on a year 2000 aerial basemap and field surveys, which identified 18 distinct land cover classes. As part of an effort to quantify changes in vegetation cover from 1943 to 2005, Knapp (2007a) separately mapped Island Scrub Oak Chaparral. This distinction between Island Scrub Oak Chaparral and Island Chaparral resulted in a total of 19 vegetation classes, as shown in Table 2-5 and visualized in Figure 2-52.

Table 2-5 Catalina Island 2000 Vegetation Map (Modified from Knapp 2005a).

Vegetation Community (Veg Code)	Percent of Island	Acres	Hectares
Woodland, Chaparral, and CSS			
Island Woodland with Other Classifications (IW)	0.6	272	110
Island Chaparral (IC)	18.5	8,859	3,585.1
Island Chaparral with Other Classifications (IC)	7.7	3,716	1,504
Island Scrub Oak Chaparral (ISOC)	6.2	2,980	1,205.9
Mix of Island Chaparral and CSS (IC/CSS)	18.0	8,608	3,483.7
Coastal Sage Scrub (CSS)	20.2	9,682	3,918.5
CSS with Nonnative Grassland or Bare (CSS)	8.3	3,963	1,603.8
Maritime Cactus Scrub (MCS)	<0.1	3	1.2
Coastal Bluff Scrub (CBS)	0.2	78	31.4
Riparian, Marsh, Dune, and Reservoirs			
Southern Riparian Woodland with Bare Streambed (SRW)	0.3	164	66.3
Mulefat Scrub with Bare Streambed (MFS)	<0.1	9	3.7
Riparian Herbaceous with Bare (RH)	0.1	25	10
Bare Streambed (BSB)	0.1	40	16.4
Coastal Marsh with Bare (CM)	<0.1	3	1.3
Southern Beach and Dune (SBD)	0.3	128	52.1
Vernal Ponds and Reservoirs (VPR)	0.1	44	17.9
Nonnative Vegetation, Grassland, Bare, and Developed			
Nonnative Woodland with Nonnative Scrub or Grassland (NNW)	0.2	105	42.7
Nonnative Scrub with CSS (NNS)	0.1	59	24
Nonnative Herbaceous with Nonnative Grassland (NNH)	0.5	239	96.9
Grassland (GR)	12.0	5,734	2,320.4
Nonnative Grassland with Bare (GR)	0.4	203	82.1
Bare (B)	5.2	2,497	1,010.6
Developed (D)	1.1	544	220.3

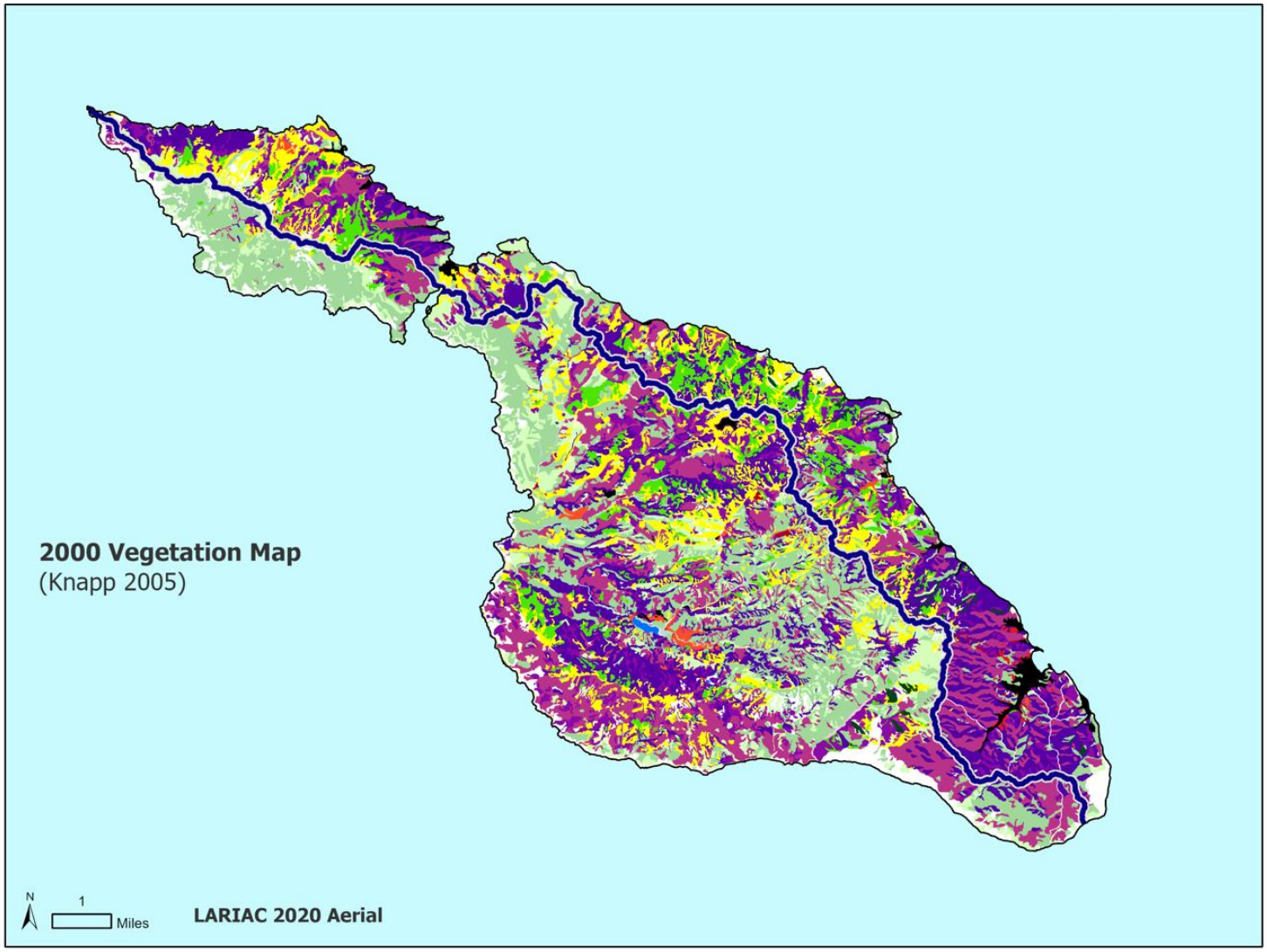


Figure 2-52 Vegetation Map for Year 2000.

Data provided by the Conservancy (Knapp 2005a). Legend on the next page.

Woodland, Chaparral, and CSS

Veg Code | Percent of Island | Veg Community

- IW | 0.6 | Island Woodland with Other Classifications
- IC | 18.5 | Island Chaparral
- IC | 7.7 | Island Chaparral with Other Classifications
- IC/CSS | 18 | Mix of Island Chaparral and CSS
- ISOC | 6.2 | Island Scrub Oak Chaparral
- CSS | 20.2 | Coastal Sage Scrub (CSS)
- CSS | 8.3 | CSS with Nonnative Grassland or Bare
- MCS | <0.1 | Maritime Cactus Scrub
- CBS | 0.2 | Coastal Bluff Scrub

Riparian, Marsh, Dune, and Reservoirs

Veg Code | Percent of Island | Veg Community

- SRW | 0.3 | Southern Riparian Woodland with Bare Streambed
- MFS | <0.1 | Mulefat Scrub with Bare Streambed
- RH | 0.1 | Riparian Herbaceous with Bare
- BSB | 0.1 | Bare Streambed
- CM | <0.1 | Coastal Marsh with Bare
- SBD | 0.3 | Southern Beach and Dune
- VPR | 0.1 | Vernal Ponds and Reservoirs

Nonnative Vegetation, Bare, and Developed

Veg Code | Percent of Island | Veg Community

- NNW | 0.2 | Nonnative Woodland with Nonnative Scrub or Grassland
- NNS | 0.1 | Nonnative Scrub with CSS
- NNH | 0.5 | Nonnative Herbaceous with Nonnative Grassland
- GR | 12 | Nonnative Grassland
- GR | 0.4 | Nonnative Grassland with Bare
- B | 5.2 | Bare
- D | 1.1 | Developed

- Main Drainage Divide

2.3.3 VEGETATION ALLIANCES AND ASSOCIATIONS

Due to the significant alteration of plant and community distributions on the island, primarily caused by invasive ungulate herbivory, and the high diversity of island-endemic plants, vegetation communities on the California Channel Islands may share similar lifeforms with mainland communities under comparable bioclimatic conditions and disturbance regimes but differ in their characteristic or dominant species. To address this, Junak et al. (2012) provided a crosswalk of vegetation types described for the California Channel Islands, incorporating the vegetation types identified by Knapp (2005a) in the 2000 Vegetation Map, and aligning them with the CNPS Manual of California Vegetation (MCV) as published in 2005.

Based on habitat suitability modeling for select island plants (Appendix D), analysis of co-occurrence models (Appendix E), we identified likely native vegetation alliances or associations using the most recent version of the CNPS MCV, which is maintained online (CNPS 2024). These native vegetation alliances or associations, along with potential vegetation maps, are presented in Appendix D and listed here for reference:

ISLAND WOODLAND

CALIFORNIAN BROADLEAF FOREST AND WOODLAND GROUP

Three potential woodland associations were identified:

- **a. Island Live Oak Woodland and Forest** (*Quercus tomentella* Forest & Woodland Association) is defined by dominance by *Quercus tomentella* in the tree canopy.
- **b. Catalina Ironwood Woodland and Forest** (*Lyonothamnus floribundus* subsp. *floribundus* Forest & Woodland Association) is defined by dominance by *Lyonothamnus floribundus* subsp. *floribundus* in the tree canopy.
- **c. Catalina Cherry Woodland and Forest** (*Prunus ilicifolia subsp. lyonii* Forest & Woodland Association) is defined by *Prunus ilicifolia* subsp. *lyonii* in the tree canopy.

ISLAND CHAPARRAL

CALIFORNIA MARITIME CHAPARRAL GROUP

Two potential maritime chaparral associations were identified:

- **a. Santa Catalina Island Manzanita Chaparral** (*Arctostaphylos catalinae* Shrubland Association) is defined by dominance or co-dominance of *Arctostaphylos catalinae* in the shrub layer.
- **b. Island Scrub Oak Chaparral** (*Quercus pacifica* Shrubland Association) is defined by dominance or co-dominance of *Quercus pacifica* in the shrub layer.

CALIFORNIA XERIC CHAPARRAL GROUP

Five potential xeric chaparral alliances or associations were identified:

c. **Mission Manzanita – Lemonadeberry Chaparral** (*Xylococcus bicolor - Rhus integrifolia* Shrubland Association) is defined by co-dominance of *Xylococcus bicolor and Rhus integrifolia* in the shrub layer.

d. **Chamise – Sage Chaparral** (*Adenostoma fasciculatum - Salvia* spp. Shrubland Alliance) is defined by co-dominance of *Adenostoma fasciculatum* and *Salvia* spp. (e.g., *S. mellifera*).

e. **Island Ceanothus Chaparral** (*Ceanothus megacarpus* var. *insularis* Shrubland Association) is defined by dominance or co-dominance of *Ceanothus megacarpus* var. *insularis* in the shrub layer.

f. **Felt-Leaf Ceanothus Chaparral** (*Ceanothus arboreus* Shrubland Association) is defined by dominance or co-dominance of *Ceanothus arboreus* in the shrub layer.

g. **Big-Pod Ceanothus Chaparral** (*Ceanothus megacarpus* Shrubland Alliance) is defined by dominance or co-dominance of *Ceanothus megacarpus* var. *megacarpus* in the shrub layer.

COASTAL SAGE SCRUB

CENTRAL AND SOUTH COASTAL CALIFORNIAN COASTAL SAGE SCRUB (CSS) GROUP

Six potential CSS alliances or associations were identified:

a. **California Sagebrush – Coast Prickly Pear Scrub** (*Artemisia californica - Opuntia littoralis* Shrubland Association) is defined by co-dominance of *Artemisia californica* and *Opuntia littoralis* in the shrub layer.

b. **California Sagebrush Scrub** (*Artemisia californica* Shrubland Alliance) is defined by dominance or co-dominance of *Artemisia californica* in the shrub layer.

c. **Island Buckwheat Scrub** (*Eriogonum grande* var. *grande* Shrubland Association) is defined by dominance or co-dominance of *Eriogonum grande* var. *grande* in the shrub layer.

d. **California Brittle Bush Scrub** (*Encelia californica* Shrubland Association) is defined by dominance or co-dominance of *Encelia californica* in the shrub layer.

e. **White Sage Scrub** (*Salvia apiana* Shrubland Alliance) is defined by dominance or co-dominance of *Salvia apiana* in the shrub layer.

f. **Black Sage Scrub** (*Salvia mellifera* Shrubland Alliance) is defined by dominance or co-dominance of *Salvia mellifera* in the shrub layer.

COASTAL BLUFF SCRUB

COASTAL BAJA CALIFORNIA NORTE MARITIME SUCCULENT SCRUB GROUP

Five potential succulent scrub alliances or associations were identified:

a. **Giant Coreopsis Scrub** (*Leptosyne gigantea* Shrubland Alliance) is defined by dominance or co-dominance of *Leptosyne gigantea* in the shrub layer.

b. **Coast Prickly Pear Scrub** (*Opuntia littoralis – Opuntia oricola – Cylindropuntia prolifera* Shrubland Alliance) is defined by dominance or co-dominance of *Opuntia littoralis, Opuntia oricola,* or *Cylindropuntia prolifera* in the shrub layer.

d. **Island Tarplant – Saint Catherine's Lace Scrub** (*Deinandra clementina – Eriogonum giganteum* var*. giganteum* Shrubland Alliance) is defined by dominance or co-dominance of *Deinandra clementina* and/or *Eriogonum giganteum* var. *giganteum.*

e. **Green Liveforever Succulent Scrub** (*Dudleya virens subsp. hassei* Succulent Scrub Association) is defined by dominance by *Dudleya virens subsp. hassei* in the herb layer.

f. **Saint Catherine's Lace Scrub** (*Eriogonum giganteum* var*. giganteum* Shrubland Association) is defined by dominance or co-dominance of *Eriogonum giganteum* var*. giganteum* in the shrub layer.

MARITIME CACTUS SCRUB

COASTAL BAJA CALIFORNIA NORTE MARITIME SUCCULENT SCRUB GROUP

One potential succulent scrub alliances or associations was identified, which is in the same MCV Group as the five vegetation communities identified above in the Coastal Bluff Scrub Vegetation Type, but has previously been described as Maritime Cactus Scrub Vegetation Type:

c. **California Boxthorn Scrub** (*Lycium californicum* Shrubland Alliance) is defined by dominance or co-dominance of *Lycium californicum* in the shrub layer.

VERNAL PONDS AND RESERVOIRS

ARID WEST FRESHWATER EMERGENT MARSH GROUP

One potential marsh alliance was identified:

a. **Cattail Marshes** (*Typha* spp. Herbaceous Alliance) is defined by *Typha* (e.g., *domingensis*) dominant or co-dominant in the herbaceous layer.

CALIFORNIAN MIXED ANNUAL/PERENNIAL FRESHWATER VERNAL POOL/SWALE BOTTOMLAND GROUP

One potential vernal pool/swale bottom alliance was identified:

b. **Clustered Tarplant Fields** (*Deinandra fasciculata* Herbaceous Alliance) is defined by *Deinandra fasciculata* dominant or co-dominant with other herbs (e.g., *Hordeum intercedens*).

COASTAL MARSH

TEMPERATE PACIFIC TIDAL SALT AND BRACKISH MEADOW GROUP

One potential brackish meadow alliance was identified:

c. Salt Grass Flats (*Distichlis spicata* Herbaceous Alliance) is defined by *Distichlis spicata* dominant or co-dominant with other herbs (e.g., *Cressa truxillensis*).

SOUTHERN BEACH AND DUNE

VANCOUVERIAN/PACIFIC DUNE MAT GROUP

One potential dune mat association was identified:

d. Dune Mat (*Ambrosia chamissonis - Abronia maritima - Cakile maritima Herbaceous Association*) is defined by *Abronia maritima* other perennial herbs, grasses, and low shrubs, often including the invasive plant, *Cakile maritima.*

Not included above, are potential vegetation alliances for the following three vegetation types because there was insufficient data for the modeling effort in Appendix D: Southern Riparian Woodland (SRW), Riparian Herbaceous (RH), and Mulefat Scrub (MFS). While these three vegetation types represent only 0.3%, 0.1%, and less than 0.1% of the land area respectively, their association with riparian habitat gives them more value to the island ecology than the land area suggests. More detailed investigation focused on these island riparian systems would benefit management of associated wildlife, such as bats and the Catalina Island Shrew. Given the limited land area, these riparian systems can be censused as part of a future survey effort, as needed.

This updated information provides valuable insights into the unique plant communities that could be restored on Catalina Island and will help inform conservation efforts targeting these distinct and vulnerable ecosystems.

The vegetation types on Catalina Island are often afflicted by various invasive annual grasses (*Avena* spp., *Bromus* spp., *Brachypodium distachyon*) and forbs, which can alter the native plant communities. Some areas are dominated by patches of invasive perennial grass, such as Harding grass. Mediterranean Broom can be found throughout the island, particularly in the Avalon watershed, where it has formed dense, nonnative scrub communities. Similarly, sweet fennel and Italian thistle can create dense patches, defining nonnative herbaceous vegetation communities.

While the existing 2000 Vegetation Map (Figure 2-52) provides a valuable baseline understanding of the island's vegetation types, it lacks vital information on lifeform types (e.g., herbaceous, shrub, and tree cover) and dominant or characteristic plant species cover classes. Conducting a new vegetation mapping effort for the island in accordance with current CNPS Vegetation Mapping Protocols and Guidelines would help quantify changes in vegetation cover compared to the 2000 map. This could be achieved through a vegetation type crosswalk with the MCV classification levels used in the new map.

An updated vegetation map would provide the Catalina Island Conservancy with more detailed information, enabling them to refine the identification of site-specific habitat restoration opportunities and better understand the dynamics of native and nonnative plant communities on the island. Additionally, this updated map would assist the Conservancy in effectively implementing management strategies for invasive species and support long-term conservation efforts on Catalina Island. However, there is sufficient information in this plan and in the Conservancy's geospatial database to implement the HRMP, as is.

2.3.4 WILDLIFE

The Project is anticipated to significantly enhance breeding, foraging, and refuge habitats for various wildlife species, including the Federally and State threatened Santa Catalina Island Fox (*Urocyon littoralis catalinae*), Catalina Hutton's vireo (*Vireo huttoni unitti*), Island loggerhead shrike (*Lanius ludovicianus anthonyi*), two-striped gartersnake (*Thamnophis hammondii*), Catalina California quail (*Callipepla californica catalinensis*), and the Catalina Island Shrew. Each of these species is designated as a Species of Greatest Conservation Need under the 2015 California Department of Fish and Wildlife (CDFW) State Wildlife Action Plan.

The Catalina Hutton's vireo is expected to particularly benefit from habitat improvements, as its preferred oak woodland habitats have experienced diminished seed banks and persistent pressures from nonnative browsers that impede natural regeneration. By addressing these issues, the Project aims to promote the recovery and resilience of these critical ecosystems, ultimately supporting the conservation of the diverse and unique wildlife that inhabits Catalina Island.

2.3.5 CLIMATE CHANGE IMPACTS

Downscaled global climate models (GCMs) have been developed to provide guidance on future conditions within local regions. In southern California these models predict an increase in temperature (Cook et al. 2015) but without any significant change in average precipitation (Berg et al. 2015) (Figure 2-53).

Impacts to fog are not well understood but expected to result in less fog (Olson and Farley 2013). The resulting effect will be one of increased drought, wherein periods of low precipitation occur with higher temperatures (Diffenbaugh et al. 2015). Attributable to such conditions is an observed decrease in greenness of Chaparral and Coastal Sage Scrub vegetation over the period 2000 to 2016 in the nearby Santa Monica Mountains (Gillespie et al. 2018). Increased temperatures will affect plant phenology, affecting the start and end of the growing season, duration of the growing season, and total productivity (Parmesan and Yohe 2003). This is occurring in other Mediterranean regions, with the largest effects on the timing of spring growth and blooming (Gordo and Sanz, 2010).

Ecological niche models developed to predict the distribution of CSS under future climate conditions (Principe et al. 2013, Riordan and Rundel 2014) predicted large losses in suitable habitat for southern California plant taxa. More recent models using higher

resolution topographic data (270 m vs. 1 km resolution) predict a high degree of habitat stability for CSS species (modeled independently) (Riordan et al. 2018). This result is also consistent with State of California models showing that CSS habitat remains suitable in the Puente Hills under late 21st Century climate conditions (Thorne et al., 2016).

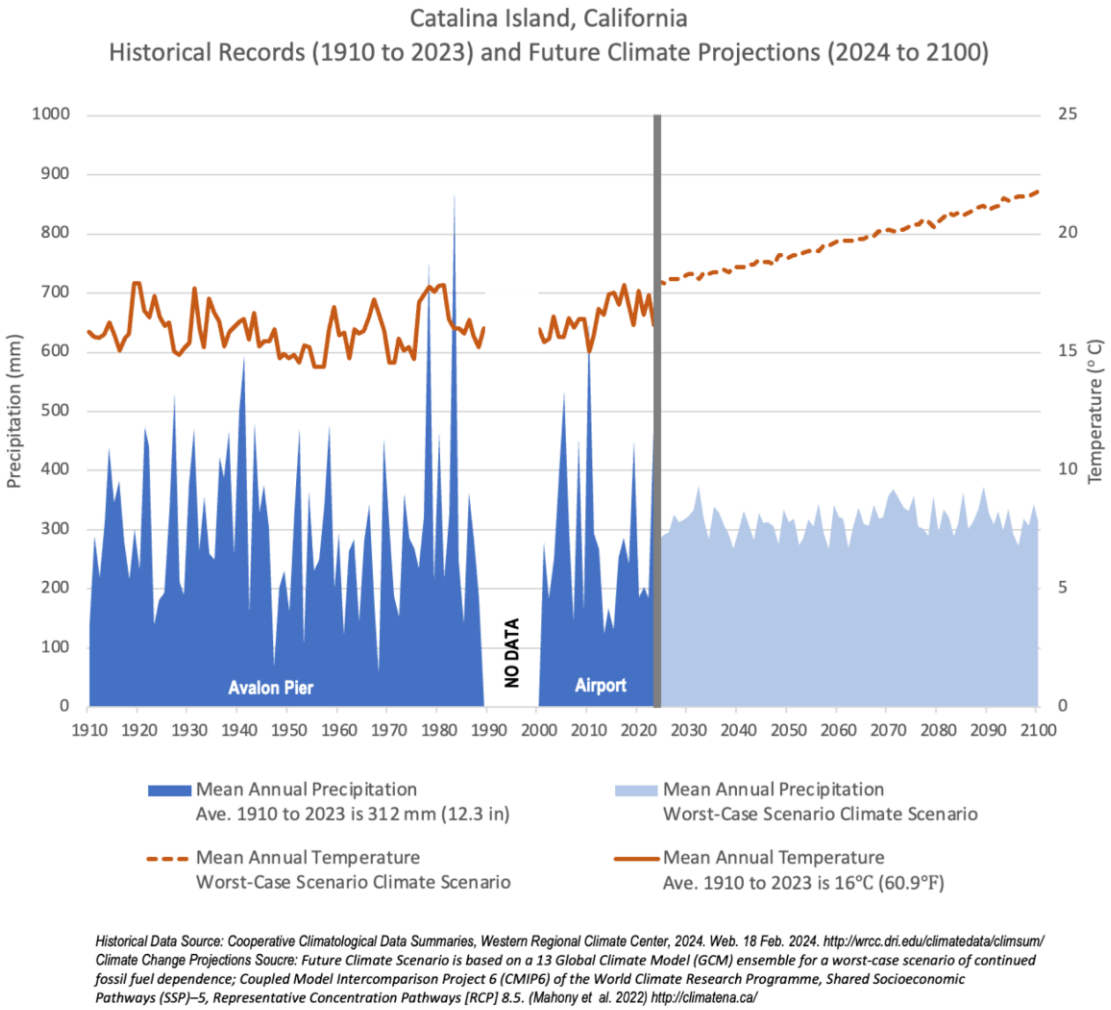


Figure 2-53 Historic Records and Future Climate Change Scenario for Catalina Island.

Source: Downscaled climate data from ClimateNA. Future Climate Scenario is based on a 13 Global Climate Model (GCM) ensemble for a worst-case scenario of continued fossil fuel dependence; Coupled Model Intercomparison Project 6 (CMIP6) of the World Climate Research Programme, Shared SocioeconomicPathways (SSP)–5, Representative Concentration Pathways [RCP] 8.5.

Although Coastal Sage Scrub was thought to be more vulnerable to drought, recent data from the 2012 to 2016 drought indicates that chaparral ecosystems were more heavily impacted (Okin et al. 2018). Chaparral plants rely on deeper soil water, making them more resistant to short-term drought but more susceptible to prolonged droughts. Local

responses to drought in both communities depend on soil texture and elevation, with lower, warmer sites experiencing greater drought sensitivity. This implies that future climate warming could intensify drought impacts on Chaparral ecosystems, suggesting that Chaparral may be more resilient in wetter landscapes on Catalina Island.

While climate change projections suggest increased soil moisture aridity, which will reduce resources for local wildlife populations, the most significant future threat may be increased fire frequency due to both wind-driven and fuel-driven fires. Too frequent fires in CSS and chaparral communities results in type conversion to invasive nonnative grasslands (Keeley 2002). Fire frequency in the South Pacific Coast is not affected by temperatures during any season (Keeley and Syphard 2017). Fire spread is driven predominantly by Santa Ana winds (Moritz et al., 2010) and human-caused ignitions (Syphard and Keely 2015). Extreme wind conditions spread fires and are more important than preceding drought (Keeley 2004), although drought conditions will extend the fire season (Dennison et al. 2008) and facilitate larger fires through vegetation die-back (Keeley and Zedler 2009).

The probability for large fires in California under climate change scenarios (RCP4.5 and RCP8.5 from 2040 to 2069 and 2070 to 2099) will intensify in summer and lengthen into spring and fall compared to historic conditions (1970 to 1999) is likely related to decreased fuel moisture and increased vapor pressure deficit (Dong et al. 2022). While the effects of Santa Ana winds (SAW) on autumn and winter wildfire may weaken in the future, projected to peak from November to January (Guzman-Morales and Gershunov 2019)—when SAW and human-ignition coincide there will continue to be high risk of large wildfires in southern California (Keeley et al. 2021).

Type-conversion of vegetation from shrubland to grassland will likely be a result of an increased frequency of wildfires and not directly correlated to changes in temperature and precipitation. The presence of mule deer and larger fires will drastically magnify these climate change impacts. While management of climate is beyond the scope of local management, removing the invasive mule deer and reducing human-caused fire ignition sources are two management actions that will significantly conserve existing island habitat and will likely lead to restoration of more diverse and climate resilient island ecosystem.

2.4 ENDEMIC TAXA

Dozens of plant and wildlife taxa (species, subspecies, varieties) are endemic to the Channel Islands, meaning that they are found on one or more of the eight islands that make up the archipelago but not on the mainland, and some species are found only on Catalina Island.

In the following lists of endemic taxa, an asterisk (*) denotes designation as “special-status species” by federal or state governments (see Section 2.5).

2.4.1 ENDEMIC PLANTS

Many plant species are found on Catalina Island and other Channel Islands, but the following ten taxa are endemic to Catalina Island.

- Catalina Island Dudleya (*Dudleya virens* subsp. *hassei*) *
- Catalina Island Mountain Mahogany (*Cercocarpus traskiae*) *
- Santa Catalina Island Bushmallow (*Malacothamnus fasciculatus* var. *catalinensis*) *
- Santa Catalina Island Ironwood (*Lyonothamnus floribundus* subsp. *floribundus*) *
- Trask's Yerba Santa (*Eriodictyon traskiae* subsp. *traskiae*)
- Santa Catalina Island Manzanita (*Arctostaphylos catalinae*) *
- Santa Catalina Island Buckwheat (*Eriogonum giganteum* var. *giganteum*) *
- Santa Catalina Island Bedstraw (*Galium catalinense* subsp. *catalinense*) *
- Santa Catalina Island Popcorn Flower (*Cryptantha catalinensis*)
- Santa Catalina Island Monkeyflower (*Diplacus traskiae*) * [Potentially extinct]

Source: Catalina Island Conservancy (2022).

2.4.2 ENDEMIC INVERTEBRATES

The following invertebrate taxa are endemic to Catalina Island, and in some cases additional Channel Islands, as noted.

- Catalina Island Centipede (*Pectiniunguis catalinensis*)
- Catalina Island Parajulid Millipede (*Bollmaniulus catalinae*)
- Catalina Island Cambalid Millipede (*Nannolene catalina*)
- Catalina Lancetooth Snail (*Haplotrema catalinense*) *
- Catalina Cactussnail (*Xerarionta kellettii*); two other Channel Islands
- Catalina Mountainsnail (*Radiocentrum avalonense*) *
- Shepard's Snail (*Pristiloma shepardae*) *; three other Channel Islands
- Catalina Ribbed Vertigo (*Vertigo catalinaria*); four other Channel Islands
- Insular Birddrop Snail (Sterkia [*Vertigo*] *clementina*) *; three other Channel Islands
- Pimu Island Vertigo (*Vertigo pimuensis*)
- Avalon Islandsnail (*Micrarionta beatula*)
- Santa Barbara Islandsnail (*Micrarionta facta*) *; two other Channel Islands
- Santa Catalina Islandsnail (*Micrarionta rufocincta*); two other Channel Islands

- Catalina Island Death Watch Beetle (*Euvrilletta catalinae*)
- Southern Island Death Watch Beetle (*Xarifa insularis*); two other Channel Islands
- Catalina Island Soldier Beetle (*Cultellunguis hatchi dorothyae*)
- undescribed minute brown scavenger beetle (*Fuchsina* n.sp.); three other Channel Islands
- Catalina Island Broad-Nosed Weevil (*Trigonoscuta catalina*)
- Catalina Island Rain Scarab (*Phobetus ciliatus*)
- Catalina Island Gleaming Scarab (*Serica catalina*)
- Channel Island Checkered Beetle (*Cymatodera insularis*); two other Channel Islands
- Catalina Island Soft-winged Flower Beetle (*Dasytastes catalinae*)
- Island Soft-winged Flower Beetle (*Dasytastes insularis*)
- Soft-Winged Flower Beetle (*Microasydates punctipennis*), recently described
- Catalina Island Junebug (*Coenonycha clypeata*)
- Yellow Channel Islands Junebug (*Coenonycha fulva*); one other Channel Island
- Catalina Island Rove Beetle (*Actium vestigialis*)
- Channel Islands Textured Darkling Beetle (*Apsena grossa*); five other Channel Islands
- Channel Islands Cluster Beetle (*Cibdelis bachei*); four other Channel Islands
- Channel Islands Dune Beetle (*Coelus pacificus*); seven other Channel Islands
- Channel Islands Oval Darkling Beetle (*Coniotis lata*); six other Channel Islands
- Channel Islands Stink Beetle (*Eleodes inculta*); seven other Channel Islands
- Channel Islands Narrow Darkling Beetle (*Metoponium insulare*); taxon's validity "dubious" (Gimmel et al. 2023)
- Blotched Leaf Miner (*Amauromyza insularis*)
- Catalina Island Cicada (*Tibicinoides* [*Okanagana*] *catalina*)
- Catalina Island Plant Bug (*Insulaphylus meridianus*)
- Catalina Island Longhorn Bee (*Anthophorula cockerelli*)
- Avalon Cuckoo Bee (*Nomada avalonica*); following major revisions of the genus *Nomada* (Alexander 1994, Odanaka et al. 2022), taxon's validity is uncertain
- Channel Islands Funnel Ant (*Aphaenogaster patruelis*); three other Channel Islands

- Channel Islands Carpenter Ant (*Camponotus bakeri*); three other Channel Islands
- Avalon Sweat Bee (*Lasioglossum avalonense*); three other Channel Islands
- Large Spotted Sweat Bee (*Lasioglossum megastictum*); two other Channel Islands; mainland report (https://www.inaturalist.org/observations/163446889)
- Scavenger Moth (*Holcocera phenacocci*)
- Cambrid Snout Moth (*Evergestis angustalis catalinae*)
- Island Painted Tiger Moth (*Arachnis picta insularis*); three other Channel Islands; mainland report (https://www.inaturalist.org/observations/101729572)
- Meadows' Painted Tiger Moth (*Arachnis picta meadowsi*); mainland reports (https://www.inaturalist.org/taxa/478396-Arachnis-picta-meadowsi)
- Indistinct Tiger Moth (*Lophocampa indistincta*); three other Channel Islands
- undescribed twirler moth (*Chionodes* sp.); three other Channel Islands
- Catalina Island Geometer Moth (*Pero catalina*)
- San Clemente Island Geometer Moth (*Pterotaea crinigera*)
- Meadows' Owlet Moth (*Feralia meadowsi*); one other Channel Island
- Channel Islands Owlet Moth (*Zosteropoda clementei*); three other Channel Islands; mainland reports (https://www.inaturalist.org/observations?taxon_id=472726)
- Santa Cruz Island Snout Moth (*Acrobasis comptella*); one other Channel Island
- Channel Islands Snout Moth (*Sosipatra proximanthophila*); one other Channel Island
- Channel Islands Driedfruit Moth (*Vitula insula*); one other Channel Island; mainland reports (https://www.inaturalist.org/observations?taxon_id=364110)
- Avalon Tortrix Moth (*Pelochrista* [*Eucosma*] *avalona*); one other Channel Island; mainland reports (https://www.inaturalist.org/taxa/511578-Pelochrista-avalona)
- Avalon Scrub-Hairstreak (*Strymon avalona*)
- Catalina Island Orangetip (*Anthocharis cethura catalina*)
- Catalina Island Monkey Grasshopper (*Morsea catalinae*)
- Silk-spinning Cricket (*Cnemotettix miniatus*); preliminary analysis indicates the Catalina Island population "is genetically very distinct" from specimens collected at the Tijuana River Estuary (Backlin et al. 2005)
- undescribed Jerusalem cricket (*Stenopelmatus* sp.)
- Santa Catalina Island Shieldback (*Neduba propsti*)

- Catalina Walkingstick (*Pseudosermyle catalinae*)

Sources: Gimmel et al. (2023) for beetles; Backlin et al. (2005) for Silk-spinning Cricket (*Cnemotettix miniatus*); Knapp et al. (2021) for all other groups and for most of the common names.

Knapp et al. (2021) reported *Melissodes scotti* as a long-horned bee endemic to Catalina Island (presumably following Menke and Miller 1985) but this species was described from a collection at San Clemente Island (Cockerell 1939) and the species does not appear to have been recorded on Catalina Island.

2.4.3 Endemic Reptiles

The Catalina Two-striped Garter Snake (*Thamnophis hammondii* subsp.), a special-status species, is endemic to Catalina Island (Backlin et al. 2005).

2.4.4 Endemic Birds

The following avian taxa are endemic to Catalina Island, and in some cases additional Channel Islands, as noted.

- Catalina California Quail (*Callipepla californica catalinensis*) *; introduced to two other Channel Islands
- Allen's Hummingbird (*Selasphorus sasin sedentarius*); other Channel Islands and mainland
- Catalina Hutton's Vireo (*Vireo huttoni unitti*) *
- Island Loggerhead Shrike (*Lanius ludovicianus anthonyi*) *; two other Channel Islands
- Island Horned Lark (*Eremophila alpestris insularis*); other Channel Islands
- Channel Island Western Flycatcher (*Empidonax difficilis insulicola*); three other Channel Islands
- Catalina Bewick's Wren (*Thryomanes bewickii catalinae*)
- House Finch (*Haemorhous mexicanus frontalis*); three other Channel Islands
- San Clemente Spotted Towhee (*Pipilo maculatus clementae*) *; two other Channel Islands, historically, but extirpated from San Clemente Island
- Dusky Orange-crowned Warbler (*Oreothlypis celata sordida*); other Channel Islands and mainland

Sources: Dvorak (2015), Catalina Island Conservancy (2022).

2.4.5 Endemic Mammals

The following mammalian taxa are endemic to Catalina Island.

- Catalina Ground Squirrel (*Otospermophilus beecheyi nesioticus*)

- Santa Catalina Island Harvest Mouse (*Reithrodontomys megalotis catalinae*)
- Santa Catalina Island Deer Mouse (*Peromyscus maniculatus catalinae*)
- Santa Catalina Island Shrew (*Sorex ornatus willetti*) *
- Santa Catalina Island Fox (*Urocyon littoralis catalinae*) *

Sources: Backlin et al. (2005), Catalina Island Conservancy (2022).

2.5 SPECIAL-STATUS PLANT AND WILDLIFE TAXA

Federal and state regulations exist to protect and conserve plant and wildlife species identified by federal or state governments as endangered, threatened, rare, protected, sensitive, vulnerable, Species of Special Concern, or candidates for federal or state listing. On Catalina Island, these "special-status species" include a mix of island endemics (i.e., taxa denoted with an asterisk in the preceding Section 2.4) and species whose ranges include the mainland.

The following Table 2-6 identifies the special-status plants and wildlife known or believed to occur on Catalina Island on a regular basis, and generally in a role that is afforded protection, per the California Natural Diversity Data Base (CNDDB 2024a, 2024b). Biologist Robert Hamilton selected the taxa for inclusion in Table 2-6 based upon review of the following materials:

- Backlin et al. (2005), Knapp et al. (2021), Gimmel et al. (2023), Catalina Island Conservancy (2022), and other relevant reports.
- Online databases and resources, including eBird (http://www.ebird.org), iNaturalist (http://www.inaturalist.org), Calflora (http://www.calflora.org), and NatureServe Explorer (http:// https://explorer.natureserve.org/).
- A Biogeographic Information and Observation System (BIOS) report of all special-status species reported from the U.S. Geologic Survey 7.5' topographic quadrangles Santa Catalina Island North, Santa Catalina Island South, Santa Catalina Island East, Santa Catalina Island West (CNDDB 2024c).

Excluded from Table 2-6 are marine mammals, species that occur only on offshore rocks (e.g., Ashy Storm-Petrel), and bird species that occur only in an unprotected role. For example, the CNDDB identifies the Olive-sided Flycatcher as a Species of Special Concern, but only on its nesting grounds; because this bird occurs on Catalina Island only as a non-breeding migrant, it is not included in Table 2-6.

One introduced plant species, Torrey Pine, is included in Table 2-6, but only to clarify that this species has no conservation status on Catalina Island, which lies outside of its natural range. For the remaining species that are included, the table provides their regulatory status, briefly describes their habitat requirements and general status on Catalina Island and provides notes on protecting the species in the context of this HRMP.

Table 2-6 uses the following abbreviations:

C **Candidate** for Listing (State or Federal governments).

E **Endangered** (listed by State or Federal governments). "Take" of the species or disturbance of occupied habitat are prohibited unless specifically authorized.

FP **Fully Protected** by the State of California. These species may not be taken or possessed at any time, although take may be authorized for necessary scientific research.

T **Threatened** (listed by State or Federal governments). "Take" of the species or disturbance of occupied habitat are prohibited unless specifically authorized.

PT **Proposed Threatened**. Species recently proposed to be listed as threatened by State or Federal governments.

SSC **Species of Special Concern**. The California Dept. of Fish and Wildlife has designated certain vertebrate species as Species of Special Concern because declining population levels, limited ranges, and/or continuing threats have made them vulnerable to extinction. The goal of designating species as Species of Special Concern is to halt or reverse their decline by calling attention to their plight and addressing the issues of concern early enough to secure their long-term viability.

California Native Plant Society (CNPS). Table B includes plant taxa assigned the following ranks by CNPS:

- **1A**, referring to taxa CNPS presumes to be extirpated in California and either rare or extinct elsewhere.

- **1B.1**, referring to taxa CNPS considers to be rare, threatened, or endangered in California and elsewhere; seriously threatened in California (over 80% of occurrences threatened / high degree and immediacy of threat).

- **1B.2**, referring to taxa CNPS considers to be rare, threatened, or endangered in California and elsewhere; moderately threatened in California (20-80% of occurrences threatened / moderate degree and immediacy of threat).

- **1B.3**, referring to taxa CNPS considers to be rare, threatened, or endangered in California and elsewhere; not very threatened in California (less than 20% of occurrences threatened / moderate degree and immediacy of threat).

- **2B.2**, referring to taxa CNPS considers to be rare, threatened, or endangered in California, but more common elsewhere; moderately threatened in California (20-80% occurrences threatened / moderate degree and immediacy of threat).

- **3**, referring to taxa for which CNPS lacks the necessary information to assign them to one of the other ranks or to reject them; taxonomy is typically uncertain.

- **4.1**, referring to taxa of limited distribution or infrequent throughout a broader area in California, whose status should be monitored regularly; moderately threatened in California (>80% occurrences threatened / moderate degree and immediacy of threat).

- **4.2**, referring to taxa of limited distribution or infrequent throughout a broader area in California, whose status should be monitored regularly; moderately threatened in California (20-80% occurrences threatened / moderate degree and immediacy of threat).

- **4.3**, referring to taxa of limited distribution or infrequent throughout a broader area in California, whose status should be monitored regularly; not very threatened in California (less than 20% of occurrences threatened / low degree and immediacy of threat or no current threats known).

NatureServe Element Rankings. In some cases, species are recognized as ecologically sensitive by the California Natural Diversity Database (CNDDB), which uses a ranking methodology maintained by NatureServe. Species are given a State rank (S-rank) that applies to the taxon's conservation status in California. "Q" denotes questionable taxonomy. Taxa with rankings of S1, S2, or S3 may be considered "sensitive" at the state level, and potentially worthy of special consideration in resource planning. Taxa with higher rankings (S4, S5) are considered "apparently secure" or "secure" at the state level and therefore are not treated as "sensitive" for purposes of this report. NatureServe Element Rankings are identified in Table 2-6 only for taxa that have no other federal or state special status. NatureServe Ranks:

- **S1, Critically Imperiled,** referring to taxa critically imperiled in the state because of extreme rarity (often 5 or fewer populations) or because of factor(s) such as very steep declines making it especially vulnerable to extirpation from the state.

- **S2, Imperiled,** referring to taxa imperiled in the state because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the state.

- **S3, Vulnerable,** referring to taxa vulnerable in the state due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation from the state.

- **SX,** referring to taxa presumed to be extirpated from the state.

Notes on Protection. The last column of Table 2-6 briefly discusses any resource-protection issues relevant to the planning and implementation of habitat restoration projects under this plan.

Table 2-6 Special-Status Species on Catalina Island.

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Plants — Bryophytes					
Tortula californica California Screw Moss	—	S2	1B.2	Sandy soils in shady locations. A few records from Catalina Island.	Restoration activities are unlikely to negatively impact because of its habitat requirements.
Plants — Lichens					
Graphis saxorum Baja Rock Lichen	—	S1	3	Volcanic rocks that are moderately shaded, usually north-facing, vertical or almost vertical; underhangs, recesses, small cavities, and roofs of caves where the substrate receives little or no direct rainfall. Generalized records from northwestern part of Catalina Island.	Restoration activities are unlikely to negatively impact because of its habitat requirements.
Plants — Vascular					
Abronia maritima Red Sand-Verbena	—	S3	4.2	Coastal dunes and sandy openings in scrub.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Acmispon dendroideus* var. *dendroideus Island Broom	—	S3	4.2	Coastal bluffs and cliffs, coastal sage scrub, grassland. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance.
Acmispon dendroideus* var. *traskiae San Clemente Island Broom	—	E	1B.3	Coastal bluffs and cliffs, coastal sage scrub, grassland. Record from Cape Canyon in 1973.	Restoration activities are unlikely to negatively impact because of its distinctive appearance.
Aphanisma blitoides Aphanisma	—	S2	1B.2	Coastal bluff scrub and beach dunes. Several records from Catalina Island, mainly on the west side.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Aphyllon parishii* subsp. *brachylobum Short-lobed Broomrape	—	S3	4.2	Coastal bluff scrub and beach dunes. A few records from the west side of Catalina Island.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Arctostaphylos catalinae Santa Catalina Island Manzanita	—	S2	1B.2	Chaparral with volcanic soils. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Arctostaphylos crustacea* subsp. *subcordata Santa Cruz Island Manzanita	—	S3	4.2	Chaparral with rocky soils. Historical records from northern half of Catalina Island.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Atriplex coulteri Coulter's Saltbush	—	S1S2	1B.2	Inconspicuous. Clay or alkaline soils in coastal bluff scrub, coastal dune, coastal scrub, valley, and foothill grassland. Numerous Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Atriplex pacifica South Coast Saltscale	—	S2	1B.2	Inconspicuous. Clay soils in coastal bluff scrub, coastal dunes and scrub, playas. Numerous Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Atriplex serenana* var. *davidsonii Davidson's Saltscale	—	S1	1B.2	Inconspicuous. Alkaline soils on cliff faces and bluffs. Small number of records from Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Bergerocactus emoryi Golden-spined Cereus	—	S2	2B.2	Chaparral and coastal scrub. Scattered records from Catalina Island.	Restoration activities are unlikely to negatively impact because of its distinctive appearance.
Calochortus catalinae Catalina Mariposa Lily	—	S3S4	4.2	Grassland, coastal scrub, chaparral, cismontane woodland. Numerous records from Catalina Island.	**Restoration personnel should be trained to recognize this native species, especially when it Is not in flower, to prevent inadvertent removal.**
Calystegia macrostegia* subsp. *amplissima Island Morning-glory	—	S4	4.3	Rocky slopes and canyon walls, coastal sage scrub and chaparral. 2023 record from slopes above White Cove (iNaturalist).	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Ceanothus megacarpus* var. *insularis Island Ceanothus	—	S4	4.3	Chaparral with sandy soils. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Centromadia parryi* subsp. *australis Southern Tarplant	—	S2	1B.1	Disturbed ground, usually on edges marsh, of vernally moist grassland, or coastal scrub. Generalized record(s) from eastern part of island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Cercocarpus betuloides* var. *blancheae Island Mountain-mahogany	—	S4	4.3	Chaparral. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Cercocarpus traskiae Catalina Island Mountain-mahogany	E	E	1B.1	Chaparral, coastal scrub in sausserite gabbro soil. Very small population in Wild Boar Gully.	Restoration activities are unlikely to negatively impact because of its localized distribution and endangered status.
Cirsium occidentale* var. *compactum Compact Cobwebby Thistle	—	S2	1B.2	Chaparral, coastal dunes, coastal prairie, coastal scrub, bluffs. Historical record along road at upper end of Avalon Canyon. Other varieties also recorded on the island.	**Restoration personnel should be trained to recognize this native species, and the other varieties, to prevent inadvertent removal.**
Cistanthe maritima Seaside Cistanthe	—	S3	4.2	Grassland and coastal scrub in sandy soils. Scattered records on Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Constancea nevinii Nevin's Woolly Sunflower	—	S3	1B.3	Coastal bluff scrub and coastal scrub on Catalina and other Channel Islands.	Restoration activities are unlikely to negatively impact because of its distinctive appearance.
Convolvulus simulans Small-flowered Morning-glory	—	S4	4.2	Grassland, seeps, coastal scrub, openings in chaparral, in clay or serpentine soils. Scattered records on Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Crocanthemum greenei Island Rush-rose	T	S3	1B.2	Rocky openings in chaparral, cismontane woodland, coastal scrub. Scattered records on Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Crossosoma californicum Catalina Crossosoma	—	S3	1B.2	Chaparral and coastal scrub in rocky soils. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Cryptantha wigginsii Wiggins' Cryptantha	—	S1	1B.2	Coastal scrub, often in clay soils. Scattered records on Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Deinandra clementina Island Tarplant	—	S4	4.3	Dry slopes, valleys, and bluffs in grass and scrub communities, possibly rocky or with heavy soils. Numerous Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Dendromecon harfordii* var. *rhamnoides South Island Bush-poppy	—	S1	3.1	Chaparral, cismontane woodland, and coastal scrub. Numerous Catalina Island records of D. harfordii but not of this variety, which is questionably distinct.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Dichondra occidentalis Western Dichondra	—	S3S4	4.2	Chaparral, cismontane woodland, coastal scrub, grassland. Numerous recent Catalina Island records (iNaturalist).	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Diplacus traskiae Santa Catalina Island Monkeyflower	—	SX	1A	Coastal scrub. Single collection in 1901.	**Unlikely to be affected** by restoration activities because presumed extinct.
Dissanthelium californicum California Dissanthelium	—	S1	1B.2	Coastal scrub. Scattered records on Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Dithyrea maritima Beach Spectaclepod	—	T	1B.1	Coastal dunes and strand. No recent records from Catalina Island.	Restoration activities are unlikely to negatively impact because of its distinctive appearance, habitat requirements, and lack of recent records.
Dudleya virens* subsp. *hassei Catalina Island Dudleya	—	S2	1B.2	Rock outcrops and cliffs. Endemic to Catalina Island.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Dudleya virens* subsp. *insularis Island Green Dudleya	—	S3	1B.2	Rock outcrops and cliffs. Endemic to Catalina Island.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Dudleya virens* subsp. *virens Bright Green Dudleya	—	S2	1B.2	Rock outcrops and cliffs. Endemic to Catalina Island.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Eriogonum giganteum* var. *giganteum Santa Catalina Island Buckwheat	—	S2	4.3	Chaparral and coastal scrub with rocky soils. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Eriogonum grande* var. *grande Island Buckwheat	—	S4	4.2	Coastal scrub and grassland. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Eschscholzia ramosa Island Poppy	—	S4	4.3	Coastal scrub and chaparral. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Euphorbia misera Cliff Spurge	—	S2	2B.2	Coastal scrub and chaparral. Scattered records on Catalina Island.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Galium catalinense subsp. catalinense Santa Catalina Island Bedstraw	—	S2	1B.3	Coastal scrub and chaparral. Numerous Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Galium nuttallii* subsp. *insulare Nuttall's Island Bedstraw	—	S4	4.3	Chaparral, cismontane woodland, coastal scrub. Numerous Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Gambelia speciosa Showy Island Snapdragon	—	S3	1B.2	Coastal scrub. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Gilia nevinii Nevin's Gilia	—	S4	4.3	Coastal scrub, grassland. Scattered records on Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Harpagonella palmeri Palmer's Grapplinghook	—	S3	4.2	Grassland, coastal scrub, chaparral with clay soils. Numerous Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Hordeum intercedens Vernal Barley	—	S3S4	3.2	Grassland, vernal pools, coastal dunes, coastal scrub. Numerous Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Isocoma menziesii* var. *decumbens Decumbent Goldenbush	—	S2	1B.2	Chaparral, coastal scrub, in sandy, often disturbed, areas. Few Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Jepsonia malvifolia Island Jepsonia	—	S4	4.2	Chaparral, coastal scrub. Numerous Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Juncus acutus* subsp. *leopoldii Southwestern Spiny Rush	—	S4	4.2	Alkaline seeps, coastal salt marsh, mesic coastal dunes, coastal scrub. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Lavatera assurgentiflora* subsp. *assurgentiflora Island Mallow	—	S1	1B.2	Coastal scrub in rocky or sandy soil. Historical records from Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Lepechinia fragrans Fragrant Pitcher Sage	—	S3	4.2	Chaparral. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Lonicera subspicata* var. *subspicata Santa Barbara Honeysuckle	—	S3	4.2	Chaparral, cismontane woodland, coastal scrub. Two records south of White's Landing.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Lycium brevipes var. hassei Santa Catalina Island Desert-thorn	—	S1	3.1	Coastal scrub. Four historical records. Taxon of questionable validity.	Restoration activities are unlikely to negatively impact because of its distinctive appearance, habitat requirements, and lack of recent records.
Lycium californicum California Boxthorn	—	S4	4.2	Coastal scrub. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Lyonothamnus floribundus* subsp. *floribundus Santa Catalina Island Ironwood	—	S2	1B.2	Cismontane woodland, chaparral. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Malacothamnus fasciculatus* var. *catalinensis Santa Catalina Island Bush-mallow	—	S2	4.2	Chaparral, coastal scrub. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Microseris douglasii* subsp. *platycarpha Small-flowered Microseris	—	S4	4.2	Grassland, vernal pools, coastal scrub, cismontane woodland with clay soils. Scattered records on Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Nemacaulis denudata* var. *denudata Coast Wooly-heads	—	S2	1B.2	Coastal dunes. Historically recorded on Catalina Island.	Restoration activities are unlikely to negatively impact because of its habitat requirements and lack of recent records.
Ophioglossum californicum California Adder's-tongue	—	S4	4.2	Grassland, vernal pools, chaparral. A few recent records from Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Pentachaeta lyonii Lyon's Pentachaeta	E	E	1B.1	Chaparral, coastal scrub in rocky or clay soil. Records from near the Two Harbors isthmus.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Phacelia lyonii Lyon's Phacelia	—	S2	1B.2	Chaparral, coastal scrub, dunes. Numerous Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Pinus torreyana* subsp. *torreyana Torrey Pine	—	S1	1B.2	Introduced species. Planted grove of mature trees at Black Jack Campground. 2018 record of a naturalized sapling south of Avalon.	**Species has no conservation status where planted outside of its natural range.**
Piperia cooperi Chaparral Rein Orchid	—	S3S4	4.2	Chaparral, cismontane woodland, grassland. Scattered records from Catalina Island.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Quercus pacifica Island Scrub Oak	—	S4	4.2	Chaparral, cismontane woodland. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Quercus tomentella Island Oak	—	S3S4	4.2	Chaparral, cismontane woodland, riparian woodland. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Rhamnus pirifolia Island Redberry	—	S4	4.2	Chaparral, cismontane woodland, coastal scrub. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Ribes viburnifolium Santa Catalina Island Currant	—	S2	1B.2	Chaparral, cismontane woodland. Numerous Catalina Island records.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Scrophularia villosa Santa Catalina Figwort	—	S3	1B.2	Chaparral, coastal scrub. Numerous Catalina Island records.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Senecio aphanactis Chaparral Ragwort	—	S2	2B.2	Dry, open ground, especially alkaline flats in chaparral, cismontane woodland, and coastal scrub. One historical record from Avalon.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Sibara filifolia Santa Cruz Island Winged-rockcress	E	S2	1B.1	Currently known only from south-facing, sunny, volcanic screes but historical populations were apparently found in shady places. Rediscovered on Catalina Island in recent years.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Solanum wallacei Wallace's Nightshade	—	S2	1B.1	Chaparral, cismontane woodland, canyons, rocky hillsides.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Suaeda taxifolia Woolly Seablight	—	S4	4.2	Saline areas near the coast; salt marshes, beaches, dunes, scrub.	Restoration activities are unlikely to negatively impact because of its distinctive appearance and habitat requirements.
Trifolium palmeri Southern Island Clover	—	S4	4.2	Various open habitats, including grasslands, grass/scrub, and disturbed areas.	**Restoration personnel should be trained to recognize this native species, to prevent inadvertent removal.**
Invertebrates					
Cicindela hirticollis gravida Sandy Beach Tiger Beetle	—	S2	—	Moist sand on beaches or in swales behind dunes.	Restoration activities are unlikely to negatively impact because of its habitat requirements.
Coelus globosus Globose Dune Beetle	—	S1S2	—	Foredunes, sand hummocks, sometimes backdunes.	Restoration activities are unlikely to negatively impact because of its habitat requirements.
Bombas crotchii Crotch's Bumblebee	—	S2/CE	—	Coastal scrub, chaparral, grassland. Nest typically underground. Three individuals reported in Avalon 8-26-23 (iNaturalist).	**Surveys should be undertaken to determine whether species is resident on the island or occurs only as a waif. If resident, surveys per CDFW-approved methods may be required prior to restoration involving ground disturbance.**

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Haplotrema catalinense Santa Catalina Lancetooth Snail	—	S1	—	Chaparral, cismontane woodland, riparian woodland, coastal scrub; typically, under leaf litter. Few recent records from Catalina Island (where endemic).	To minimize impacts to native snails, restoration personnel should check mesic areas (e.g., under rocks, wood, other debris, or deep leaf litter) prior to disturbing such areas.
Radiocentrum avalonense Catalina Mountainsnail	—	S1	—	Coastal scrub on south-facing slopes in the southeastern part of Catalina Island; may be associated with roots of native shrubs. Few recent records from Catalina Island (where endemic).	To minimize impacts to native snails, restoration personnel should check mesic areas (e.g., under rocks, wood, other debris, or deep leaf litter) prior to disturbing such areas.
Pristiloma shepardae Shepard's Snail	—	S1	—	Habitat requirements not well known. Pristiloma species generally occur on moist surfaces of plants, wood, rocks. Few recent records from Catalina Island.	To minimize impacts to native snails, restoration personnel should check mesic areas (e.g., under rocks, wood, other debris, or deep leaf litter) prior to disturbing such areas.
Sterkia* [*Vertigo*] *clementina Insular Birddrop Snail	—	S1S2	—	Habitat requirements not well known. Few records from Catalina Island.	To minimize impacts to native snails, restoration personnel should check mesic areas (e.g., under rocks, wood, other debris, or deep leaf litter) prior to disturbing such areas.
Micrarionta facta Santa Barbara Islandsnail	—	S1S2	—	Habitat requirements not well known. Few records from Catalina Island.	To minimize impacts to native snails, restoration personnel should check mesic areas (e.g., under rocks, wood, other debris, or deep leaf litter) prior to disturbing such areas.
Reptiles					
Diadophis punctatus modestus San Bernardino Ringneck Snake	—	S2	—	Chaparral, cismontane woodland, riparian woodland, coastal scrub, grassland; moist microclimates. Numerous records from Catalina Island.	To minimize chances of inadvertent mortality, restoration personnel should check for snakes in mesic areas (e.g., under rocks, wood, other debris, or deep leaf litter) prior to disturbing such areas.

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Thamnophis hammondii [Pop. 1] Santa Catalina Gartersnake	—	S1	—	Semiaquatic species; known only from a stretch of Cottonwood Canyon with permanent flow.	**To minimize chances of inadvertent mortality, restoration personnel should check for snakes in mesic areas (e.g., under rocks, wood, other debris, or deep leaf litter) prior to disturbing such areas.**
Birds					
Callipepla californica catalinensis Catalina California Quail	—	SSC	—	Cismontane woodland, chaparral, coastal scrub, grassland. Common and widely distributed on Catalina Island.	Restoration activities are unlikely to negatively impact; plan includes protections for nesting birds.
Haliaeetus leucocephalus Bald Eagle	—	E	—	Several pairs resident on Catalina Island, nesting on cliffs and rock shelves, and in trees.	Restoration activities are unlikely to negatively impact; plan includes protections for nesting birds. Restoration sites should be selected to avoid potential nest disturbance.
Falco peregrinus anatum American Peregrine Falcon	—	S3S4	—	Several pairs resident on Catalina Island, nesting on cliffs and rock shelves, and in trees. Two active nests as of 2022 (Sharpe 2022).	Restoration activities are unlikely to negatively impact; plan includes protections for nesting birds. Restoration sites should be selected to avoid potential nest disturbance.
Synthliboramphus scrippsi Scripps's Murrelet	—	T	—	Nests in burrows and under dense bushes on steep slopes around the perimeter of Catalina Island.	Restoration activities are unlikely to negatively impact; plan includes protections for nesting birds.
Athene cunicularia Burrowing Owl	—	SSC	—	Grassland, coastal scrub. Rare in fall/visitor on Catalina Island.	Restoration activities are unlikely to negatively impact; plan includes protections for nesting birds in unlikely event a nesting pair is found.
Lanius ludovicianus anthonyi Island Loggerhead Shrike	—	SSC	—	Grassland, coastal scrub. Scarce but widely distributed on Catalina Island.	Restoration activities are unlikely to negatively impact; plan includes protections for nesting birds.
Vireo huttoni unitti Catalina Hutton's Vireo	—	SSC	—	Cismontane woodland, chaparral. Uncommon but widely distributed on Catalina Island.	Restoration activities are unlikely to negatively impact; plan includes protections for nesting birds.
Ammodramus savannarum Grasshopper Sparrow	—	SSC	—	Grassland, grass/scrub. May records of 1–2 singing males in hills between Emerald Bay and Parsons Landing (eBird data).	Restoration activities are unlikely to negatively impact; plan includes protections for nesting birds.

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Pipilo maculatus clementae San Clemente Spotted Towhee	—	SSC	—	Cismontane woodland, chaparral. Common and widely distributed on Catalina Island.	Restoration activities are unlikely to negatively impact; plan includes protections for nesting birds.
Pooecetes gramineus affinis Oregon Vesper Sparrow	—	SSC	—	Grassland, grass/scrub. Some of the small numbers of Vesper Sparrows in fall/winter could involve this subspecies (eBird data).	Restoration activities are unlikely to negatively impact; species does not nest in the region.
Mammals					
Sorex ornatus willetti Catalina Island Shrew	—	SSC	—	Riparian woodland and adjacent habitats. Recorded sparingly on Catalina Island, where it is endemic.	**Restoration personnel working in and near riparian areas should take feasible precautions to avoid inadvertent mortality of shrews.**
Antrozous pallidus Pallid Bat	—	SSC	—	Cismontane woodland, chaparral, coastal scrub, grassland. Roosts under bark and in rock crevices. Historical collection at Avalon.	Restoration activities are unlikely to negatively impact because of its habitat requirements and apparent rarity on the island.
Corynorhinus townsendii Townsend's Big-eared Bat	—	SSC	—	Various habitats near roosting locations in caves, tunnels, crevices in cliffs, in trees under bark and in hollows, and in buildings. Historical collections and scattered recent records from Catalina Island	Restoration activities are unlikely to negatively impact because of its habitat requirements.
Lasiurus frantzii Western Red Bat	—	SSC	—	Roosts in foliage of many types of tree; feeds over a wide variety of habitats, often close to water in coastal lowlands. Record(s) of one or more at Wrigley Memorial and Botanic Garden (Catalina Island Conservancy unpubl.).	Restoration activities are unlikely to negatively impact because of its habitat requirements and apparent rarity on the island.
Myotis evotis Long-eared Myotis	—	S3	—	On mainland, occurs mainly in wooded areas at higher elevations. One historical collection from a roof at White's Landing (von Bloeker 1967).	Restoration activities are unlikely to negatively impact because of its habitat requirements and rarity on the island.

Latin name Common name	Fed.	State	CNPS	Habitat/Status on Catalina Island	Notes on Protection
Urocyon littoralis catalinae Catalina Island Fox	T	T	—	Many habitats. Due to successful recovery efforts in response to steep decline from a distemper outbreak, the species is becoming once again common and widespread on Catalina Island.	Restoration activities are unlikely to negatively impact; plan includes specific protections for Catalina Island Foxes.

3 HABITAT RESTORATION AND ENHANCEMENT OPPORTUNITIES AND PRIORITIES

Landscape-scale habitat restoration and enhancement planning that leverages nature-based solutions is crucial for cost-efficient and feasible conservation of biodiversity. With long-term horizons in mind, combining passive and active restoration approaches can ensure the preservation of sensitive island flora and fauna while improving the overall health of the ecosystem.

Passive restoration focuses on:

1. Removal of invasive species, like mule deer, to promote passive recovery of biodiversity.
2. Utilizing natural processes, like succession, to enhance island habitats over time.
3. Weed management (CHRIP, Appendix A) to manage highly invasive plants.

Active restoration, on the other hand, involves more direct intervention, such as:

1. Restoration efforts targeting Island Scrub Oak Chaparral habitats.
2. Top-of-watershed habitat restoration projects to manage erosion and restore degraded areas affected by past land use and nonnative ungulates.

This plan seeks to identify and prioritize restoration opportunities that maximize the benefits to the island's ecosystem health and native habitats. By developing site-specific project plans under an adaptive management framework, this approach allows for flexibility in responding to changing conditions and new knowledge gained from monitoring efforts.

To ensure the protection of sensitive, protected, and locally rare species, all projects must adhere to the provided guidelines, methods, and sensitive species protection measures. It is important to note that nearly the entire island can be considered ecologically or culturally sensitive, including developed areas, as improper management of these areas may negatively impact adjacent areas. For instance, feeding island foxes in urban areas can lead to the spread of disease and human-wildlife conflicts. Additionally, the potential presence of indigenous and archaeological resources in the soil profile beneath developed properties must be considered. As a result, even developed sites can hold significant cultural and ecological value, further emphasizing the need for thoughtful and comprehensive restoration efforts.

3.1 WATERSHED MANAGEMENT UNIT PRIORITIZATION

To address the challenges posed by invasive plant species on the island, Catalina Island Conservancy established Watershed Management Units (WMUs) as part of the Catalina Island Invasive Plant Control Program (CIPP; see Appendix A). The Conservancy strategically selected these units to prioritize habitat restoration efforts that would protect high-value biological and cultural resources (Figure 3-1 and Table 3-1). Additional WMUs were chosen due to their function as transportation corridors, with the goal of reducing the spread of invasive plants through habitat restoration in these areas (Knapp 2007b).

Table 3-1 Priority Watershed Management Units.

WMU Code(s)	WMU Name	Acres	Hectares
4, 5	Parson's Landing	631.3	255.5
6	Emerald	806.6	326.4
9	Cherry Valley	309.5	125.3
20	Empire Landing	225.2	91.1
28	Goat Harbor	197.2	79.8
32a	White's Landing	738.7	298.9
50b	Haypress	1,102.4	446.1
51	Coffeepot Canyon	935.8	378.7
61b, 61e, 61f, 61m	Middle Canyon	2,012.8	814.6
63a, 63c, 63d	Cottonwood Canyon	2,743.54	1110.3
64	Shark Harbor	499.9	202.3
65	Big Springs Canyon	417.8	169.1
66a	Little Harbor	135.1	54.7
66b	Little Springs	1,102.8	446.3

The WMUs serve as critical management areas for the Conservancy to focus its efforts on preserving the island's unique ecosystems and cultural heritage. By prioritizing these units, the Conservancy aims to enhance the effectiveness of its conservation strategies, ensuring that the most vulnerable and valuable resources receive the attention and protection they require. Moreover, the restoration of habitats within these units will not only help to mitigate the impacts of invasive species but also contribute to the long-term resilience of the island's native plant communities.

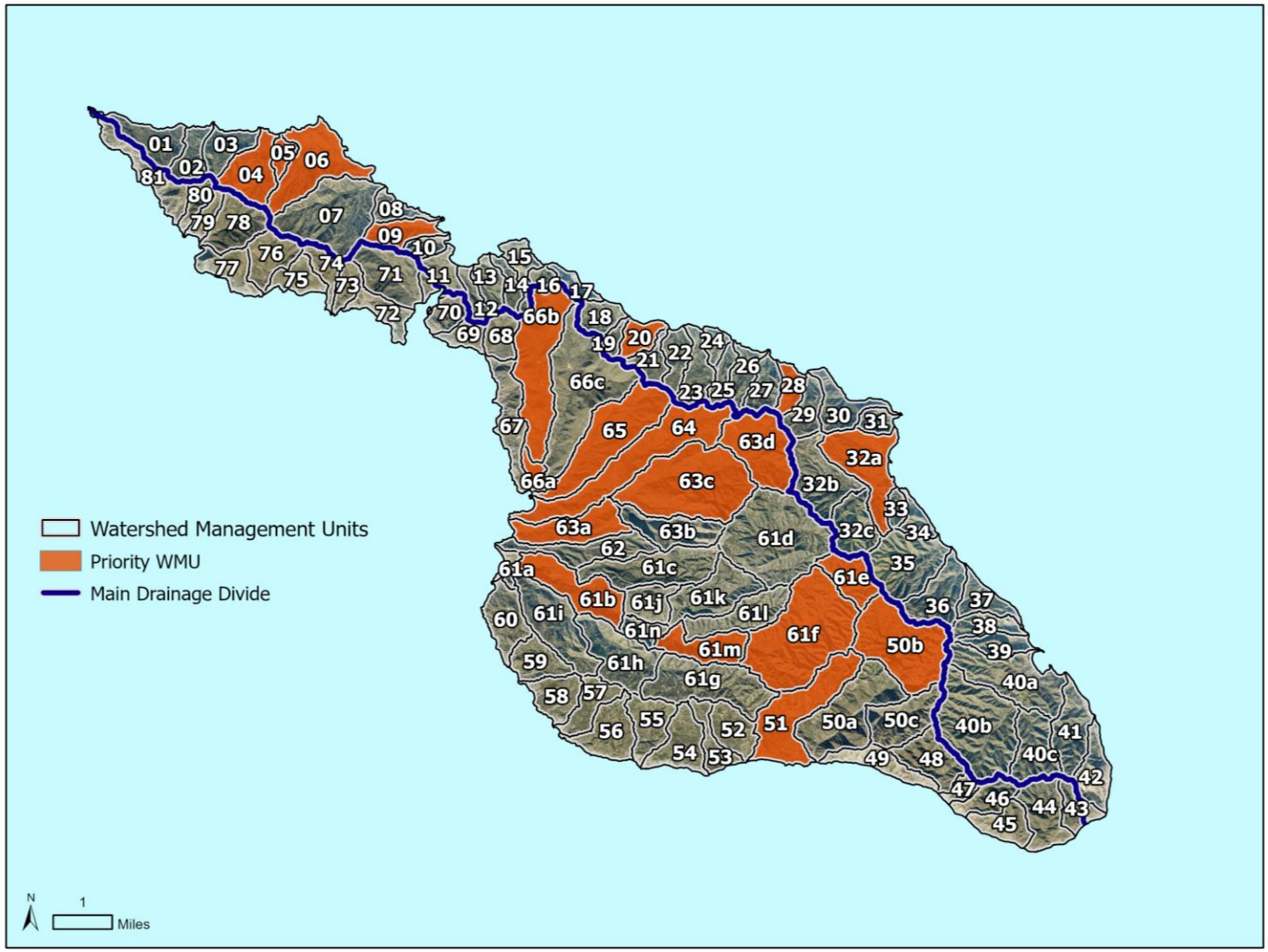


Figure 3-1 Priority Watershed Management Units.

Data provided by the Conservancy. The Watershed Management Units were developed as part of the existing invasive plant control program called CIPP and are based on watersheds that defined by the island topography. The larger watersheds are divided into smaller management units.

3.2 HABITAT RESTORATION TARGETS

Utilizing the habitat suitability models developed in Appendix D, binary (i.e., suitable or not suitable) composite maps were generated for the three most common vegetation types based on the dominant or characteristic species selected to represent potential vegetation alliances or associations:

- Island Chaparral (Figure 3-2)
- Coastal Sage Scrub (CSS) (Figure 3-2)
- Coastal Bluff Scrub (Figure 3-6). The latter encompasses the Maritime Succulent Scrub vegetation alliance and California Boxthorn Scrub.

The combination of the individual vegetation alliance and association maps is presented in Figure 3-4, representing a potential natural vegetation map for the island, focused on the most common vegetation types. These maps serve as valuable tools to identify suitable locations and targets for habitat restoration efforts. By providing a comprehensive understanding of the distribution and suitability of these key vegetation types, these maps will aid in the development of site-specific habitat restoration targets that align with the unique characteristics and needs of each area.

The habitat suitability models and resulting maps offer essential guidance for the Conservancy to prioritize and tailor restoration projects effectively. This data-driven approach ensures that efforts are focused on the most suitable areas for each vegetation type, thereby enhancing the overall success of habitat restoration initiatives and promoting the long-term health and resilience of Catalina Island's ecosystems.

3.3 HABITAT RESTORATION PLANT PALETTES

The plant palettes presented in Table 3-2 and Table 3-3 focus on the primary restoration approaches and opportunities in this plan. The plant palettes developed for this project focus on species that are likely to be available from wild seed collection, seed bulking, or nursery propagation. While these palettes do not encompass all plant species found in each vegetation community, they emphasize those that contribute to the diversity of plant functional types. This targeted approach ensures that the seed mixes used in habitat restoration efforts support a range of ecological functions and promote the overall resilience of the restored communities.

In addition to these selected plant palettes, the Conservancy may develop different or more targeted plant palettes based on the (1) goals and objectives of a site-specific or habitat-focused restoration project, (2) known native flora of the island (Appendix B), (3) the identification of suitable revegetation locations based on reference site surveys in the field and review of existing resources on environmental preferences of the plant species, including the potential vegetation models presented in Appendix D, (4) the availability of plant material for seeding or container-based planting of nursery transplants, and (5) the guidelines presented in Section 5 of Appendix F for seed mix development, plant propagation, and planting.

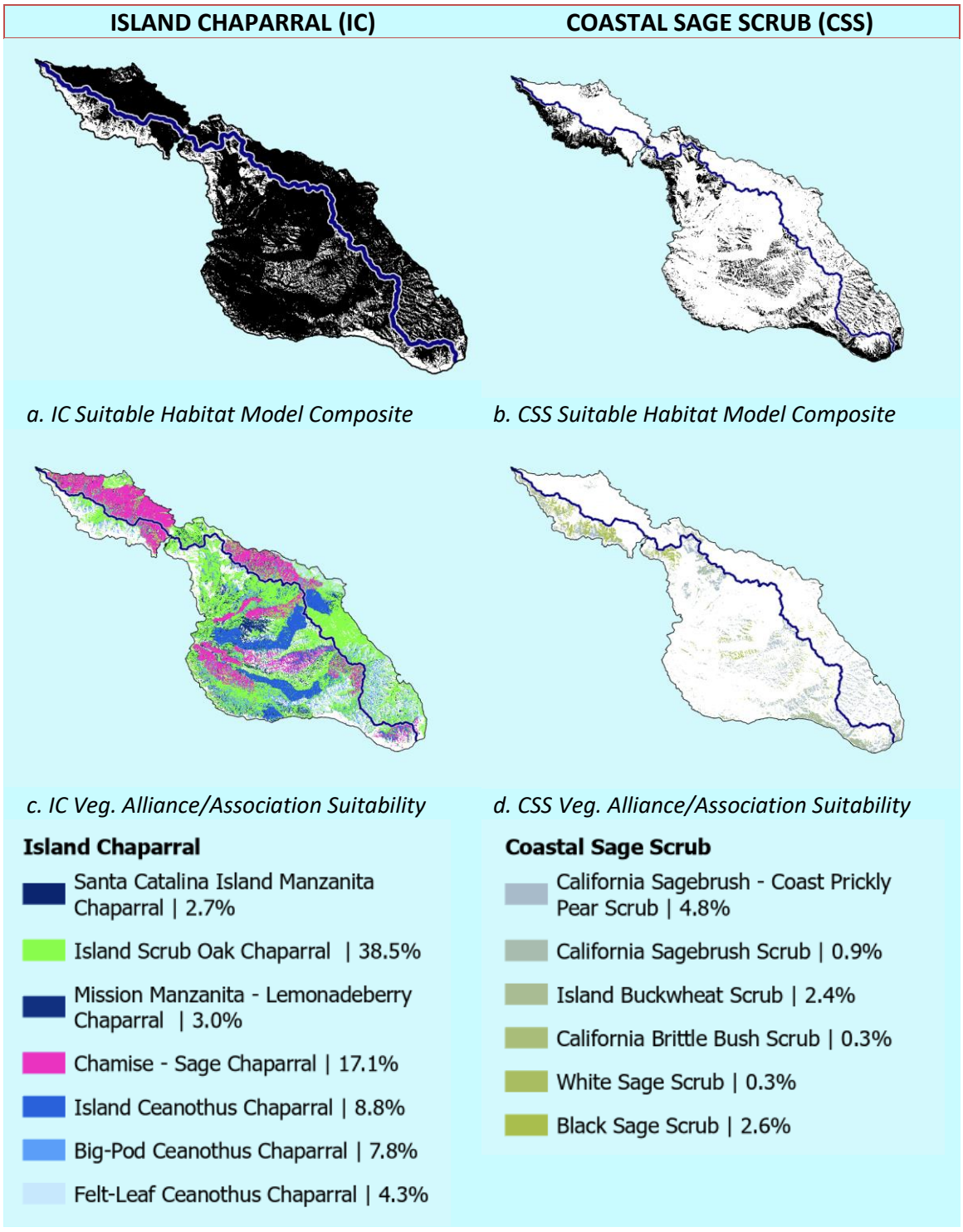


Figure 3-2 Island Chaparral and CSS Suitability Maps.

See Appendix D for details on the development of the models. The geospatial dataset can be used to help develop site-appropriate habitat restoration plans.

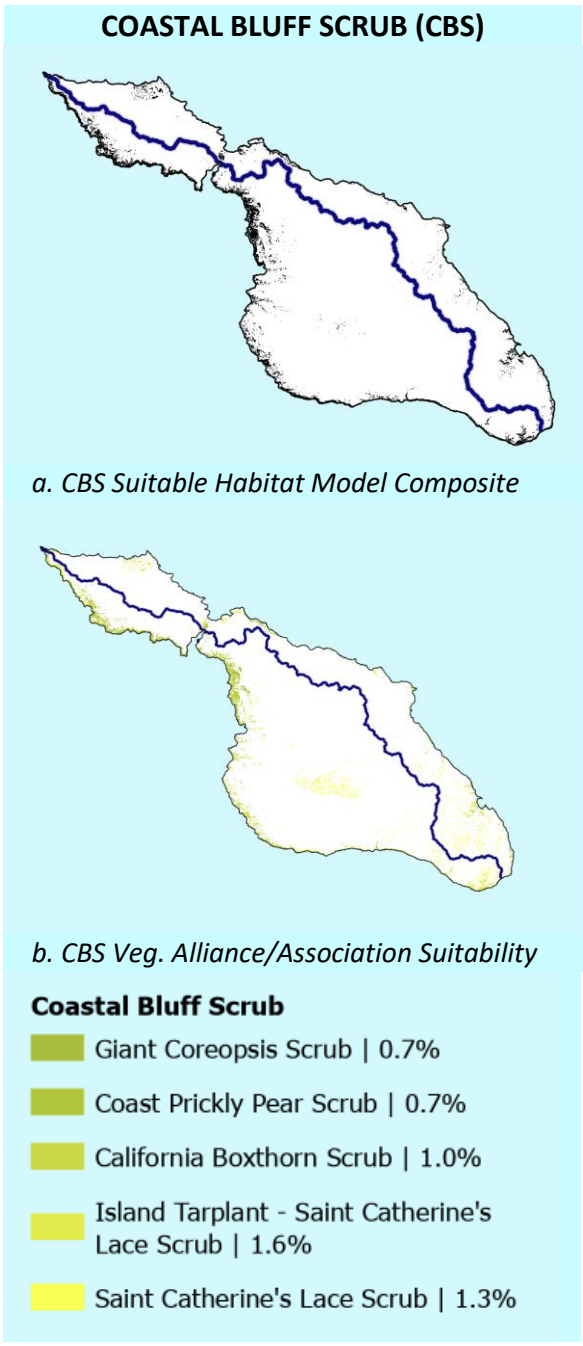


Figure 3-3 *Coastal Bluff Scrub Suitability Maps.*

See Appendix D for details on the development of the models. The geospatial dataset can be used to help develop site-appropriate habitat restoration plans.

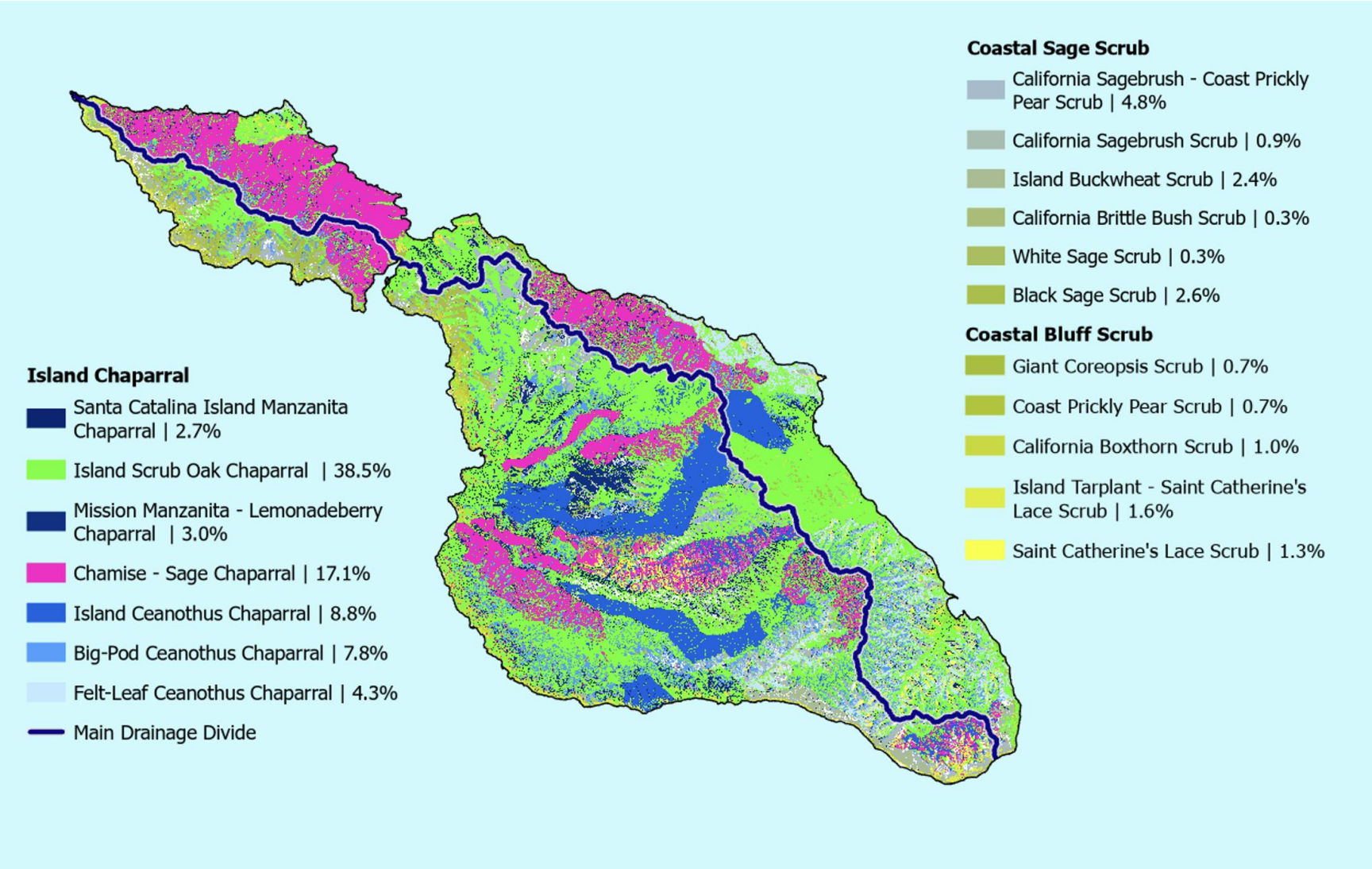


Figure 3-4 Potential Natural Vegetation Map for Island Chaparral, CSS, and Coastal Bluff Scrub.

See Appendix D for details on the development of the models. The geospatial dataset can be used to help develop site-appropriate habitat restoration plans.

ISLAND CHAPARRAL

The Island Chaparral plant palette (Table 3-2) emphasizes the establishment of shrub communities resembling coastal sage scrub (CSS) due to the challenges associated with propagating and transplanting many longer-lived chaparral plants. Selecting from this plant palette to develop site-specific seed mixes would be most appropriate for the active habitat restoration Approach 2, Island Scrub Oak Chaparral Restoration (see Section 4.1 for more discussion of the different approaches). Restoring chaparral habitats is an intensive process because many of these plants require specific germination cues (Allen et al. 2018). The primary objective is to enhance soil health and establish native vegetation from seed that facilitates the recruitment of longer-lived chaparral plants from surrounding seed sources in the watershed and through animal-mediated propagule (Brooks et al. 2019).

To achieve successful restoration, it is essential to address various barriers to the natural recruitment of longer-lived chaparral species in these habitat areas. These barriers include controlling invasive animals (e.g., removing mule deer and managing the bison herd) and mitigating the impact of highly invasive plants (e.g., Mediterranean broom and sweet fennel) (see Approach 1, Whole Island Passive Recovery, in Section 4.1 for more detail). By implementing these measures, the restoration efforts will promote the recovery of native chaparral ecosystems and support overall ecosystem health and resilience.

LOW-DIVERSITY NATIVE COVER CROP

The installation of a low-diversity native seed mix is a key part of active habitat restoration method Approach 3, Top-of-Watershed Habitat Restoration (Table 3-3). The goal is to revegetate highly degraded areas, which are infested with invasive grasses and forbs, with a native cover crop to reduce topsoil erosion and rebuild soil health with deeper rooted native perennials and increased native vegetation cover. The species identified meet multiple criteria, including that they are either feasible to bulk in the seed farm and/or can be reliably collected from existing vegetation on the island, higher establishment rates, and relatively short-lived. For example, coyote bush (*Baccharis pilularis*) is a relatively aggressive wind dispersed native plant that readily colonizes in coastal areas of southern California. Coyote bush can grow in disturbed, low nutrient soils to help build soil health. Coyote brush is relatively short lived and can be replaced by longer-lived CSS and chaparral species, such as observed on Santa Rosa Island (Clark et al. 1990) and the Santa Monica Mountains (Brennan et al. 2018).

Table 3-2 Island Chaparral Plant Palette.

Scientific Name	Common Name
Arctostaphylos catalinae	Catalina Manzanita
Artemisia californica	California Sagebrush
Baccharis pilularis ssp. *consanguinea*	Coyotebrush
Calochortus catalinae	Catalina Mariposa Lily
Ceanothus arboreus	Feltleaf Ceanothus
Ceanothus megacarpus var. *insularis*	Island Bigpod Ceanothus
Cercocarpus traskiae	Catalina Mountain Mahogany
Comarostaphylis diversifolia ssp. *planifolia*	Summer Holly
Constancea nevinii	Catalina Silverlace
Crocanthemum greenei	Island Rush-rose
Dendromecon harfordii	Island Bush Poppy
Dichelostemma capitatum	Blue Dick
Dienandra clementina	Island Tarweed
Diplacus puniceus	Southern Monkeyflower
Dissanthelium californicum	Catalina Grass
Elymus condensantus	Giant Wild Rye
Epilobium canum	California Fuchsia
Epipactis gigantea	Stream Orchid
Eriodictyon traskiae	Trask's Yerba Santa
Eriogonum giganteum var. *giganteum*	Santa Catalina Island Buckwheat
Galium catalinense	Catalina Bedstraw
Gambelia speciosa	Island Snapdragon
Heteromeles arbutifolia	Toyon
Keckeillia cordifolia	Heartleaf Penstemon
Lepechinia fragrans	Fragrant Pitcher Sage
Leptosyne gigantea	Giant Coreopsis
Lonicera subspicata var. *subspicata*	Southern Honeysuckle

Lupinus spp. *(albifrons, bicolor etc.)*	Lupine
Lycium californicum	California Boxthorn
Lyonothamnus floribundus ssp. *floribundus*	Catalina Ironwood
Malacothamnus fasciculatus var. *catalinensis*	Catalina Island Bushmallow
Malosma laurina	Laurel Sumac
Melica imperfecta	Small-leaf Melic
Cleomella arborea	Bladderpod
Prunus ilicifolia ssp. *lyonii*	Island Cherry
Quercus pacifica	Island Scruboak
Quercus tomentella	Island Oak
Rhamnus pirifolia	Island Redberry
Rhus integrifolia	Lemonadeberry
Ribes viburnifolium	Catalina current
Salvia apiana	White Sage
Salvia mellifera	Black Sage
Scrophularia villosa	Catalina Figwort
Stipa pulchra	Purple Needlegrass
Solanum wallacei	Catalina Nightshade
Xylococcus bicolor	Mission Manzanita

Table 3-3 Low Diversity Cover Crop Plant Palette.

Scientific Name	**Common Name**
Achillea millefolium	Common Yarrow
Acmispon argophyllus var. *argenteus*	Island Silver Lotus
Acmispon dendroideus var. *dendroideus*	Island Broom
Artemesia californica	California Sagebrush
Baccharis pilularis ssp. *consanguinea*	Coyotebrush
Deinandra fasciculata	Clustered Tarplant
Diplacus puniceus	Southern Monkeyflower
Encelia californica	California Sunflower
Eriogonum giganteum var. *giganteum*	Santa Catalina Island Buckwheat
Eriogonum grande var. *grande*	Island Buckwheat
Isocoma menziesii	Coast Goldenbush
Stipa spp. (*pulchra, lepida, cernua*)	Needlegrass

3.4 TOP-OF-WATERSHED HABITAT RESTORATION OPPORTUNITIES

Many areas of the island have areas of significant topsoil erosion (Section 2.1.4) that have contributed to the degradation of island habitat and ecosystem function (Knapp 2010a). The spatial distribution of areas on the island with high-levels of bare soil are modeled using the Dry Bare-Soil Index (DBSI) and can be used to focus top-of-watershed habitat restoration projects in areas with bare soil or minimal vegetation cover (Figure 2-36). It should be noted however, that the most extreme soil conditions, such as in the "Valley of the Moons", where excessive erosion may be difficult to reverse without intensive soil stabilization efforts, should be a low priority for restoration until such time in the future that less challenging habitat restoration opportunities are exhausted.

Areas identified on Figure 3-5 within 500 feet (150 meters) of primary or secondary roads were selected based on their proximity to these transportation corridors. An additional qualifying factor for selection was the presence of significant degradation, indicated by substantial nonnative herbaceous or shrub cover or bare ground, as determined from the 2000 Vegetation Map geodatabase (Figure 2-52).

It is important to note that these opportunities are based on the 2000 Vegetation Map, and land cover change analysis (Appendix C) has identified areas that experienced sustained tree cover loss (comparable to Island Chaparral), as of 2022, following the 2006 and 2007 wildfires. Consequently, additional top-of-watershed habitat restoration opportunities may exist along roadways within the burn scar areas. To assess these potential opportunities, field reconnaissance would be valuable in determining whether there has been an increase in longer-lived chaparral shrub resprouts or germination in the years following mule deer removal.

3.5 ISLAND SCRUB OAK CHAPARRAL RESTORATION OPPORTUNITIES

Island Scrub Oak Chaparral (ISOC) Restoration Opportunities were identified by evaluating degraded areas with a substantial presence of nonnative vegetation, typically nonnative annual grassland, or bare ground. These areas were further assessed based on their classification as ISOC on the 2000 Vegetation Map and their proximity (150 meters) to primary or secondary roadways (Figure 3-5).

Degraded areas whose edges are more than 150 meters from the roadway were categorized as "Potential Other Habitat Restoration Opportunities." While these areas may be less accessible and thus less desirable for restoration efforts, the presence of sensitive resources in such locations could provide additional motivation for their inclusion in a restoration project. By considering both accessibility and the potential ecological benefits, this approach ensures that restoration efforts are targeted to maximize the overall impact on the island's ecosystem health.

For prioritizing areas with a higher likelihood of new oak establishment or growth, the Conservancy can consult the Potential Vegetation Map for Island Scrub Oak (Figure 3-6 and Appendix D).

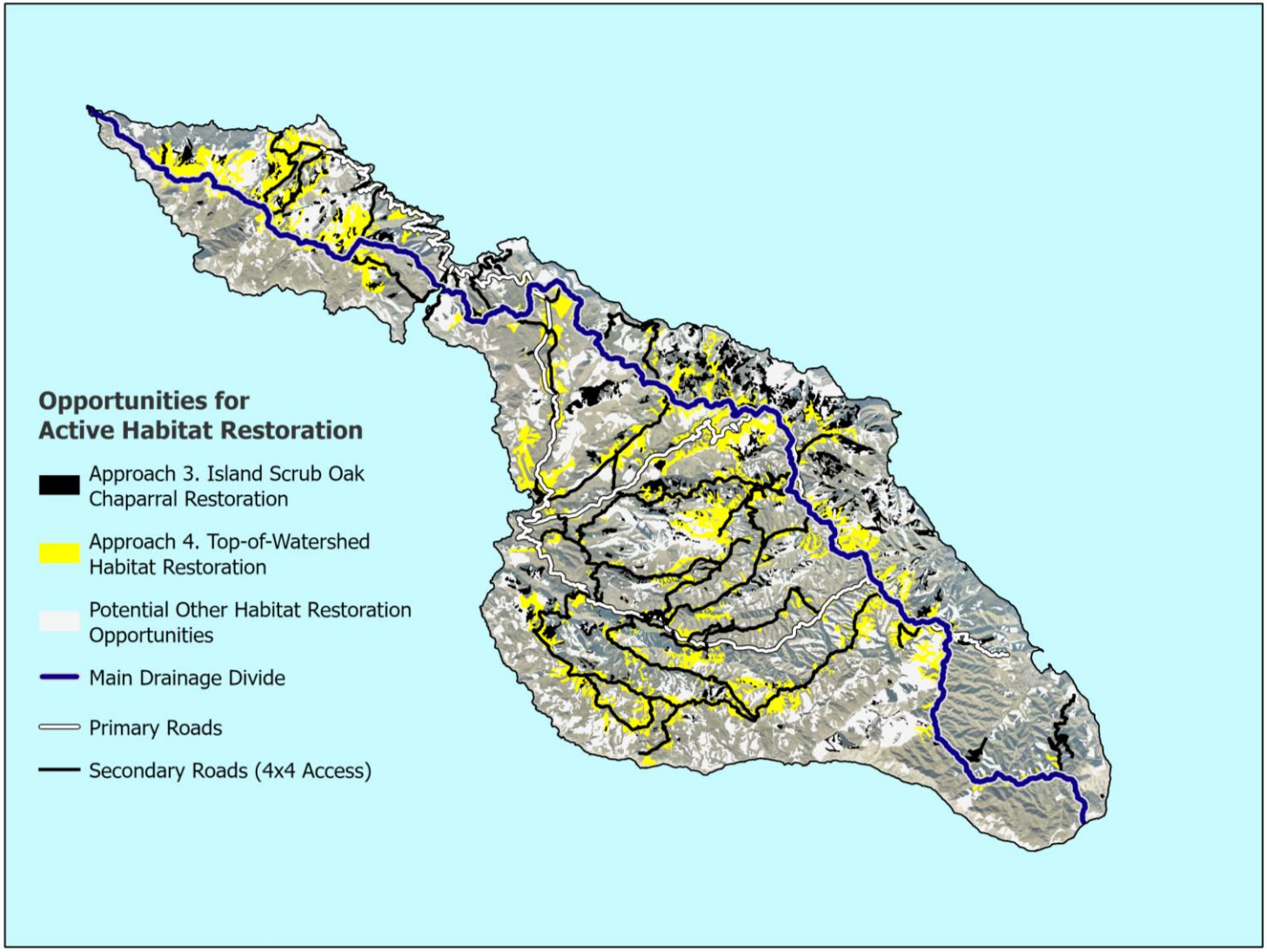


Figure 3-5 Opportunities for Island Scrub Oak Chaparral and Top-of-Watershed Habitat Restoration.

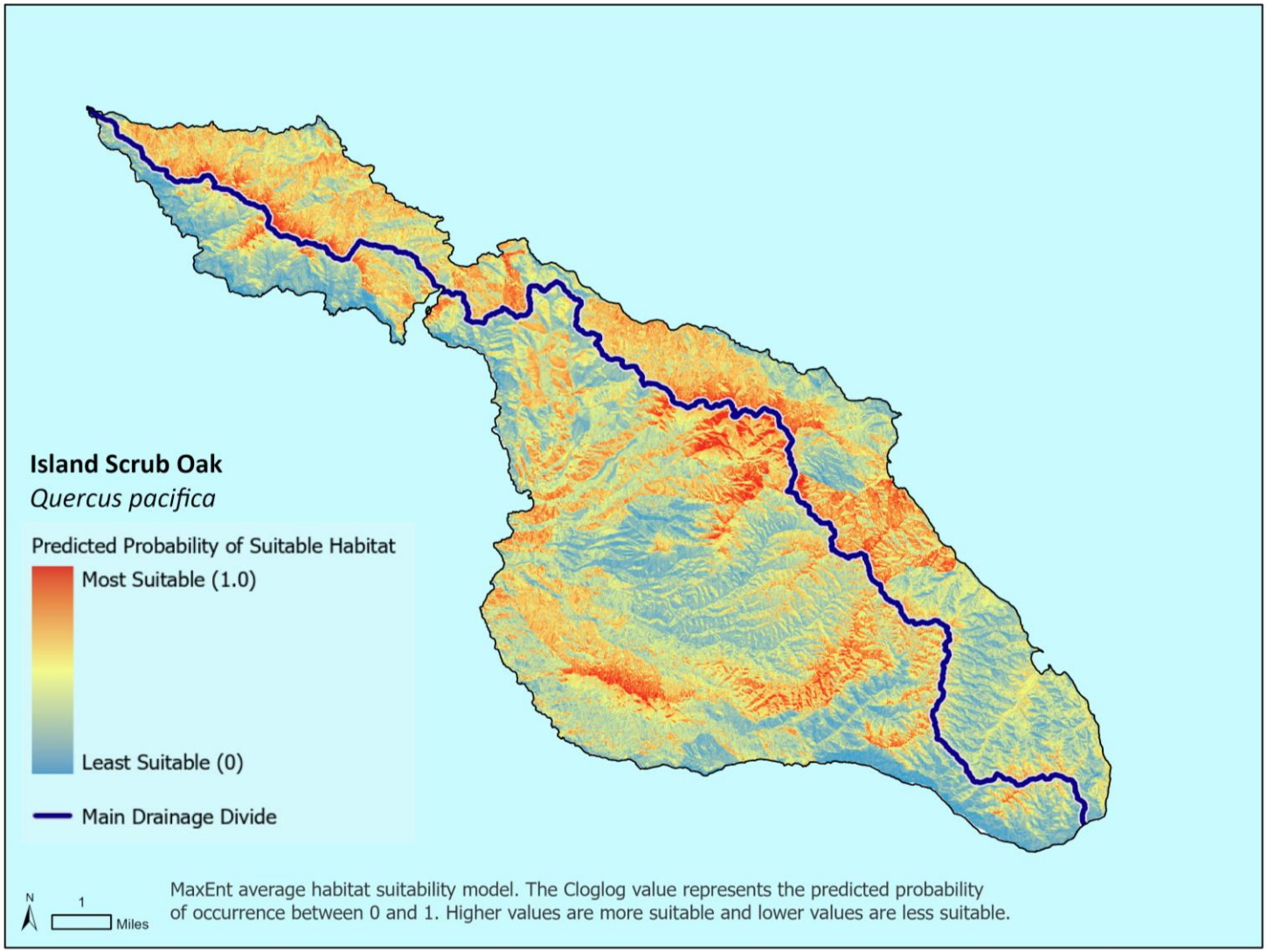


Figure 3-6 Potential Vegetation Map for Island Scrub Oak (Quercus pacifica).

4 ADAPTIVE WEED MANAGEMENT AND HABITAT RESTORATION

Having identified habitat restoration and enhancement opportunities and established a prioritization scheme for selecting suitable restoration projects by Watershed Management Unit (Section 3), this section presents cost-effective approaches for landscape-scale island habitat restoration. Four habitat restoration approaches are discussed, with the primary method being the removal of the invasive mule deer population to facilitate the natural recovery and growth of native vegetation, including island endemics, that are not deer-resistant (Section 4.1.2). Additionally, three additional approaches for active habitat restoration projects are outlined, targeting areas where further intervention is necessary to restore essential ecosystem functions and wildlife habitats (Section 4.1.3). These comprehensive strategies aim to promote the successful restoration and preservation of the island's unique ecological characteristics while ensuring efficient use of resources.

A central component of the Habitat Restoration and Management Plan (HRMP) is the recognition and management of uncertainties inherent in natural systems. Several common uncertainties are often encountered when implementing habitat restoration projects in southern California and the Channel Islands:

- Microsite edaphic diversity, including areas with dense summer fog banks that can increase soil moisture while simultaneously reducing solar insolation.
- Limited documentation of historical native vegetation community distribution and species diversity prior to disturbances from ranching and invasive ungulate introductions.
- Uncertainty regarding the composition of existing soil seed banks.
- Lack of information on past land use practices at a local scale, such as the intensity and duration of livestock grazing or vegetation clearance activities.
- Unclear understanding of local hydrological dynamics due to variable rainfall and alterations of the natural watershed from land development, road construction, groundwater extraction, and dam construction for stockponds.
- Uncertain impacts of climate change, including increased soil aridity earlier in the year, reduced fog duration, and a higher frequency of summer rainfall events.
- High variability in weather patterns between years, affecting the timing and intensity of rainfall events and wind events like Santa Ana winds.
- Unpredictable stochastic events, such as wildfires.

By acknowledging these uncertainties and incorporating flexible, adaptive management strategies, the HRMP aims to address the complex challenges associated with habitat restoration in the region and ensure the long-term success of conservation efforts. This HRMP strategically manages uncertainty through three project implementation steps:

1. Ecologically appropriate site selection
2. Adaptive weed management
3. Seed-based habitat restoration

The HRMP implementation is based on an adaptive management approach (Section 4.1.1). Key factors for recovering island biodiversity and restoring the ecosystem include removing mule deer (Section 4.2) and controlling high-priority invasive plants (Section 4.3). Four strategic habitat restoration methods have been identified, leveraging natural processes and cost-effective techniques such as seed-based, rainfall-driven restoration (Section 4.1.3). The following sections outline essential components for each restoration approach:

- Design of habitat restoration plant palettes (Sections 4.5 and 3.2)
- Erosion control measures to restore degraded soils (Section 4.7)
- Adaptive weed management for reducing the weed soil seed bank (Section 4.8)
- Seeding methods (Section 4.10)
- Container plant production for strategically introducing underrepresented shrubs and trees that do not establish easily from seed (Section 4.11)
- Post-seeding site maintenance (Section 4.12)

These components collectively contribute to the restoration of diverse habitats, promote ecosystem resilience, and support the recovery of native species.

4.1 OVERVIEW

Four approaches were identified for island habitat restoration. Figure 4-1 illustrates how these approaches are integrated, emphasizing the essential elements of implementation, monitoring, assessment, and adaptation to achieve the island habitat restoration goals. Table 4-1 provides additional details for each restoration action within the four approaches, along with citations of relevant subsections of this HRMP for further detail. Detailed guidance on restoration implementation methods can be found in Appendix F, Habitat Restoration Methods Guidelines, which serves as a valuable resource for Conservancy staff to support project success.

As a voluntary undertaking, the Catalina Island Conservancy acknowledges that the HRMP is guided by a commitment to conserve and restore the unique natural and cultural heritage of the island. The Conservancy is dedicated to using the best available science, planning, and practices to direct its efforts, while also recognizing that its primary obligations are to avoid adverse impacts and make a good faith effort to conserve and restore native habitats, protect culturally significant resources, and serve as responsible stewards of the island for the benefit of the public and future generations.

In pursuing this habitat restoration plan, the Conservancy aims to demonstrate its dedication to preserving the rich biodiversity and cultural legacy of Catalina Island, while promoting environmental stewardship and fostering a deeper understanding and appreciation of the island's natural and cultural treasures for generations to come.

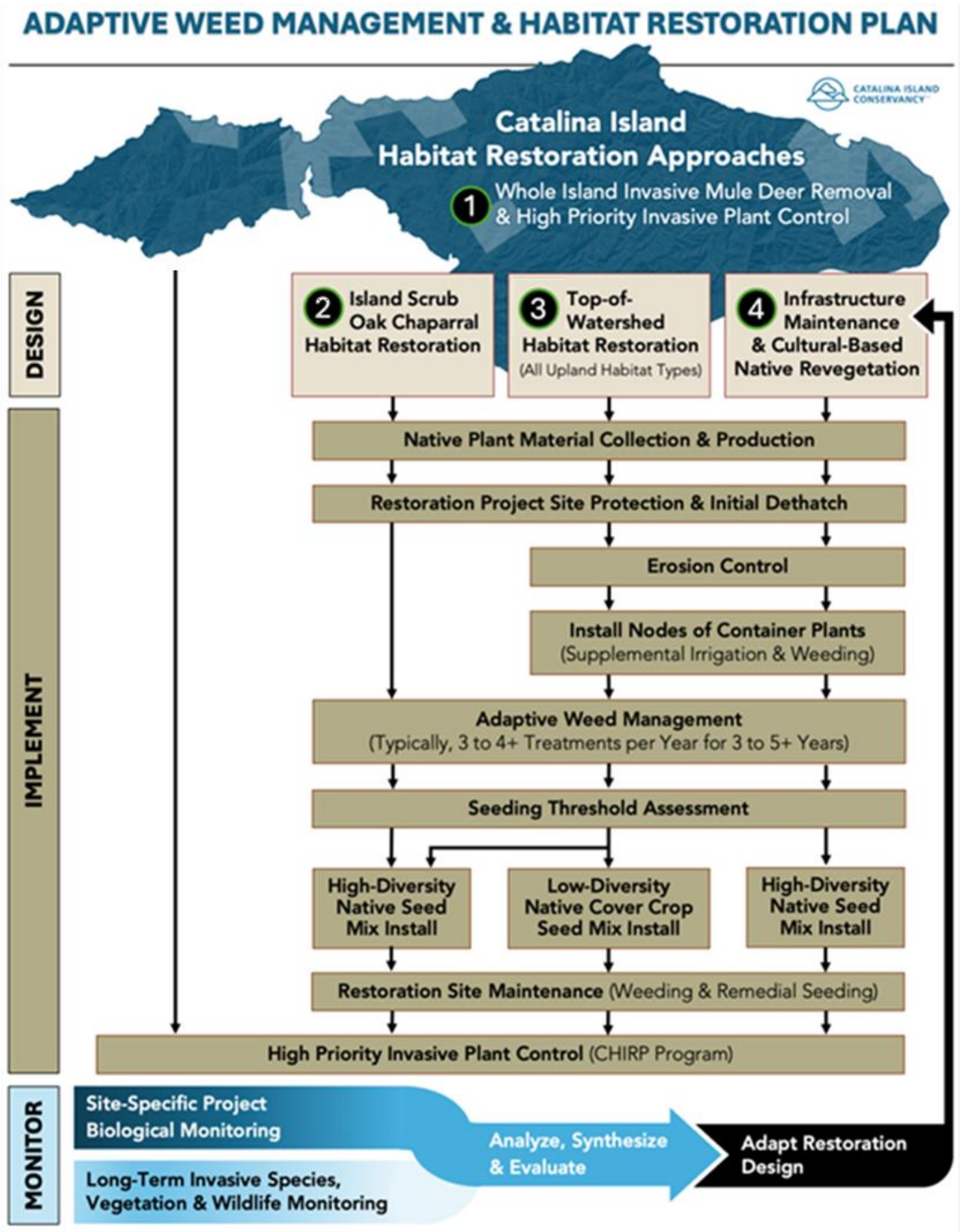


Figure 4-1 Catalina Island Adaptive Weed Management and Habitat Restoration Plan Overview.

Diagram identifying the 4 approaches to island habitat restoration in an adaptive management scheme, of designing site-specific projects, implementation, and monitoring, followed by analysis, synthesis, and evaluation of monitoring data to adapt restoration planning as needed to achieve restoration goals.

Table 4-1 Summary of Adaptive Weed Management and Habitat Restoration Activities by Approach.

HABITAT RESTORATION APPROACHES:	Passive	Active		
	1	2	3	4
Restoration Action	**Whole Island mule deer removal and high priority invasive plant control**	**Island Scrub Oak Habitat Restoration**	**Top-of-Watershed Habitat Restoration**	**Infrastructure Maintenance Native Revegetation**
Whole Island Restoration				
Mule Deer Removal (Section 4.2)	x			
High-Priority Invasive Plant Control (Section 4.3)	x	x	x	x
Site-Specific Restoration Project Design				
WMU Prioritization (Section 3.1)		x	x	
Habitat Restoration Approach and Site-Selection (Section 4.4.1)		x	x	x
Native Plant Palette Design (Section 4.5)		x	x	x
Site-Specific Restoration Project Implementation				
Native Plant Material Collection and Production (Sections 4.5.4, 4.5.2 and 4.11.1)		x	x	x
Restoration Project Site Protection (Section 5.2**)**		x	x	x
Initial Dethatch, *If Needed* (Section 4.6)		x	x	x
Install Nodes of Container Plants (Section 4.11.2)				
Erosion Control Measures (Section 4.7)		x	x	x
Adaptive Weed Management (Section 4.8)		x	x	x
Seeding Threshold Assessment (Section 4.9)		x	x	x
High-Diversity Native Seed Mix Installation (Sections 4.5.5 and 4.10)		x	x	x
Low-Diversity Native Cover Crop Seed Mix Installation (Sections 4.5.5 and 4.10)			x	
Restoration Site Maintenance (Section 4.12)		x	x	x
Remedial Seeding or Planting, *If Needed* (Section 4.12)		x	x	x
Site-Specific Restoration Project Monitoring				
Sensitive Species Protection (Section 5.1)		x	x	x
Horticultural Monitoring (Section 5.2.1)		x	x	x
Plant Establishment Monitoring (Section 5.2.2)		x	x	x
Long-Term Monitoring				
Vegetation Monitoring (Section 5.3.2)	x	x	x	
Wildlife Monitoring (Section 5.3.4)	x	x	x	
Soil Monitoring (Section 0)	x	x	x	x
Invasive Plant Species Monitoring (Section 5.3.7)	x	x	x	x
Assess and Adapt (Section 5.4)	x	x	x	x
Reporting (Section 5.5)	x	x	x	x

4.1.1 Adaptive Management

The adaptive management approach employed in this habitat restoration plan encourages flexibility and continuous learning. The plan encompasses the design and implementation of site-specific projects, biological monitoring, data analysis, and periodic adjustments to restoration project design based on new insights. It allows for updates to key elements, such as restoration principles, management hypotheses, plant palettes, species distribution models, and restoration specifications, as well as monitoring methods, scientific research, and innovative techniques. Any deviations from the plan will be documented by the Conservancy. However, core elements of the HRMP, including goals, sensitive species protection measures, monitoring goals, and reporting requirements, will remain unchanged unless the plan is formally amended. This combination of adaptability and consistency ensures that the plan remains effective and responsive to new information while staying focused on its primary objectives.

4.1.2 Passive Habitat Restoration

Approach 1. Whole Island passive recovery of biodiversity through removal of mule deer and high priority invasive plant control using the existing CIPP program.

The term "passive restoration" might be somewhat misleading, as it still involves a significant amount of work. However, the primary goal of passive restoration is to convey that it relies less on active interventions compared to traditional habitat restoration approaches. The removal of mule deer alone will contribute to the enhancement and restoration of island biodiversity and native cover. This process will be further supported by maintaining the existing high-priority invasive plant control program, known as CIPP (Section 4.3). By combining these strategies, the Project aims to achieve a comprehensive and sustainable restoration of the island's unique habitats.

4.1.3 Active Habitat Restoration

There are two approaches to active habitat restoration, and a third approach that covers best practices for native revegetation for infrastructure maintenance and cultural-based projects:

- Island scrub oak chaparral habitat Restoration
- Top-of-watershed habitat restoration
- Infrastructure maintenance and cultural-based native revegetation

Approach 2. Island Scrub Oak Chaparral Restoration

The island scrub oak, a key species in the scrub oak chaparral community, faces significant threats due to habitat loss and the legacy effects of past land use practices. These threats include mule deer impacts, the effects of feral pigs, and invasion by nonnative grasses and forbs. To address these challenges, a restoration approach will focus on restoring diverse native island upland scrub in areas dominated by nonnative species. This will help improve soil health and create suitable conditions for island scrub

oak regeneration and other suitable co-dominant long-lived chaparral plants that may naturally recruit into suitable areas in the future.

Priority will be given to areas near accessible roads, allowing for effective seasonal weed management using natural rainfall-driven cycles to reduce the weed soil seed bank. However, areas with minimal weed presence may be considered for limited weed management prior to seed installation. Diverse native seed mixes, representing various plant functional groups, will be used to emulate the natural disturbance recovery process characteristic of island scrub ecosystems. By implementing this restoration approach, the Conservancy aims to enhance the resilience and long-term viability of the island scrub oak population and its associated plant communities.

Approach 3. Top-of-Watershed Habitat Restoration

To restore areas with eroded topsoil and loss of native vegetation due to historical overgrazing, overbrowsing, and the introduction of invasive ungulates, a targeted active restoration approach is proposed. This approach includes implementing erosion control measures, reducing the nonnative soil seed bank through weed management, strategically planting key shrub and tree species, and installing a low-diversity native cover crop. In some cases, a high-diversity native seed mix, like what is recommended for Approach 2, may be appropriate.

Weed management methods will involve mechanical and chemical treatments, with a focus on conducting most weed management prior to seeding. This approach aims to create a favorable environment for native seedling establishment by focusing on intensive weed management in the early stages of restoration.

The targeted areas, identified in Section 3.4, have been significantly impacted by topsoil loss and are accessible by well-maintained roads to facilitate crew access for weed management and container transplant maintenance. The prioritization of this habitat restoration approach across watershed management units will be based on the sensitivity of downstream biological resources that will be protected and enhanced by this approach.

Approach 4. Infrastructure Maintenance and Cultural-Based Native Revegetation

Infrastructure Maintenance Native Revegetation

For the maintenance and repair of existing infrastructure, such as roadways, buildings, and equipment, revegetation efforts should prioritize the use of native plant species that are compatible with the adjacent built environment. These restoration activities should align with the methods outlined in this plan for other active habitat restoration methods, but may require modifications to accommodate specific constraints, such as fuel modification zone requirements.

When undertaking habitat restoration in conjunction with infrastructure maintenance or erosion repair, the following steps can be taken to ensure compatibility with adjacent built environments and adherence to management restrictions:

- Site assessment: Conduct a thorough assessment of the site to understand existing conditions and identify any specific requirements or constraints for revegetation efforts.
- Plant selection: Choose native plant species that are well-suited to the site conditions, considering factors such as soil type, sun exposure, and water availability. Prioritize species that are compatible with adjacent built environments and meet fuel modification zone requirements, if applicable.
- Restoration planning: Develop a restoration plan that incorporates the specific requirements and constraints of the site, including any necessary modifications to standard active habitat restoration methods.
- Implementation: Implement the restoration plan, ensuring compliance with all management restrictions and consideration of adjacent built environments.
- Monitoring and maintenance: Monitor the progress of revegetation efforts and provide ongoing maintenance as necessary to ensure the successful establishment and growth of native plant species.

By following these guidelines, restoration efforts can effectively enhance habitat while also supporting the maintenance and repair of existing infrastructure. This approach ensures compatibility with adjacent built environments and compliance with existing land management restrictions, contributing to the overall sustainability and resilience of the restored ecosystem.

CULTURAL-BASED NATIVE REVEGETATION

Cultural-based native revegetation projects are initiatives that focus on restoring and preserving indigenous plant species with significant cultural importance to tribal nations. These projects not only protect and promote native flora but also provide valuable habitat and resources for local wildlife. An example of such a project is the planting wetland plants, such as spiny rush (*Juncus acutus*) and tule (*Schoenoplectus acutus*), that are culturally significant plants for many indigenous communities, along the edges of reservoirs. This approach serves a dual purpose: it offers tribal nations the opportunity to collect culturally important native materials outside of the bird breeding season, while simultaneously providing a natural screen to shield birds from human activity. The enhanced habitat created by the tule plantings contributes to improved aquatic conditions for both resident and migratory bird species, fostering biodiversity and promoting the overall health of the ecosystem.

To accomplish cultural-based native revegetation projects, the Conservancy is encouraged to consider entering a Memorandum of Understanding (MOU), or other appropriate instrument, with indigenous communities or nations of people (indigenous people) of southern California to establish a collaborative partnership that balances the preservation of sensitive biological resources with the cultural needs and traditions of the indigenous people. This partnership would create an environment of mutual

respect, cooperation, and shared learning, fostering a deeper understanding of local ecosystems and informing sustainable management strategies.

By granting indigenous people access to designated areas for the cultural collection of plant materials and animals, the Conservancy can support the continuation of traditional practices while ensuring the sustainability of these resources. In return, if willing indigenous people can contribute their traditional ecological knowledge and practices, enhancing the Conservancy's conservation efforts and fostering a richer understanding of the land and its ecosystems (Long et al. 2020).

The recommended MOU should include provisions for clear communication, consultation, and dispute resolution, ensuring that any issues are addressed promptly, and that the conservation of natural resources remains a priority. Furthermore, the agreement should be designed to be adaptable, allowing both parties to review and update the MOU as needed to incorporate new knowledge or best practices.

By considering this recommendation, the Conservancy has an opportunity to create a lasting partnership with indigenous people that respects and preserves both the cultural traditions of the indigenous people and the sensitive biological resources of the region. This collaborative approach serves as a model for the successful integration of cultural and conservation goals, promoting a harmonious coexistence between people and nature.

4.2 INVASIVE MULE DEER REMOVAL

The successful removal of mule deer from Catalina Island is a crucial step in achieving the Project's habitat restoration goals, as their presence and browsing habits significantly hinder the recovery of native vegetation. The removal process will involve ground shooting, along with the sterilization of select "Sentinel" deer to ensure comprehensive population control. In populated areas, deer management will be accomplished through capture using bait followed by culling, ground shooting, and sterilization. The timing of removal efforts will be strategically planned to align with the mule deer's reproductive cycle, specifically during the estrus period when they are more social, to maximize efficiency and reduce the need for additional removals. All project activities will adhere to the American Veterinary Medical Association's Depopulation guidelines for humane handling of animals, ensuring a safe, ethical, and responsible process.

After the mule deer are removed, the last introduced ungulate will be the bison. Sheep herding and cattle grazing ended in the 1950s, and the Conservancy removed the feral goats and pigs by the early 2000s. The Conservancy has sustainably managed the bison herd size since 2009 by injecting the females with porcine zona pelluciida (PZP), a contraceptive that had been used for fertility control in zoos, wild horses, and white-tailed deer. The bison herd is now around 80 individuals and at its height was at 527. Bison primarily graze on grasses but also selectively browse herbs and woody vegetation, especially during the summer dry season. Bison trample vegetation and compact rangeland but roam more and use riparian areas less intensively than do cattle (e.g., Steuter and Hidinger 1999).

4.3 HIGH-PRIORITY INVASIVE PLANT CONTROL

The Conservancy, in line with its mission to be responsible stewards of its lands through conservation, education, and recreation, recognized the need for a science-based invasive plant management program. This program, known as the Catalina Invasive Plant Program (CIPP), was established in 2003 to protect ecosystem health through monitoring and management of invasive plants.

Invasive species pose a significant threat to biodiversity worldwide, particularly in island ecosystems such as Catalina Island. With the removal of introduced ungulates (e.g., feral goats and pigs were removed beginning in the 1990s; pigs were fully eradicated by 2004 and goats by 2005), many invasive plant species have spread across the island, impacting flora, fauna, and ecosystem processes. To address this issue, the Conservancy commissioned an island-wide invasive plant survey and species-led management plan in 2003, which provided the necessary information to develop and implement a site-led invasive plant management plan.

Beginning in 2004, the Conservancy targeted approximately 30 species for eradication, maintaining most of their populations at less than 1 percent cover. The 2003 survey revealed that several widespread species were abundant, requiring a more focused approach to prioritize control efforts. To achieve this, the Conservancy developed a

watershed-based plan in 2008 that ranked the natural resources in each watershed or habitat management unit on the island (i.e., Watershed Management Units, WMU). This plan allows the Conservancy to systematically address new and widespread invasive species, preventing them from impacting high-value conservation sites. By integrating the species-led and site-led management plans into a comprehensive strategy, the Conservancy can holistically address invasive plants and protect important ecological areas.

The Conservancy has a 20-year history of managing invasive plant species, with notable achievements including the functional eradication of four species and the treatment of over 1.4 million individual plants. Over the years, the Conservancy has surveyed nearly 30,000 acres, treated over 3,000 acres, and managed over 200 species, investing more than 68,000 hours in these efforts. In 2023, the Conservancy surveyed 192 acres across 37 watershed management units, treating 15 different species and a total of 204,973 individual plants. In 2022, the Conservancy surveyed 274 acres across 70 watershed management units, treating 21 species and a total of 231,805 individual plants. Currently, the Conservancy targets over 40 invasive plant species for management.

The Conservancy has collaborated with various organizations, including American Conservation Experience (ACE) interns and the California Institute of Environmental Studies (CIES) contractor crews. CIES contractor crews bring valuable experience and expertise in invasive plant management, having worked on projects across the California Channel Islands. This partnership enhances the Conservancy's ability to address invasive species and protect the unique biodiversity of Catalina Island.

The CIPP program is an essential component of the broader Catalina Island habitat restoration plan, especially as the island transitions with the removal of the last large invasive browser, the mule deer. As invasive plants are released from browsing pressure, the CIPP program will play a critical role in managing and mitigating the potential spread of these species. More detailed information about the CIPP program and its role in high-priority invasive plant management can be found in Appendix A.

4.4 SITE-SPECIFIC RESTORATION PROJECT DESIGN

Selecting the right location is crucial for the success of active habitat restoration projects. To identify suitable project sites, it is essential to consider the existing mosaic of nonnative annual grasslands and native vegetation communities, including island chaparral, island scrub oak, CSS, native perennial grasslands, forblands, riparian, wetland, and woodlands. Since the pre-European condition of the island vegetation communities is not well understood in highly degraded areas that would benefit from active habitat restoration projects, it is necessary to carefully evaluate the current conditions of each potential site.

Particular attention should be given to sensitive native riparian and wetland habitats, which are more susceptible to changes from drought, climate change, and human alterations to the environment. These habitats depend on specific hydrological and geomorphic conditions that may have been altered due to past development, flood control measures, or extended drought conditions. Consequently, some species may struggle to recruit new individuals, leading to long-term shifts in the composition of riparian and wetland natural communities.

To ensure the long-term success of restoration efforts, priority should be given to sites that still retain some of their historical hydrological and geomorphic characteristics. In cases where these conditions have been significantly altered, additional restoration measures may be required to restore or mimic the natural processes that support the target habitat type, such as erosion control.

4.4.1 HABITAT RESTORATION APPROACH AND SITE-SELECTION

Once a Watershed Management Unit (WMU) and a habitat restoration approach have been selected based on the guidance provided in Section 3, it is crucial to conduct on-the-ground field assessments to create a detailed, site-specific habitat restoration plan. While the predictive potential vegetation modeling offers a consistent, probabilistic evaluation of suitable restoration targets, it is essential to recognize that these models, which form the basis for identifying habitat restoration opportunities, have limitations and may not be entirely accurate. Field assessments provide valuable site-specific information that may not be captured in a landscape-scale model, such as:

1. Existing plant species: Document both native and nonnative plant species present on the site, along with their distribution. Pay particular attention to sensitive or protected species that may require special considerations during the restoration process. The pattern of existing weed and native plants may also inform us about their surrounding growing environment (e.g. Pfieffer 2013) by serving as habitat proxy indicators and can be used to help refine weed management approaches and habitat restoration targets.
2. Reference habitat: Observations of nearby extant stands of vegetation communities that occur in similar environmental conditions may also help inform the development of habitat restoration targets in the project area.

3. Wildlife observations: Note any observations of wildlife, including the identification and presence of sensitive or protected species. This information can help guide restoration efforts to minimize disruption to local fauna.
4. Unique soil conditions: Identify any distinct soil conditions that may impact plant growth, such as alkaline soils, rock outcrops, or significant changes in soil texture. Understanding these conditions will help inform plant selection and placement during the restoration process.
5. Alterations of natural hydrology: Assess any modifications to the natural hydrology of the site. These alterations may impact the current and future hydrologic functions critical to vegetation communities, like oak woodlands and riparian habitats.
6. Fire severity assessment: Evaluate the qualitative impact of fire events on the site, as fire severity may influence the ability of native plants to regenerate. This information will help guide the restoration strategy and determine whether additional interventions are needed to promote native plant recovery.
7. Accessibility: It is important to determine what constraints there may be to access for equipment or restoration crews because it will influence the selection of viable weed management and seeding methods.

By incorporating data from field assessments into the site-specific habitat restoration plan, the Conservancy can address local conditions and factors that may not be captured in the broader landscape-scale models. This approach will help ensure that the restoration efforts are tailored to the unique needs and characteristics of each site, ultimately increasing the likelihood of successful habitat restoration and long-term ecological health.

Additional factors to consider when selecting a restoration site include current disturbance levels, such as unwanted trespassing, frequently used illegal trails, and vandalism. If the site is within an area accessible to the public, the level of use in the area should be considered, particularly when the goal is to restore habitat for sensitive species. Implementing measures such as fencing and educational signage can help protect the site and inform the public about the restoration project. Furthermore, leveraging the Conservancy's public recreation and education programs can play a vital role in minimizing potential disturbances caused by public activities, whether intentional or unintentional.

In some cases, it may be beneficial to conduct soil sampling and laboratory testing to gain a better understanding of the growing conditions or constraints present in the restoration area. Additionally, reviewing available historical aerials or photographs can provide valuable insights into past land use and disturbances, such as vegetation clearing or ranching, that may have impacted the native vegetation. This information can help inform restoration strategies and guide the decision-making process for the Project.

4.4.2 SITE-SPECIFIC RESTORATION PLAN

With restoration targets selected, knowledge of site-specific implementation opportunities and constraints, and explicit restoration hypotheses to guide plan development, sufficient information is available to create a site-specific habitat restoration plan. Choose the most appropriate methods based on factors such as site-specific constraints and opportunities, budget, available equipment, site access, and staff, while following one of the active habitat restoration approaches (Section 4.1.3), the guidelines in this section, and the detailed specifications in Appendix F.

Tailor success criteria to each site-specific habitat restoration project, considering factors such as project goals, regulatory requirements, habitat restoration targets, and the presence of rare, sensitive, or protected species. For vegetation-related success criteria, account for the significant impact of site and year (e.g., variable rainfall) on vegetation response, including diversity, cover, and phenology. Incorporate reference habitat samples (where available) into success criteria to address this variability.

4.4.3 SITE-SPECIFIC RESTORATION PROJECT SUCCESS CRITERIA

Developing success criteria for individual active restoration projects depends on several factors, including the most suitable active habitat restoration approach for the specific area (see Section 4.1.3) and local site conditions (see Section 4.4.1). Although the Conservancy is not obligated to meet any mandatory success criteria as a voluntary project, adhering to guidelines is crucial for proper implementation of the HRMP.

A common measure of habitat restoration project success is the establishment of native plant cover or diversity, including the survivorship of planted material. General plant establishment success criteria should be integrated into project plans, with monitoring methods detailed in Section 5.2.3.

In addition to these criteria, it is essential to consider any supplementary requirements associated with external funding sources, such as state or federal grants, private grants, and mitigation-funded projects. These requirements should be incorporated into the site-specific project success criteria.

4.5 NATIVE PLANT PALETTE DESIGN

This plan advocates for seed-based restoration of vegetation communities as an economical approach to convert sites dominated by nonnative grasses and forbs into native scrub or other suitable vegetation types. Seed-based habitat restoration in upland southern California has been shown to result in greater diversity (McGuire et al. 2022) and cost-effectiveness (Brooks et al. 2019) compared to container plant-based methods. The primary focus is on native seeds, but strategic groupings of outplantings are also included in the top-of-watershed approach to introduce a diverse range of large shrubs and trees that may not establish easily from seed and are underrepresented in the local watershed.

4.5.1 Ecological Succession Model

Ecological succession refers to the gradual change in species composition and structure within an ecological community over time. Chaparral and Coastal Sage Scrub (CSS) vegetation communities are characterized by fire-adapted traits, enabling them to recover following wildfire events. Understanding the natural recovery process of these communities is crucial for developing effective habitat restoration strategies.

The ecological succession model proposed in this plan focuses on incorporating a diverse range of native plant species in seed mixes, mimicking the natural succession of chaparral and CSS plant communities after disturbances like wildfires. This approach emphasizes seeding over planting to establish restoration sites.

In the initial stages, fast-growing, early germinating native annual species in the seed mix will outcompete nonnative weeds, dominating the restoration areas for the first few years. Subsequently, slower-developing native perennial species will begin to dominate beyond the third year of establishment.

Relying primarily on seeding ensures that native plant species will establish themselves in their preferred microclimate within the restoration area. This will build a seed bank consisting of early successional species and later successional community stages, providing a foundation for self-recovery and resilience in the face of future disturbances. Seeding with early successional native species will also encourage the development of arbuscular mycorrhizal associations between plant roots and fungi, promoting native habitat establishment and inhibiting the growth of nonnative species.

Using a diverse seed mix of native species with varied life-form characteristics, such as annuals and perennials, early and late-season species, and species with varying drought tolerance, is essential for adapting to potential changes brought on by climate change. The plant palettes for restoration areas should be designed to incorporate this diversity, ensuring a robust foundation for the restoration sites to thrive and withstand future environmental challenges. The exception is the development of the low-diversity native crop mix, which has different objectives focused on rebuilding healthy soil that will promote natural recruitment of endemic and rarer island plants over longer time periods.

4.5.2 Wild Seed Collection and Provenance

While researchers are exploring the benefits of sourcing seeds from bioclimatic regions that match future climate scenarios for habitat restoration (e.g., Ramalho et al. 2017, Vitt et al. 2022), the Conservancy will prioritize the wild collection of seeds from Catalina Island itself. Minimizing the import of seed collections from outside appropriate bioclimatic zones is a priority for conservation managers (e.g., Garrambone and Saroa 2020). This approach maintains local genetic integrity and ensures the use of plants adapted to the island's unique conditions, which is crucial given the Channel Islands' relative climatic stability and high rate of endemism.

During wild seed collection, best practices will be followed, such as collecting at the appropriate time for each species, limiting collection to a maximum of 5 to 10% of individual plants' seed production, and collecting from no more than 5 to 10% of individuals in a population. To ensure genetic diversity, seeds will be collected from a variety of plants within each population. The genetic integrity of plant populations will be preserved by bulk-producing seeds for restoration efforts from Santa Catalina Island populations, and potentially other Channel Islands populations if necessary. This approach will protect the unique genetics of Catalina Island populations and prevent the introduction of mainland genetics that could outcompete or overshadow the native genetics. Seeds will be produced and processed at the island's seed farm and processing facility to maintain control over the genetic material.

4.5.3 Seed Bulk In-Place for Rare Plant Populations

Managing competing weeds in areas with known or expected rare plant populations can reduce competition, allowing the desired rare plants to germinate more frequently, grow larger, and allocate more resources to flowering and producing viable seeds. This "seed bulk in-place" approach replenishes the native seed bank and is more cost-effective than nursery seed bulking programs, which involve wild seed collection, plant cultivation in a nursery, and the reintroduction of first-generation seeds (F1) back into the wild population.

4.5.4 Native Plant Production Decision Analysis

A major hurdle for large-scale habitat restoration is the consistent production of native seeds. Seed sources include commercial wildland seed collection, commercially grown seed operations, and landowner/manager seed collection and growing operations. While volunteer-based seed collection efforts are generally not suitable for large-scale projects, skilled and experienced volunteers can contribute by focusing on a limited set of easily identifiable and accessible species under proper guidance and oversight.

While most seed for restoration projects can be collected from Catalina Island, supply can vary by species and by year. For some species the existing stands that are on accessible for seed collection cannot be relied upon as a seed source because they are too small to provide the amount of viable seed required. Additionally, the viability of seed can be influenced by annual rainfall amounts, which can result in collections with low germination rates during periods of drought.

To enhance the availability of wildland collected seeds for restoration projects, seeds can be collected and stored over multiple years for later use, such as after multi-year weed management efforts. Additionally, establishing a regional native seed bank through coordination between seed suppliers and land managers can increase the number and amount of seed species available for native revegetation projects. Collaboration among land managers from other Channel Islands can help address the challenge of increasing native seed suppliers, reducing the cost of seed-based habitat restoration projects.

Since it is not practical to supply all required species quantities from wildland collections, bulked seeds produced using traditional farming methods can be an alternative source. The Conservancy plans to develop a seed farm on the island to bulk seeds that are challenging to collect from the wild. If necessary, the Conservancy may consider sourcing seeds from mainland collections or mainland-produced container plants, employing biosecurity measures to prevent the introduction of invasive species or hybridized plants. Although third-party mainland seed collection, seed bulking, or nursery-grown container plants may be more cost-effective and feasible due to the Conservancy's staffing limitations and space constraints at Middle Ranch, appropriate biosecurity measures will be crucial. A native plant production decision tree has been developed to assist the Conservancy in assessing plant production opportunities (Figure 4-2).

4.5.5 High-Diversity Native Habitat Restoration Seed Mix Design

A well-designed seed mix is essential to the establishment of a diverse and sustainable native vegetation community. Seed species should be selected to include the appropriate level of diversity for the target vegetation community and based on the site conditions (e.g., soil type, hydrology, slope, aspect, landscape position). Seed mixes can also be augmented with additional species that are typical of the vegetation communities predicted to be suitable in the future (e.g., Riordan et al. 2018), which will help facilitate potential future shifts in plant assembly.

The composition of seed mixes for habitat restoration projects may need to be adjusted based on several factors:

1. Seed availability: The types and quantities of seeds available for the restoration project may vary, requiring alterations to the initial seed mix design.
2. Weed management response: Multiple years of weed management efforts and their impact on the restoration site can influence the choice of seeds in the mix. Adjustments may be necessary to address persistent weed issues or to accommodate successful weed suppression.
3. Natural recruitment: The emergence of new plants from the soil seed bank or surrounding native propagule sources during the weed management phase may change the desired diversity, functional groups, or specific species in the final seed mix.

These factors should be considered during the project's design phase and throughout the site preparation and weed management stages. By regularly re-evaluating and fine-tuning the seed mix, the project can better address site-specific needs, ensuring adequate cover and diversity. This adaptive approach allows for optimal restoration outcomes by accounting for real-time changes and challenges at the restoration site.

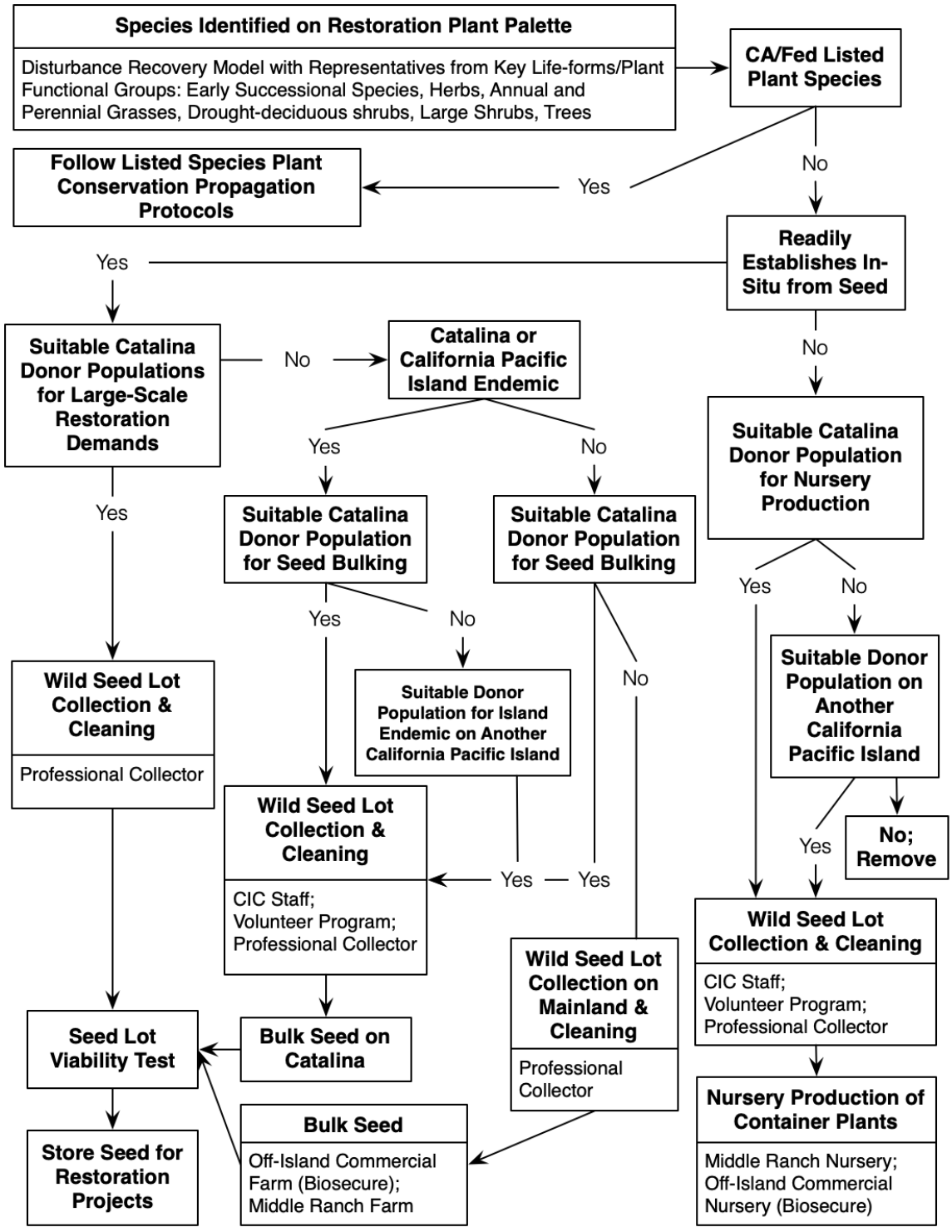


Figure 4-2 Catalina Island Native Plant Material Decision Analysis

Decision tree to determine the most appropriate source of native plant material for restoration projects on Catalina Island.

In addition to the factors previously mentioned, seed viability testing results should also be considered when adjusting seeding rates for habitat restoration projects. Seed viability refers to the percentage of seeds that are capable of germinating and developing into healthy plants under favorable conditions. Knowing the viability of the seeds in the mix is crucial for determining appropriate seeding rates.

If seed viability testing reveals lower-than-expected viability rates, it may be necessary to increase seeding rates to compensate for the reduced potential for germination and establishment. Conversely, if viability rates are high, seeding rates can be adjusted downward to avoid overcrowding or unnecessary resource expenditure. By incorporating seed viability testing results into the decision-making process, restoration project managers can optimize seeding rates to achieve desired plant cover, diversity, and overall restoration goals while considering the specific conditions and challenges of the restoration site.

Refer to Appendix F for detailed guidance on developing a site-specific seed mix, including information on plant functional groups, species selection, and seeding rates.

4.5.6 Low-Diversity Native Cover Crop Seed Mix

A low-diversity native cover crop offers several benefits for reclaiming soils that have lost their topsoil due to past land use practices. The native cover crop plants, such as coyote brush (*Baccharis pilularis*), California sagebrush (*Artemisia californica*), island buckwheat (*Eriogonum grande* var. *grande*), coast goldenbush (*Isocoma menziesii*), and clustered tarplant (*Deinandra fasciculata*), are fast-growing and have seeds that can be easily collected on the island and/or bulked. The primary goal of a native cover crop is to establish native perennial vegetation that contributes to soil health, reduces erosion, and fosters the conditions necessary for the long-term recruitment of diverse native island vegetation communities through natural processes.

1. Soil health: Native cover crops help rebuild healthy soils by improving soil structure, increasing organic matter content, and promoting nutrient cycling. These plants help restore the soil's natural fertility and create a favorable environment for other native plant species to establish and thrive.
2. Erosion control: The roots of native cover crops help bind the soil together, reducing the risk of erosion. Additionally, these plants intercept rainfall, slowing down water runoff and allowing more water to infiltrate the soil, further reducing erosion and promoting water retention.
3. Facilitating natural recruitment: Establishing a native cover crop creates a more hospitable environment for the germination and growth of other native plant species. As the cover crop plants grow and reproduce, they contribute to the local seed bank, increasing the likelihood of natural recruitment and the gradual development of a more diverse native vegetation community over time.

Overall, a low-diversity native cover crop serves as a catalyst for ecosystem restoration, providing essential services that help to repair degraded soils and promote the long-term recovery of diverse native plant communities.

Cover crops could be one to three shrub species depending on seed availability and likelihood of successful establishment based on site conditions, and the inclusion of an early germinating native cover crop (e.g., *Plantago erecta*). In general, all the shrub cover crop should total about 10 to 25 pure live seed (PLS) per squarefoot, and the early germinating species should total be between 50 to 75 PLS per squarefoot. See Appendix F for guidelines on how to calculate bulk seeding rates for seed mixes.

4.6 INITIAL DETHATCH

Dethatching, the initial stage of weed management, should be implemented in the fall before the first significant rainfall, if necessary. Not all sites have enough nonnative litter accumulation to require an initial dethatching event. Generally, if residual dry matter (RDM) is about less than 800 lbs per acre, then dethatching is not necessary to promote weed growth. Areas with high biomass accumulation from nonnative vegetation and little to no bare ground should be dethatched before beginning the weed management phase, if feasible.

Thatch removal exposes bare ground and optimizes weed germination from the seed bank for grow-and-kill treatments. Select the most appropriate and feasible method from the several dethatching options described below. For larger restoration sites, mechanical equipment such as mowing and windrowing is recommended for thatch removal, while hand or line trimmer dethatching is suggested for smaller sites, as needed. See Appendix F for details on methods.

Schedule the initial site clearing activity outside of the bird breeding season for all sensitive species present at the site, if possible. Follow all applicable resource protection measures, including biological monitoring during the bird breeding season, as outlined in Section 5.1.

4.7 EROSION CONTROL MEASURES

Erosion control measures are essential for restoring degraded areas affected by invasive ungulates and intense ranching practices. These measures help to stabilize slopes, trap soil, and promote the growth of healthy soil to support island vegetation. Some effective erosion control measures include:

1. Straw wattles: Biodegradable natural wattles made of straw or coir rolls, with non-plastic, biodegradable netting, help interrupt and slow down water flow on steep slopes, capturing sediment and preventing erosion of bare soil surfaces.
2. Fiber mats: Made from 100% natural biodegradable fiber, these mats provide erosion control on bare steep slopes, preventing topsoil and sediment movement until vegetation can establish for slope stabilization. They can be

used in combination with other erosion control measures, like straw wattles, and should have an open area percentage of at least 50% to allow for seeding.

3. Silt fences: Temporary permeable fabric fences that intercept and slow down sheet flow runoff, capturing sediment and preventing erosion around the perimeter of a project, below exposed and erodible soils, along streams, or around temporary spoil or stockpiles.
4. Check dams: Temporary erosion control tools used in smaller drainages or deep erosion gullies to reduce debris flow, scour, and erosion. They slow down water flow in channels or gullies and prevent undercutting when installed correctly.
5. Hydromulch with soil stabilizers: Effective for protecting bare erodible slopes, including steep slopes between 25% to 50%, by reducing raindrop impact, sheet flow, and providing favorable conditions for seed germination and establishment.

Details on the methods and implementation of these erosion control measures can be found in Appendix F. By employing these measures, restoration efforts can effectively address erosion issues and foster the recovery of native vegetation in degraded areas.

4.8 ADAPTIVE WEED MANAGEMENT

Holistic weed management and high-priority invasive plant control are distinct approaches with different goals and methodologies. Holistic weed management focuses on depleting the nonnative soil seed bank through consistent and timely treatments over multiple years, often in non-irrigated grow-and-kill programs. This approach is typically part of a site-specific habitat restoration project, where the long-term success depends on a combination of natural recruitment from the extant native soil seed bank, propagules from nearby native vegetation, and the intentional introduction of native material through seeding and planting.

In contrast, the Catalina Invasive Plant Program (CIPP) is an early detection monitoring program aimed at detecting and eradicating new invasive plants, as well as monitoring and containing high-priority invasive plants. CIPP focuses on species that have a significant negative impact on wildlife habitat or ecosystem function, and which are feasible to eradicate. While both approaches involve weed management, CIPP is more targeted and reactive, focusing on specific invasive species, while holistic weed management is a proactive, broader strategy that supports overall habitat restoration efforts for as site-specific project.

4.8.1 WEED MANAGEMENT PRINCIPLES

The Conservancy has a successful track record of controlling high-priority invasive species over the past two decades. However, many nonnative plant species in the degraded areas of the island are not as well-understood, as a significant portion of their population lies dormant in the soil seed bank at any given time. This means that even after a weed crop is controlled in an area for a single season, different weed species can germinate from the soil seed bank in subsequent seasons or years, occupying the same

space. The removal of mule deer may also lead to an increase in some invasive weed populations.

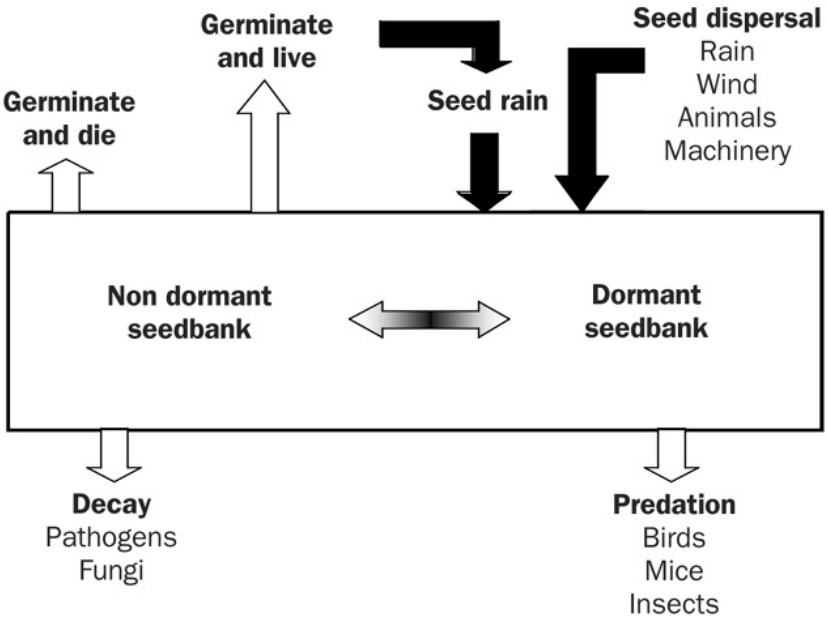
For effective full-community restoration, weed control efforts should focus on the weed soil seed bank rather than solely targeting the visible weeds at a particular point in time. The emergence of these weeds is influenced by annual and variable factors such as temperature, rainfall amount and timing, and competition. Therefore, understanding soil seed banks and their dynamics is a critical first step in implementing a comprehensive weed management strategy for habitat restoration.

SEED BANK DEFINITIONS AND DYNAMICS

The soil seed bank consists of the individual elements in the soil that might develop into a plant. Literally defined it includes seeds, but it also comprises rhizomes, tubers, stolons, and other vegetative structures produced by perennial weeds that might grow into new plants. The seed "bank" is an apt metaphor because its contents are a balance of "deposits" and "withdrawals" that result in a dynamic accumulation or depletion of plant propagules (Menalled and Schonbeck 2011) (see Figure 4-3).

Weed seed bank deposits include annual weed seed "rain" from reproductively mature weeds that are within or adjacent to a site. In some instances, seed rain can come from a distance, but it is most highly influenced by local plants. Seeds can be brought in by human action, such as hikers, vehicles, or equipment or by intentional or unintentional transport through other means. Seeds can also be brought to a site by wind, animals, or hydrologic movement. Viable seed that is still retained by dead plant matter in the surface thatch can also contribute to the seed bank.

Withdrawals from the soil seed bank take several forms as well (Liebman et al. 2001, Davis et al. 2005). First, seeds can germinate and grow to mature plants that themselves set seed. Alternatively, seeds may be lost through fatal germination, where a seed or propagule sprouts, but does not reach the soil surface because it is at an excessive depth or by exposure to allelochemicals (natural phytotoxic substances released by plants), microbial pathogens, insects, burrowing animals, or other organisms in the soil. Seeds can also be consumed before germinating by a range of organisms, including, but not limited to, ground beetles, crickets, earthworms, slugs, field mice and birds. Finally, seeds can lose viability or decay over time.



Source: Menalled and Schonbeck 2011

Figure 4-3 Conceptual Model of Deposits to and Withdrawals from a Soil Seed Bank

REDUCING THE WEED SOIL SEED BANK

Effective weed seed bank management at restoration sites involves several strategies to minimize the overall quantity of viable weed seeds within the soil and surface weed thatch. These strategies can be broadly categorized into two approaches: reducing seed inputs and decreasing germination.

1. Reducing seed inputs: Control methods can be employed to minimize seed production from weed species. These methods include:
    a. Chemical control: Applying herbicides after germination but before seed production can help control weed populations.
    b. Mechanical control: Hand weeding, mowing, and line trimming can be used to remove weeds before they produce seeds.
2. Decreasing germination: By limiting the exposure of seeds to conditions that stimulate growth, the weed seed bank can be reduced over time through decomposition and seed predation. Key factors influencing seed germination are light and temperature. To decrease germination:
    a. Minimize soil disturbance: Avoiding soil disturbance during weed management helps prevent seeds from being exposed to light and temperature conditions that promote growth. This approach is especially effective for seeds located at depths where germination is less likely.
    b. Consider vertical seed distribution: The effectiveness of minimizing soil disturbance depends on the vertical distribution of seeds in the soil. In

some cases, a significant percentage of seeds may be found at depths that do not lead to germination when the soil is undisturbed.

Each weed control method has pros and cons, considering the timing of application, equipment and trained staff availability, and site access limitations. Control nonnative seedlings and flowering plants before they produce viable weed seeds to minimize contributions to the weed seed bank. Minimize soil disruption to prevent new weed germination, injury to native species, and disturbance to biological soil crusts. However, limited soil disturbance, such as from mowing equipment, can be beneficial during the site preparation phase in areas with no biological crusts and low native cover to promote weed seed germination and enhance weed control efficiency.

Generally use only post-emergent herbicides, avoiding pre-emergent herbicides that hinder native seedling development. Adjust herbicide application rates based on the target weed species. Refer to Appendix F for sample specifications of weed management control methods.

In areas with significant native cover or sensitive species, trained crews should perform careful weeding to avoid damage to native species. Adaptive management, including regular monitoring by the project biologist or restoration specialist, is crucial for guiding the scheduling and selection of control methods.

By combining these strategies, restoration efforts can more effectively manage weed seed banks, promoting the growth and establishment of native plant communities while reducing the impact of invasive species.

See Appendix F for details on mechanical and chemical weed management methods.

GROW-AND-KILL WEED MANAGEMENT WITH NATURAL RAINFALL

The "grow-and-kill" weed control method, driven by natural rainfall, is a cost-effective approach for managing weed seed banks at many sites. This method involves treating seedlings and new growth before seed production to deplete the existing seed bank and prevent new weed seeds from entering it.

Typically, three or more years of rainfall-driven grow-and-kill weed management are needed to sufficiently control and deplete the seed bank, allowing for the successful recruitment and establishment of native plants from restoration seed mixes. The number of treatments per year depends on annual precipitation rates, germination cues, and the extent of the weed seed bank.

In drought years with low weed loads, fewer treatments per year may be required. In this case, reserve weed management budgets for future treatments such as may be necessary in wetter years. Conversely, higher rainfall years with greater weed productivity may require additional treatments per season in that year (e.g., late spring or summer).

Irrigation can be used to accelerate the process by stimulating weed germination, potentially reducing the time needed to treat the site. However, irrigation is a significant investment and may not be cost-effective or feasible at the landscape scale, especially

on Catalina Island. In cases with low weed loads due to limited disturbance history, successful restoration may be possible with just one year of irrigated grow-and-kill treatments.

Effective weed seed bank management may take several years, depending on the weed seed population size and the number of grow-and-kill events driven by rainfall and weather conditions. Relying on natural rainfall-driven grow-and-kill treatments is generally more cost-effective and feasible for managing large areas. However, this approach is subject to unpredictable weather patterns, which may impact the timing and effectiveness of treatments.

Germination of certain weed species depends on various cues, such as temperature and light, in addition to rainfall. If these conditions are not met, target weed species may remain dormant in the soil seed bank and emerge in later years when conditions are favorable. This unpredictability necessitates an adaptive weed management approach that allows for flexibility in the timing and intensity of grow-and-kill events.

Adaptive weed management is also crucial because it is challenging and impractical to accurately quantify the size and extent of the weed seed bank during the planning phase. Instead, the required weed management effort can only be estimated based on field observations and experience with similar habitat restoration projects.

In situations where it is essential to minimize the time required for habitat restoration, supplemental irrigation can be employed to accelerate weed seed bank management. Irrigation can facilitate more grow-and-kill events than natural rainfall alone, potentially shortening the restoration timeline. For instance, a site requiring eight grow-and-kill cycles before seed addition could complete the process in two to three years with supplemental irrigation, instead of four to five years with natural rainfall alone.

However, using a temporary irrigation system for habitat restoration projects must be both feasible (e.g., accessible water source) and justified by the need, given the significant costs associated with water purchase, installation, and maintenance of the system. Additionally, labor costs increase due to the need for constant monitoring and maintenance of the irrigation system during operation to prevent leaks or damage that could harm the restoration area or adjacent areas.

WEED MANAGEMENT METHOD IS A FUNCTION OF SITE AND YEAR

The choice of suitable weed management techniques largely depends on site-specific factors, such as land manager preferences, applicable regulations (e.g., herbicide restrictions), available resources (labor, equipment, funding), and site conditions like land use history, fire history, topography, and hydrography. Additionally, year-specific factors, such as weather patterns, can influence weed density and composition, affecting the feasibility and effectiveness of weed control efforts.

TIMING OF TREATMENTS IS CRITICAL

The success of mechanical or chemical weed control efforts heavily relies on precise timing. Delaying control by even a week can result in viable seeds being dispersed

instead of halting seed development. Timing varies between warm, dry microclimates and cool, moist microclimates, with earlier intervention needed in the former. The active nonnative species in the seed bank during a given year or season will influence the timing of treatments, which may vary across a management area.

Generally, at least two to three treatments per growing season are required, targeting:

- Nonnative annual grasses following winter rains
- Spring-growing broadleaf weeds
- Summer-growing broadleaf weeds

CONSISTENT AND THOROUGH WEED TREATMENT IS KEY

Manage weeds as consistently and thoroughly as possible between years during the weed management step. Gaps in treatments within and between years can significantly lengthen the time to reach weed management objectives and thresholds prior to seeding.

ADJUST METHODS AND TIMING YEARLY, AS NEEDED

Adjust weed control methods and timing each year, as needed, based on weed phenology and weather conditions. For example, a rotary mower may be used to cut nonnative annual grasses initially, but may be replaced later by a flail mower, which can cut closer to the ground, as nonnative grasses decrease in stature and abundance in response to weed management efforts. Over time, as the weed seed bank is depleted and weed cover decreases during the growing season, the increased amount of bare ground results in higher rates of evaporative loss of soil moisture. Many annual grasses respond to the increased water stress by growing shorter stems and flowering earlier in the season and thus, may require subsequent adjustments in weed management methods and timing.

TAILOR WEEDING METHOD TO FOCAL WEEDS

In some cases, it may be necessary to tailor the treatment method to the focal weed species because of growth habit. For example, controlling purple false brome (*Brachypodium distachyon*) can be difficult because it can have a low or prostrate stature when flowering making it impossible to cut the flowering parts with a rotary mower. In this case, flail mowing is an effective option as it allows cutting closer to the ground (except on rocky sites). In winter, post-emergent grass-specific herbicide is the preferred treatment for purple false brome.

LEAVE CUT MATERIAL ONSITE

Generally, leave mowed or line-trimmed material in place to decompose, unless a significant amount of nonnative biomass accumulates and hinders the germination of the native seed bank. Leaving cut weed material (without viable seed) on-site reduces or eliminates disposal costs and provides wildlife habitat. The material will decompose over time, but it is essential to continue weed treatments to prevent substantial thatch buildup.

Place cut weed material with viable seed in mulch piles outside sensitive areas. Treat any germinating weed seeds in the piles during subsequent seasons with herbicide or cut flowers before seed set. The cost of controlling germination from mulch piles is usually minimal. Alternatively, cut material with viable seed can be disposed of offsite if preferred.

An exception to leaving cut biomass in place is when using an herbicide that retains the active ingredient in the dead plant material (e.g., clopyralid). In such cases, collect and mulch the biomass in a buffer area or remove and properly dispose of the material off-site.

MECHANIZED METHODS ARE MORE COST-EFFECTIVE THAN HAND METHODS

Mechanized weed control methods are cost-effective, efficient, and as effective as hand weed control methods, particularly in larger restoration sites with less native cover:

- Mowing is more cost-effective than line trimming.
- Truck-mounted herbicide spray system applications are more economical than backpack sprayer applications.

Line trimming can effectively replace tractor mowing for smaller restoration sites (e.g., <1-2 acres) or sites inaccessible to mechanized equipment. However, line trimming is more expensive due to increased labor time.

Restoration crews should use line trimmers or backpack sprayers instead of mechanized methods and larger equipment when working around dense native plants or in smaller project areas.

FIELD MONITORING IS KEY TO TIMING AND SELECTION OF WEED CONTROL TREATMENTS

Effective weed management requires decision-making based on field observations of weed phenology, typically obtained through visual estimates during walkover field assessments. Relevé samples, designed to cover uniform vegetation types and capture weed species diversity, are suitable for estimating nonnative weed cover and flowering status without being overly time-consuming or technical. For a sample methodology, refer to the CDFW-CNPS "Protocol for the Combined Vegetation Rapid Assessment and Relevé Field Form."

Surveys for weed management purposes can focus on recording the cover of target weed species or plant functional groups into relevant cover classes. Considerable field knowledge of target weed species is essential for proper timing of weed control

interventions, such as mowing or chemical treatments. For instance, mowing should be performed after nonnative annual grasses begin to flower but before seeds reach the "milk stage" to prevent regrowth and maximize seed viability reduction. Similarly, chemical control is most effective when applied before the milk stage of grass seed development.

CONSIDER PHASING LARGE PROJECTS

For large restoration areas, consider phased implementation of the weed management program to (1) ensure consistent, well-timed, and thorough treatment with available resources, and (2) retain some local wildlife habitat during project implementation (e.g., raptor hunting grounds within existing nonnative annual grasslands). “Stuck” sites may be prioritized for more intensive management in the future, if warranted.

ALLOW FOR “STUCK” SITES IN RESTORATION AREA

Allow for inclusions of weedy/nonnative “stuck” sites (smaller problematic areas within a larger habitat restoration project) that are not cost-efficient to restore but may have some wildlife habitat value.

Part of successful habitat restoration projects is planning for potential failure. Consideration should be given to allowing “stuck” sites to remain as isolated nonnative dominated vegetation communities. Assuming that the larger project area has been adequately managed and best practices applied to planning and implementation of the habitat restoration project—as evidenced by successful achievement of habitat restoration goals and performance criteria for the rest of the project area—relatively small areas that are resistant to habitat restoration efforts may be best left alone. However, it is advised to treat and eradicate highly invasive plant species that could readily invade the restoration area.

4.8.2 WEED MANAGEMENT GUIDELINES TO AVOID NATIVE VEGETATION

AVOIDANCE AND MINIMIZATION OF IMPACTS TO WOODY NATIVES

Woody native shrubs shall be identified by the crew and avoided when using mechanical approaches, mowing and line trimming. Crews will be trained to identify sensitive and rare plants to be avoided.

AVOIDANCE AND MINIMIZATION OF IMPACTS TO NATIVE HERBS

Mowing and line trimming shall be timed to the phenology of the flowering of invasive annual grasses and forbs, which typically germinate and flower earlier than the native herbaceous vegetation due to the adaptive traits that reinforce their invasive nature in disturbed areas.

No application of broad-spectrum herbicides except in areas that have been surveyed and don’t have any sensitive, rare, or protected species.

AVOIDANCE AND MINIMIZATION OF IMPACTS TO NATIVE PERENNIAL BUNCHGRASSES

Grass-specific herbicides may be used in areas with significant infestations of nonnative annual grasses, applied before flowering to avoid seed set. Areas with known or suspected populations of native annual grasses shall be avoided. Native perennial bunchgrasses (e.g., *Stipa pulchra* and *Stipa lepida*), which are common on the island, are tolerant to applications of grass-specific herbicide when they are applied early in winter while they are still primarily senescent. Therefore, areas with large infestations of nonnative annual grasses shall be treated in early winter while the native needlegrasses haven't begun to put out significant amounts of new tillers, thereby avoiding long-term damage to the native perennial *Stipa* grasses.

4.9 SEEDING THRESHOLD ASSESSMENT

Guidelines for determining when a restoration site is ready for seeding after weed management (Brooks et al. 2019):

1. After three to five or more years of weed management, including at least two average to above-average rainfall years, assess the site's readiness for seeding.
2. Evaluate the extent of natural recruitment and determine if seeding is necessary.
3. If seeding is required to achieve project goals, ensure that absolute weed cover is around 10% or less in the spring of an average to above-average rainfall year before seeding in the following fall. Weed management can be concluded once this threshold is met.
4. High priority invasive species should generally be controlled to less than 5% cover prior to seeding or planting, depending on what is feasible, the habitat restoration goals of the project, and the resource management priorities.

The weed seed bank management timeline is important to consider, as it involves a significant "site preparation phase" before introducing native materials. This approach is analogous to preparing weathered wood siding for painting, where most of the work involves scraping, repairing, and sanding before applying paint. Similarly, successful landscape-scale revegetation programs demand a long-term commitment to weed management (typically 3+ years) to achieve optimal outcomes from subsequent seeding and planting efforts.

A one- or two-year weed management effort may not yield sustainable benefits due to the following reasons:

1. Short-term efforts may manage nonnative annual grass populations and associated thatch, but other weed seed bank components, such as broadleaf weeds, may become dominant, requiring further management.
2. Weed seeds, including Mediterranean annual grasses, have longer soil seed bank viability than often reported. Some seeds have thicker seed coats requiring more scarification to germinate, while others remain viable due to low decomposition rates during periods of low rainfall.

3. Shorter control periods are less likely to coincide with weather conditions that stimulate germination of a significant portion of the seed bank.

However, a shorter timeline may be appropriate if the primary goal of weed management is to reduce thatch and litter cover to stimulate germination of sensitive annual native plant species or if a viable native seed bank is already present. In these cases, a one- to two-year effort can be sufficient, and project success can be measured by observing the germination rate, seed production, and overall native species establishment and cover.

In some cases, such as revegetation of newly exposed virgin soil, there may be little to no weed seed bank present, eliminating the need for pre-seeding weed management or requiring only one or two weeding events. However, proper weed management before seeding or planting generally reduces the total project cost by minimizing the need for more labor-intensive and difficult weeding efforts after seeding or planting.

When there is a significant native seed bank that emerges alongside weed management efforts, the weeding process becomes more time-consuming and labor-intensive, particularly when hand methods are required to protect the native plants. This may increase costs but could be partially offset by reducing the amount of native plant material needed for the site. The seed mix can be adjusted by lowering species diversity or seeding rates as needed.

4.10 Seed Installation Methods

Native plant material will be primarily introduced to the habitat restoration area by seed after achieving seeding thresholds. Successful restoration depends largely on proper site preparation during the weed management step. It is crucial to adequately control nonnative species before installation. Weed management should continue until the weed management threshold is reached, rather than installing plant material prematurely.

Various methods can be employed for seed installation, including drill seeding, imprint seeding, broadcast seeding, hydroseeding, and the seed ball technique. The choice of seeding method will depend on site conditions and accessibility. Larger sites accessible by equipment can be efficiently seeded mechanically using a drill seeder, imprint seeder, hydroseeder, or broadcast seeder. Smaller sites, sites with a high density of native species, or sites with unavoidable sensitive species populations can be seeded (preferably during the fall season) by hand broadcast or the seed ball technique.

Hydroseeding is an effective method for seed application on very steep slopes (≥1.5:1), as the mulch provides an erosion control blanket when using materials like Flexterra® FGM™.

Seed installation should occur in the fall before the onset of significant rainfall that might limit access to the restoration site, but before the end of January at the latest. See Appendix F for details on seed installation methods.

4.11 NURSERY GROWN CONTAINER PLANTS

Cuttings and container plants play three crucial roles in habitat restoration:

1. Introducing plants past the vulnerable seedling stage to establish onsite more effectively.
2. Facilitating the introduction of species that do not establish well from seed.
3. Providing diverse plant age groups to encourage natural regeneration earlier in the restoration process.

These plants include plants grown from spores, divisions, cactus stems and pads, and various trees from larger seed (cherry pits, acorns, etc.). These container plants will be grown to plugs or various sized containers (e.g., one-gallon size, deep pot) for that best suit the plants for outplanting. These container plants will supply the stock material to be farmed at Middle Ranch for bulking or to be outplanted on the landscape for restoration.

Container plants will be strategically used in small nodes in the Top-of-Watershed Habitat Restoration Approach.

See Appendix F for details on planting layout, cuttings, acorns, and general nursery production guidelines.

4.11.1 BIOSECURITY FOR PLANT PRODUCTION AND TRANSPORT

The Conservancy will review and implement restoration design considerations and best management practices (BMPs) to help prevent pathogen contamination, as published by the "Working Group for Phytophthoras in Native Habitats" (www.calphytos.org), when there is a risk of introduction and spread of plant pathogens in site plantings.

The Conservancy will review and implement decontamination protocols to prevent the spread of pathogens among amphibians or other aquatic animals when working in aquatic habitats that may support native amphibians. Gear and equipment that may contact water will be cleaned and decontaminated to prevent the spread of chytrid fungus, following protocols in Aquatic Invasive Species Disinfection/Decontamination Protocols (CDFW 2016, or latest version).

4.11.2 NODES OF NURSERY GROWN CONTAINER PLANTS

Strategically planting nodes or small clusters of container plants containing key shrub and tree species that are underrepresented in the watershed and do not establish readily from seed can significantly enhance restoration outcomes. This approach offers several benefits:

1. Improved establishment: Container plants have a higher likelihood of successful establishment compared to direct seeding, especially for species that struggle to grow from seed.

2. Enhanced diversity: Targeted planting of underrepresented species promotes biodiversity and helps restore the natural balance of the ecosystem.
3. Efficient irrigation: Grouping plants in small clusters allows for efficient watering using a water truck or gravity-fed reservoir, reducing the time and resources required for irrigation.

To maximize these benefits, consider the following design principles:

- Spacing: Plant container plants at intervals that allow for the full mature development of each species. This ensures adequate space for growth and prevents overcrowding.
- Clustering: Arrange plants in small clusters to facilitate efficient irrigation, taking into account the road accessibility and water source.
- Manual irrigation: Employ a manually operated water system to prevent uncontrolled water flow, blowouts, and erosion from potential irrigation breaks.
- Regular monitoring: Check plants regularly until they are well-established to ensure their health and success.

By implementing these strategies, the restoration project can effectively introduce underrepresented species, promote biodiversity, and ensure the efficient use of resources for long-term success. The irrigated planting basins will require frequent hand weeding, which can coincide with irrigation events, to maximize the efficiency of each trip to the restoration site. See Appendix F for guidelines on the design of a temporary irrigation system (e.g., bubbler system).

4.12 RESTORATION SITE MAINTENANCE

A key goal of a restoration plan is to create self-sustaining, long-term native habitats. Initial maintenance is necessary for establishment, but ongoing management may be required for various reasons, including:

- Higher weed loads in some areas requiring post-seeding weed maintenance
- Containing or eradicating high-priority invasive plant species
- Supplemental irrigation for installed container plants or cuttings
- Remedial seeding in areas with germination failure after adequate rainfall
- Replacing container plantings or cuttings with less than 80% survival in the first two years
- Installing erosion control measures following significant erosion
- Conservation activities for sensitive species
- Pest and disease control (no rodenticides)
- Removing trash, debris, and litter (excluding illegal dumping and public littering)

Remedial weeding needs will depend on weather, habitat development, and weed density. The maintenance period can last up to five years, with intense maintenance in the first two years and spot-weeding as needed in years three to five. Weed control should minimize disturbance and be scheduled by the project restoration ecologist/biologist.

Adequate weed management prior to seeding can significantly reduce remedial weeding efforts. It is crucial to add native plant material only after achieving sufficient weed management. See Appendix F for details on post-seeding restoration site maintenance, including remedial seeding, container plant replacement, erosion control, pest control, and trash removal guidelines.

4.12.1 WEED MANAGEMENT

After seed and plant installation, the primary weed management method should be hand weeding.

Under the guidance of the project restoration ecologist/biologist, targeted spot spray application of herbicide for high-priority invasive species or perennial weeds, or line trimming of dense weed stands may be permitted. The restoration ecologist/biologist must evaluate the cost-benefit of weed control effectiveness versus potential damage to native plants. Only post-emergent herbicides should be applied, following the methods and recommendations outlined in the restoration plan and adhering to the Conservancy's herbicide use policies. See Appendix F for more details on post-seeding weed management.

5 BIOLOGICAL MONITORING AND RESOURCE PROTECTION

Appendix G provides the Regulatory Setting for the Project (i.e., the federal and state resource regulations potentially applicable to the proposed actions). Consistent with the applicable regulations, and the overall goal of minimizing harm to natural resources during restoration actions, the following General Protection Measures will be incorporated, as applicable, into project descriptions for individual restoration projects. Not all these measures may be appropriate or necessary to avoid and minimize impacts, depending on the scope, scale, and location of a project.

5.1 RESOURCE PROTECTION MEASURES

This section identifies resource protection measures to minimize potential adverse effects upon (a) listed or otherwise "special status" plant or wildlife species, and/or (b) nesting birds potentially present in or near the restoration sites.

Copies of Site-Specific Project Description and all required permits and supporting documents shall be always readily available at work sites (electronic copies are sufficient) during periods of active work and must be presented to any CDFW personnel, or personnel from another agency upon demand.

5.1.1 ENVIRONMENTAL AWARENESS TRAINING/ISLAND FOX PROTECTION

Prior to engaging existing or new personnel in restoration activities, new restoration personnel will participate in environmental awareness training conducted by a Biological Monitor. Personnel will be informed regarding the identification, habitat requirements, legal protections, avoidance and minimization measures, and applicable protection measures for special-status species and nesting birds with potential to occur in or immediately adjacent to the project site. Personnel will be informed of the procedures to follow should a special-status species or nesting bird be encountered during project activities. Training may be provided in an online/virtual meeting. For projects that may continue over an extended duration and require excessive training events, a training video developed under the supervision of the Biological Monitor may be used to train new personnel, if a Biological Monitor is available by phone to answer questions about the training or to answer questions that may arise during project activities.

Given the ubiquity of the state- and federally listed Catalina Island Fox (*Urocyon littoralis catalinae*) across the island, and the vulnerability of this unusually confiding species to various forms of take, the following points must be included in the training and enforced in the field:

- To avoid impacts to Catalina Island fox pupping season. Any activity that involves heavy equipment will not occur between March and April. If heavy equipment work must take place during March-April, a qualified fox biologist will conduct a pre-activity burrow surveys to look for Catalina Island fox burrows and submit the results to CDFW to request permission to work in the area if no burrows are found.

- Do not intentionally (or unintentionally) feed any wildlife, including foxes, deer, birds, and ground squirrels.
    - Foxes have lice, fleas, and ticks which are all transmittable to humans.
    - Foxes, ground squirrels, deer, and ravens have diseases and bite.
    - Feeding foxes causes them to live in higher densities which allows for:
        - Increased fighting between foxes, which can lead to lethal infections.
        - Increased spread of disease between foxes.
        - Foxes learning to cross the road daily to access food sources, increasing road mortality.
    - Foxes living in human environments (e.g., in Avalon, where they are fed) are generally unhealthier and flea-ridden than are foxes elsewhere on the island.
    - Once animals learn to beg they may be unable to unlearn the behavior.
    - Once personnel are permitted to feed animals it is very challenging to convince them to stop.
- Cover buckets and holes and ensure that doors to bathrooms and tents are closed.
    - Island fox and small terrestrial animals are prone to getting caught in small areas and holes, where they may die due to starvation or drowning.
    - Leave no open holes. If a hole cannot be permanently filled before the end of a working day, it must be *completely and securely* covered using tarp, plywood, rocks, etc. Foxes (and other wildlife) may access holes through even a small sliver of an opening, leading to potential mortality.
- Do not leave any open containers that can collect water.
    - Island Foxes drown in open containers every year.
- Use only designated restroom facilities and keep doors closed.
    - In large concentrations, both forms of human excrement can attract wildlife, change the soil chemistry, and kill native plants.
    - Foxes can easily fall into portable toilets if the door is left open.
- If a fox is present at a work area, work must cease until the fox moves out of the way to avoid harassment per the endangered species act.
- Because foxes are skilled at getting inside tents, all personal food and scented items must be secured in airtight plastic totes or Tupperware.
- Ensure doors to tents and buildings are closed during the day so wildlife cannot enter.
- All trash cans and dumpsters shall have functional sealing lids, as animals can be trapped in unsecured trash cans.
- Trash or debris cannot be allowed to accumulate and blow away. Foxes and other wildlife are known to eat plastic, trash, and food scraps.

- If a bat is seen during the daytime, do not touch as this may be a sign of rabies. Immediately inform the Biological Monitor and/or a Catalina Island Conservancy biologist right away.
- Do not touch or interfere with any wildlife found on site. If an animal needs to be relocated, please call the Biological Monitor and/or a Conservancy biologist right away.
- Do not walk off trail outside of the work site.
- If bison are on the runway, call Rangers to move them along. Only authorized personnel are permitted to move the bison, and people failing to interact correctly with bison can be badly injured.

5.1.2 Pre-Project Nesting Bird Survey

Under federal and/or state law, virtually all bird species are protected from disruption of active nesting. If project activities take place during the nesting season (generally February 1 to August 31), and the Biological Monitor determines that potential exists for birds to nest within or adjacent to the work area, the Biological Monitor shall conduct a pre-project nesting bird survey no more than one week prior to the planned start of work. If the active nest of a bird is found, a protective buffer shall be implemented using the methods described in Appendix H (Nesting Bird Management Plan).

5.1.3 Restrictions on the Use of Herbicides

As reviewed in Section 2, ten endemic plant species are known from Catalina Island, along with numerous other taxa given California Rare Plant Ranks by the California Native Plant Society (CNPS) and the State of California. As reviewed in Section 1.5.3, restoration work will generally employ only narrow-leaf herbicides that target grasses. If a situation arises that calls for the use of broad-leaf or pre-emergent herbicides, any such use would be highly targeted and carefully planned to avoid or minimize any potential impacts to endemic/special-status plants.

5.1.4 Restoration Site Protection Measures

Temporary Fencing and Signage

In order identify restoration areas that adjacent to public access along approved trails and roads, a temporary perimeter fencing shall be installed along the public access route (e.g., yellow nylon rope strung on T-posts placed 30 feet on-center). Additionally, signs (e.g., all weather, anti-graffiti red with white lettering) designating the sensitivity of the habitat shall be placed on the yellow rope to discourage unauthorized entry. The temporary fencing and signage shall be removed at the end of the project.

Pre-Work Restoration Crew Briefings

Restoration crews shall receive environmental awareness training, as described in Section 5.1.1. Before a restoration crew works in a new site, the Biological Monitor shall provide the restoration crew a pre-work briefing that discusses the work methodology, permits, plant identification, protected species/resources present, and applicable

avoidance and minimization measures. Resources that can be provided to the restoration crew for field reference include laminated color printouts, or electronic versions (e.g., accessible on a smart phone), of the targeted invasive species, common or sensitive native plant species, and sensitive wildlife species.

BIOLOGICAL MONITORING OF INITIAL WEED DETHATCHING EVENT

At the beginning of most active restoration projects, the accumulated dead nonnative litter (or thatch) will be removed prior to beginning the weed grow-and-kill cycles. This initial detaching event will occur after the end of the bird breeding season and before the start of large winter rainfall events that will limit project access (i.e., between September 1 to approximately October 31). All vegetation removal activities will be monitored by a qualified biological monitor to ensure that no adverse impacts to biological resources occur. Vegetation removal shall not be conducted when rain is forecast (with greater than 50 percent probability to occur) at the work site within 12 hours, or within 24 hours after a rainfall event.

PROJECT ACCESS

No grading or construction of access roads will occur. Access by work crews will follow established paths that will be identified by the Conservancy for restoration crews, thereby avoiding impacts to native vegetation.
Crews will use natural openings in the vegetation or existing trails for access. Native tree and shrub branches with diameters less than two inches may be cut with the approval of the biological monitor if clearance is needed for accessing an area for vegetation removal. Crews will not create new paths into areas with dense riparian habitat or other native vegetation; existing game trails or other access trails will be used while minimizing impacts to native vegetation as much as possible.

MEASURES TO PREVENT SPREAD OF INVASIVE SPECIES

The spread or introduction of nonnative, invasive plant and animal species will be avoided using the following techniques. Vehicles will be pressured washed before arriving at the island. Before vehicles or equipment are loaded on the barge or other shipping vehicle, use a high-pressure washer with secondary containment to prevent spills from traveling to surface water or drains.

STORAGE OF PROJECT MATERIALS AND EQUIPMENT MAINTENANCE

Project managers will establish staging areas for equipment storage and maintenance, construction materials, fuels, lubricants, solvents, and other possible contaminants in coordination with resource agencies. The discharge of any hazardous materials into any receiving waters shall be prohibited.

Staging areas will have a stabilized entrance and exit and will be at least 100 feet from waterbodies, unless site-specific circumstances do not provide such a setback; in such cases, the maximum setback possible will be used. Fluids will be stored in appropriate containers with covers and will be properly recycled or disposed of off-site. Machinery stored on site will have pans or absorbent mats placed underneath potential leak areas.

All herbicide mixing, cleaning and maintenance of equipment, and related work, shall be performed within staging areas along the road and outside of the bed and banks of the river and stream. Drip pans or drip cloths shall be used where necessary, and workers shall always have a fully stocked spill kit on-hand.

MATERIAL DISPOSAL

All refuse, debris, unused materials, and supplies that cannot reasonably be secured will be removed daily from the project work area and deposited at an appropriate disposal or storage site. All construction debris will be removed from the work area immediately on project completion.

FUGITIVE DUST REDUCTION

Stockpiled materials susceptible to wind-blown dispersal will be covered with plastic sheeting or other suitable material to prevent movement of the material.

TRASH REMOVED DAILY

During project activities all trash, especially food-related refuse that may attract potential predators or scavengers, will be properly contained in sealed containers, removed from the work site, and disposed of daily.

PEST CONTROL

Local wildlife such as rabbits, pocket gophers and other rodents are expected to browse on the plantings and seed material. If the Biological Monitor determines that restoration plantings are being significantly jeopardized by wildlife, corrective measures such as organic, non-toxic deterrents and protective fencing/plant cages may be used. Invertebrate pests are rarely a serious problem in seed-based habitat restoration project if site conditions are appropriate to the desired habitats.

5.1.5 CULTURAL RESOURCE PROTECTION

Catalina Island was inhabited by indigenous ocean-going tribes before European colonization. The entire island, especially burial sites and village use areas, hold significant cultural, historical, and spiritual value, even when it is located within developed areas. These lands serve as important connections to the past, providing a tangible link to the traditions, customs, and heritage of indigenous communities. They also play a critical role in preserving biodiversity, as they often contain unique ecosystems that have been shaped by traditional land management practices.

Protecting these lands is essential for maintaining cultural continuity and ensuring that future generations can continue to learn from and be inspired by the wisdom and knowledge of indigenous cultures. Moreover, recognizing and respecting the rights of indigenous peoples to their traditional territories is a fundamental aspect of promoting social justice and equity. By acknowledging and safeguarding the importance of these lands, the Conservancy can help to foster a more inclusive and culturally diverse society, while also contributing to the conservation of biological diversity and the sustainable use of natural resources.

The Conservancy has conducted outreach with representatives of the Gabrieliño-Tongva tribes, including hosting a site visits to Catalina to discuss the Project. This outreach has resulted in the development of an ongoing Gabrieliño-Tongva Community Collaborative Group to continue dialogue between the Conservancy and the indigenous community. Several California and federal regulations help protect archaeological resources on private land, such as land owned by the Conservancy. Some of the key regulations include:

- The National Historic Preservation Act (NHPA) requires federal agencies to consider the effects of their actions on historic properties, including those located on private land (54 U.S.C. § 300101 et seq.).
- The Archaeological Resources Protection Act (ARPA) makes it illegal to disturb, excavate, or remove any archaeological resource located on public or Indian lands without a permit, and imposes penalties for violating these provisions (16 U.S.C. § 470aa et seq.).
- The Native American Graves Protection and Repatriation Act (NAGPRA) applies to both public and private lands, requiring the protection of Indigenous people cultural items and human remains and providing for their repatriation to lineal descendants and culturally affiliated tribes (25 U.S.C. § 3001 et seq.).
- The California Environmental Quality Act (CEQA) requires lead agencies to consider the potential impacts of projects on archaeological resources and to mitigate any significant impacts (Cal. Pub. Res. Code § 21000 et seq.).
- The California Public Resources Code protects archaeological resources on both public and private land by prohibiting the unauthorized disturbance or removal of such resources (Cal. Pub. Res. Code § 5097.98 et seq.).
- The California Native American Heritage Commission (NAHC) protects archaeological and cultural resources on both public and private land by requiring notification of certain activities that may impact such resources (https://nahc.ca.gov/).

Documentation and maps of culturally sensitive areas, including indigenous and archaeological resources, will be consulted by the Conservancy during the planning stages of habitat restoration projects that may disturb the soil surface. Habitat restoration projects with significant soil disturbance will avoid culturally sensitive areas whenever possible. However, if a project with significant ecosystem benefits and/or wildlife conservation value conflicts with cultural resource protection, a Cultural Resource Protection Plan will be prepared. This plan will include:

1. Plan Purpose and Goals: Clearly define the objectives of the plan, including the need for monitoring, protection, and mitigation measures.
2. Project Description: Provide a detailed description of the proposed project, including its scope, location, and timeline.
3. Cultural Resources Assessment: Conduct a thorough assessment of the cultural resources that may be affected by the project, including an inventory of known and potential archaeological sites and traditional cultural places.

4. Monitoring Plan: Develop a plan for monitoring the project's impacts on cultural resources, including the establishment of a monitoring schedule, criteria for monitoring, and procedures for reporting and addressing adverse effects.
5. Protection Measures: Identify and implement measures to protect cultural resources during project implementation, such as temporary fencing, signage, and protective barriers.
6. Mitigation Plan: Develop a plan for mitigating any adverse impacts on cultural resources, including strategies for avoidance, minimization, and data recovery.
7. Consultation: Consult with relevant indigenous tribes, the State Historic Preservation Officer (SHPO), and other stakeholders to ensure that their concerns and input are considered in the development and implementation of the plan.
8. Reporting: Establish procedures for reporting on the implementation of the monitoring, protection, and mitigation measures and for updating the plan as necessary.

5.2 SITE-SPECIFIC RESTORATION PROJECT BIOLOGICAL MONITORING

The Conservancy will provide oversight of the restoration crew, conduct biological monitoring, and prepare annual reports on the status of site-specific restoration projects.

The Conservancy Restoration Specialist will layout project limits and temporary fencing and educational signage (if required) locations for the restoration crew. Prior to initial work during the bird breeding season, a qualified biological monitor will conduct a nesting bird and general biological survey of the areas to be weeded and communicate the location and duration of any buffers to avoid disturbance of sensitive and protected species to the restoration crew.

5.2.1 HORTICULTURAL MONITORING

Timing and consistency of weed treatments is critical to the outcome active habitat restoration projects. While the infestation of California's natural communities by nonnative annual grasses (e.g., bromes, oats) is evident following two centuries of agricultural and ranching practices first introduced by Spanish missionaries (White 1967, Heady 1988), including the introduction of goats to Catalina Island in 1827 (Preston 1997)—the weed seed bank in the soil is diverse, including weedy forbs that become much more abundant as nonnative annual grasses are controlled (White and Holt 2005, Bell et al. 2013, Brooks et al. 2019). As a result, the Restoration Specialist must conduct regular horticultural monitoring to assess the phenology of weed growth to direct the appropriate timing of weed management events, which will change from season-to-season and year-to-year due weather, site, and weed seed germination rates. See Section 4.1.1 for the key principles of wholistic weed management for Catalina Island.

5.2.2 PLANT ESTABLISHMENT MONITORING

After material is planted or seeded, then the Restoration Specialist shall conduct horticultural monitoring to direct the timing of irrigation events, weeding of plant container basins, and remedial weeding events in seeded areas. The health, development, and cover of native vegetative shall be estimated visually by site walk overs, performed regularly during weed management by the Restoration Specialist. The Restoration Specialist will keep track of annual spring survivorship of planted container material.

In general, monitor habitat restoration sites for at least two years after seeding, or after the end of the initial weed management program if seeding is not required, to monitor native seed establishment and evaluate the need for additional weeding (including high priority invasive plant control), remedial seeding, pest management, or any other necessary remedial actions.

RESTORATION PLANTING SURVIVORSHIP AND EMPIRICAL HABITAT SUITABILITY MODELING

The habitat restoration targets for island vegetation communities and restoration plant palettes presented in this HRMP are based in part on the output of species habitat suitability models (Appendix D). While this is a practical approach for modeling species and vegetation communities where there is limited data (Brooks et al. 2019, Dobrowski et al. 2011, Fortini et al. 2013, van der Wal et al. 2012), for instance due to a significant disturbance history and little to no pre-disturbance floristic records, there are inherent inaccuracies in the predictions. One of the assumptions of species distribution models, such as MaxEnt used in the planning of this HRMP, is that species occurrences and the environmental factors that influence its distribution are at equilibrium. However, because of climate change, some of the established long-lived native island plant species may already be experiencing climate stress and may not currently be in their optimal environmental niche.

Therefore, the Conservancy can use annual survivorship data collected in habitat restoration projects that include outplanted nursery grown container plants to develop empirically based species distribution models. An empirical model is a type of statistical model that is based on observed data and is used to describe or predict phenomena in the real world. Empirical models are derived from actual measurements and observations, rather than being based on theoretical assumptions. A recent example of this approach was conducted by Krushelnycky et al. (2023) for Haleakalā silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*) using restoration outplantings in Hawai‘i. These models can be used to validate or falsity the MaxEnt species distribution models developed for this plan (Appendix D) to better inform future habitat restoration work in a changing climate.

This approach to learn about site suitability for restoration plant material can be applied to seeded species. However, because the dynamics that influence seed germination are complex (e.g., site, weather, interspecific competition, facilitation, soil health) and not well understood, it could take many years for some seeded species to emerge, well

beyond the period when a restoration project is being actively managed and monitored. Therefore, evaluations of the suitability of site characteristics for seeded species should be assessed as part of long-term monitoring efforts, at least 5 to 10 years after the end of active project management.

5.2.3 PROJECT SUCCESS MONITORING

Each site-specific restoration project will develop success criteria to measure whether the project has achieved the core habitat restoration objectives. Typically, these are based on vegetation characteristics, such as cover and diversity. Wildlife and soil health measures may also be monitored depending on the goals and objectives of the site-specific restoration project. Guidelines for annual restoration project success monitoring are provided below.

Seed mix establishment and nursery grown container plant survivorship guidelines are provided in Appendix F, and can be adopted or modified, as appropriate for the restoration goals for the site, to be plant establishment success criteria to judge whether the revegetation goals were achieved. Irrigation guidelines are also provided in Appendix F.

HABITAT RESTORATION PROJECT MONITORING GUIDELINES

Qualitative monitoring methods, such as photo points, field walk overs, species lists and spring vegetation cover estimates, will be used to monitor the full extent of the restoration area in a cost-effective manner, while providing relevant feedback to guide management and restoration actions. Fixed photo points shall be established in critical viewsheds that document the key features of the restoration site. At each photo point, estimates of vegetation cover classes by plant functional group will be made annually to monitor the progress of the native revegetation and the trajectory of the individual habitat restoration areas. If there is high variability within the restoration area, additional photo and vegetation cover assessment points shall be added, if necessary, to ensure all conditions of the site are represented to track the progress of the site and to guide any necessary remedial actions.

PHOTO POINTS AND COVER ESTIMATES

Permanent photo points will be established to conduct photographic documentation of restoration progress and development of the restored habitat. Photo points shall be established prior to implementation to provide representative to provide a representative overview before restoration for comparison to “after photos” taken annually during performance monitoring. The geographic coordinates will be recorded using a sub-meter precision global positioning (GPS) along with the general compass direction for each photo location.

Photo points will be taken in spring, timed to capture maximum native cover of live annuals and perennial growth. If native annuals have senesced prior to sampling due to weather or timing, individual plants can be included in the cover estimate made at each

photo point if it is clearly based on morphology and/or prior biological monitoring determines what species they are and that they are from the current growing year.

At each photo point location, relevé samples will be used to estimate cover of key plant functional groups (e.g., total native, total nonnative, native tree, native shrub, native forbs, nonnnative forbs, nonnnative grass) in a plot of approximately 300 square meters (approximate 10-meter radius from the photo point) and assigned to one of the following modified Braun-Blanquet cover-abundance scale classes: <1%, 1- 5%, >5-15%, >15-25%, >25-50%, >50-75%, or >75%. These methods are modeled after the current "California Native Plant Society – California Department of Fish and Wildlife Protocol for Combined Vegetation Rapid Assessment and Relevé," which was last updated April 2016.

SPECIES LISTS

Annual plant species lists of native and nonnative species that occur in each of project zones will be prepared based on field walk overs throughout the year, including spring. Observations of flowering by species will be noted during monitoring activities and documented in the species list generated for the project.

Incidental observations of wildlife within the project will be recorded each year and maintained as a cumulative list.

5.3 LONG-TERM MONITORING PLAN

The Long-Term Monitoring Plan (LTMP) aims to collect and analyze essential biological data across Catalina Island's diverse habitats to better understand the status and changes in the island's ecology. This proactive monitoring approach allows for the identification of trends, impacts, and potential threats to the island's natural systems, enabling timely and informed management responses.

To achieve this, the LTMP integrates various ecological assessment methods to gather consistent and comprehensive data on vegetation, soil health, and wildlife, resulting in a robust database to guide management decisions. Long-term monitoring is crucial for assessing the progress and effectiveness of the defined goals of the Project, and for providing valuable feedback to adjust and adapt the Habitat Restoration and Management Plan (HRMP) and LTMP as needed.

This plan will leverage historic vegetation monitoring data collected during the 2000s by the Catalina Island Conservancy. The Conservancy conducted a series of comprehensive vegetation surveys throughout the island during this time, gathering essential floristic information for various conservation and research purposes. For example, monitoring efforts included:

- Post-fire recovery among burn sites around Goat Harbor and the Airport.
- Responses to nonnative grazer removal on the West End.
- Sensitive habitat surrounding rare and endangered plants in Wild Boar Gully.
- Vegetation dynamics in relation to land bird populations island wide.

These datasets provide a valuable snapshot into the state of vegetation of Catalina Island in the 2000s following the removal of feral goats and pigs. Changes in the cover and diversity of plant species of island vegetation communities will provide the primary measures of habitat recovery from the Project.

In landscape-level projects, such as habitat restoration of Catalina Island, clearly defining goals at the outset is critical for successful long-term management. However, this can be challenging due to the involvement of multiple habitat types and the need to accommodate various land uses (Mills et al. 2023). By establishing clear objectives, management thresholds, and implementing a comprehensive LTMP, the Conservancy can better ensure the conservation and sustainable management of Catalina Island's unique habitats and biodiversity. The Conservancy reserves the right to modify this LTMP based to meet organizational goals and funding constraints.

5.3.1 Project Objectives and Target Thresholds

Establishing measurable and achievable objectives for the Project goals (see Section 1.5.1) is crucial. In the context of the LTMP, measurable objectives and target thresholds (presented in Table 5-1) guide how success will be measured. These thresholds help identify when remedial management actions are needed. Having clearly defined and specific objectives is essential for effective monitoring design and choosing the appropriate sampling techniques. Without clear objectives, there is a risk of conducting unnecessary sampling or using improper methodologies. In the case of the LTMP, it is likely that multiple staff members will be involved in its implementation and monitoring. Having clear goals, objectives, and well-defined monitoring methodologies will ensure that all team members are on the same page, leading to more accurate and reliable results from repeated measurements.

Monitoring results will provide a feedback loop to allow for adaptive management, which could include adjustments to management actions, the LTMP, and/or the HRMP strategies, as needed. Sampling will be done in conjunction with each other as applicable for a more dynamic and robust data set and provide a clearer picture of ecosystem health. This will also aid in finding causal relationships between variables such as the relationship between changes in native vegetation cover and wildlife health and abundance. Analyses of long-term monitoring data will help with determining which efforts were most successful in restoring the biotic communities as well as gain a better understanding of the biological processes that are important for the long-term health of the island.

Long-term monitoring variables include measuring changes in vegetation cover and species richness, tracking wildlife occupancy and diversity, determining erodibility and water infiltration of the soil, and tracking invasive species under the CIPP program. Methods will include remote sensing techniques to look at broad changes in vegetation community structure, qualitative and quantitative sampling to assess vegetation composition and structure with field level sampling, photo monitoring, soil sampling, wildlife station monitoring, and invasive species mapping and control efficacy.

Table 5-1 Project Goals, Objectives, Monitoring Methods, and Management Actions.

Project Goal	Objective and Target Threshold	Monitoring Methods	Management Actions Passive Restoration Areas	Management Actions Active Restoration Areas
Increase Cover and Quality of Native Habitat for Wildlife	Increase of a Minimum of 15% in Native Cover Above Baseline and Species Richness and 20% increase in Wildlife (Number of Species and/or Population Size) 10 Years after Mule Deer Removal Compared to Baseline Conditions	• Remote Sensing Data, e.g., Landscape Change Monitoring System (LCMS) • Vegetation Plot Data • Vegetation Transect Data • Photo Point Monitoring • Wildlife Monitoring Stations	• Increase Intensity and/or Extent of Invasive Species Control Efforts or Change Control Method • Increase Scope of Weed Control to Include other Competitive Nonnative Weed Species • Determine if Native Seed Bank is Limited and Add Native Seed Propagules with Seeding in Selective Areas	• Increase Intensity and/or Extent of Invasive Species Control Efforts or Change Control Method • Increase Scope of Weed Control to Include other Competitive Nonnative Weed Species • Remedial Seeding in Areas with <5% Native Cover • Adjust Irrigation Application for Container Plantings • Replanting if <80% Survivorship of Container Plants after the First Season
Improve Health and Vigor of Island Endemic Populations (Plant and Wildlife)	Increase of 30% in Population Size and Distribution 10 Years after Mule Deer Removal Compared to Baseline Conditions	• Vegetation Plot Data • Vegetation Transect Data • Photo Point Monitoring • Wildlife Monitoring Stations • Wildlife Health Sampling	• Increase Intensity and/or Extent of Invasive Species Control Efforts or Change Control Method • Increase Scope of Weed Control to Include other Competitive Nonnative Weed Species • Determine if Native Seed Bank is Limited and Add Native Seed Propagules with Seeding in Selective Areas	• Increase Intensity and/or Extent of Invasive Species Control Efforts or Change Control Method • Increase Scope of Weed Control to Include other Competitive Nonnative Weed Species • Remedial Seeding in Areas with <5% Native Cover • Adjust Irrigation Application for Container Plantings • Replanting if <80% Survivorship of Container Plants after the First Season

Project Goal	Objective and Target Threshold	Monitoring Methods	Management Actions Passive Restoration Areas	Management Actions Active Restoration Areas
Soil Stabilization in Highly Erosive Areas	Soil Stability Increased to 10% of Baseline Conditions	• Soil Stability Test (e.g., Herrick et al. 2017) • Remote Sensing Data, e.g., Landscape Change Monitoring System (LCMS) • Vegetation Plot Data • Vegetation Transect Data • Photo Point Monitoring		• Determine BMP and Install Erosion Control Measures • Increase Invasive Plant Species Control Efforts to Improve Native Plant Establishment • Remedial Seeding in Areas with <5% Native Cover • Adjust Irrigation Application for Container Plantings • Replanting if <80% Survivorship of Container Plants after the First Season Remedial Seeding in
Increase Water Retention in the Soil	Soil Infiltration Rate Improved by 10% of Baseline Conditions	• Soil Infiltration Test (e.g., Herrick et al. 2005) • Remote Sensing Data, e.g., Landscape Change Monitoring System (LCMS) • Vegetation Plot Data • Vegetation Transect Data • Photo Point Monitoring	• Increase Invasive Plant Species Control Efforts to Improve Native Plant Establishment	• Increase Invasive Plant Species Control Efforts to Improve Native Plant Establishment • Remedial Seeding in Areas with <5% Native Cover • Adjust Irrigation Application for Container Plantings • Replanting if <80% Survivorship of Container Plants after the First Season Remedial Seeding in
Control, Reduce, and Eradicate Invasive Species Populations	Invasive Species Populations Decreasing and no New Populations Detected	• CIPP Monitoring • Vegetation Plots • Vegetation Transects • Photo Monitoring	• Increase Intensity of Invasive Species Control • Investigate and Implement Alternative Control Methods to Improve Efficacy of Treatments	• Increase Intensity of Invasive Species Control • Investigate and Implement Alternative Control Methods to Improve Efficacy of Treatments

Project Goal	Objective and Target Threshold	Monitoring Methods	Management Actions Passive Restoration Areas	Management Actions Active Restoration Areas
			• Modify Goals on a Species-by-Species Basis, e.g., Change from Island Wide Eradication to Eradication from Specific Watershed Management Unit(s)	• Modify Goals on a Species-by-Species Basis, e.g., Change from Island Wide Eradication to Eradication from Specific Watershed Management Unit(s)

5.3.2 VEGETATION STRUCTURE AND COMPOSITION MONITORING METHODS

Vegetation monitoring will be done through remote sensing techniques and field sampling using qualitative and quantitative sampling methods.

REMOTE SENSING (SATELLITE-BASED DATA COLLECTION)

Remote sensing techniques can give a broad overview of changes in vegetation structure, for example detecting increases and decreases in shrubland/woodland habitats. Following the vegetation change approach used to assess land cover change since 1985 for this HRMP (see Appendix C), the Conservancy can periodically measure whole island change in vegetation life-form change. The Landscape Change Monitoring System (LCMS) is a remote sensing-based system developed by the USFS to map and monitor landscape change across the United States. The system uses satellite imagery and other remote sensing data to map changes in land cover, land use, and other landscape characteristics. The data is made publicly available through the Forest Service's Geodata Clearinghouse, allowing researchers, land managers, and policymakers to access and analyze the information.
It is recommended to obtain the vegetation classification data in the same year the qualitative and quantitative vegetation sampling is occurring and compare it to the previous monitoring year to detect changes. If needed, vegetation classification data is produced every year if a significant event such as a fire occurs to see changes on shorter time scale.

HIGH-RESOLUTION REMOTE SENSING (UNOCCUPIED AIRCRAFT SYSTEMS, UAS)

Recent advancements in commercially available Unmanned Aerial Systems (UAS) and Structure from Motion (SfM) technology offer potential enhancements for monitoring vegetation characteristics over larger areas or detecting changes that may be impractical to observe using traditional ground-based methods. The Conservancy should consider combining UAS-derived SfM vegetation classifications and vegetation structure data with line transect data.

This integrated approach can provide valuable insights into the condition and dynamics of various vegetation types, including ironwood groves and avian habitat. By leveraging these cutting-edge technologies, the Conservancy can optimize its monitoring efforts, detect subtle changes in vegetation structure and composition, and ultimately make more informed decisions regarding habitat restoration and management strategies.

FIELD TRANSECT SAMPLING

The Conservancy will establish long-term permanent monitoring plots stratified randomly across the island. The primary quantified method for monitoring vegetation will be a series of point-intercept transects. This quantitative method gives more accurate precision than other ocular methods to measure percent coverage, diversity, species richness, and composition. The vegetation monitoring transects protocol is aligned with the National Park Service and The Nature Conservancy's strategies to allow for cohesive long-term monitoring of island flora across the archipelago.

A total of approximately 50 permanent vegetation monitoring samples are planned, which equates to about one transect per 350 hectares of the Conservancy-managed land, which totals about 17,000 hectares (Figure 5-1). These transects were randomly selected from a combination of pre-existing datasets of Airport Burn, Goat Harbor, Wild Boar Gully, the West End, and Land Bird Monitoring. Randomly selected transects were drawn from each habitat type within these datasets to maximize observations across various plant communities.

Baseline vegetation monitoring will be conducted prior to the implementation of this HRMP to establish a comparative dataset for assessing changes in vegetation over time. This initial monitoring will serve as a reference point against which the Conservancy can evaluate the effectiveness of restoration efforts and track progress toward island restoration goals. Additionally, this dataset will allow comparison of the responses of vegetation to the eradication of pigs, sheep, and goats from the island with the datasets collected in the early 2000s. This will provide valuable insights into the long-term effects of these conservation measures.

After the baseline monitoring, the Conservancy will conduct LTMP surveys approximately every 5 to 10 years. The Conservancy will adjust the frequency of monitoring surveys as needed, based on the specific restoration efforts being implemented and the resources available. These surveys will help assess changes in vegetation after the removal of mule deer and the effectiveness of active habitat restoration projects over time.

An additional 10 new transects will be established to track vegetation recovery from the 2007 Island Fire and the 2021 Middle Ranch Fire. The Conservancy plans to begin monitoring 30 core vegetation sample sites to establish a baseline, pre-project condition for this Plan (Table 5-2). Thirty additional transects have been identified (Table 5-3) that will be monitored along with the core 30 sites on a schedule of at least every 5 to 10 years to document changes in the composition, diversity and structure of Catalina's natural communities as they recovery from fire and the removal of invasive mule deer. Care should be taken to avoid disturbance from repeated measures of the sample locations, and sampling should be a minimum of five years apart to allow for vegetation recovery from trampling for access to and sampling of transect locations.

The point-intercept transects are thirty meters long and established using vinyl measuring tape stretched in a straight line with two rebar posts securely pounded into the ground at each end of the transect. Metal tags are secured to the rebar with the transect ID noted and protected with PVC pipe to preserve the rebar and tags from the elements.

During the transect monitoring effort, monitors will stretch the vinyl measuring tape to each rebar post in a straight thirty-meter line above ground level. Monitors will place a measuring rod downward to the ground every thirty centimeters along the 30-meter tape for a total of one hundred points. A photo will be taken at either side of the transect showing the location and line being recorded.

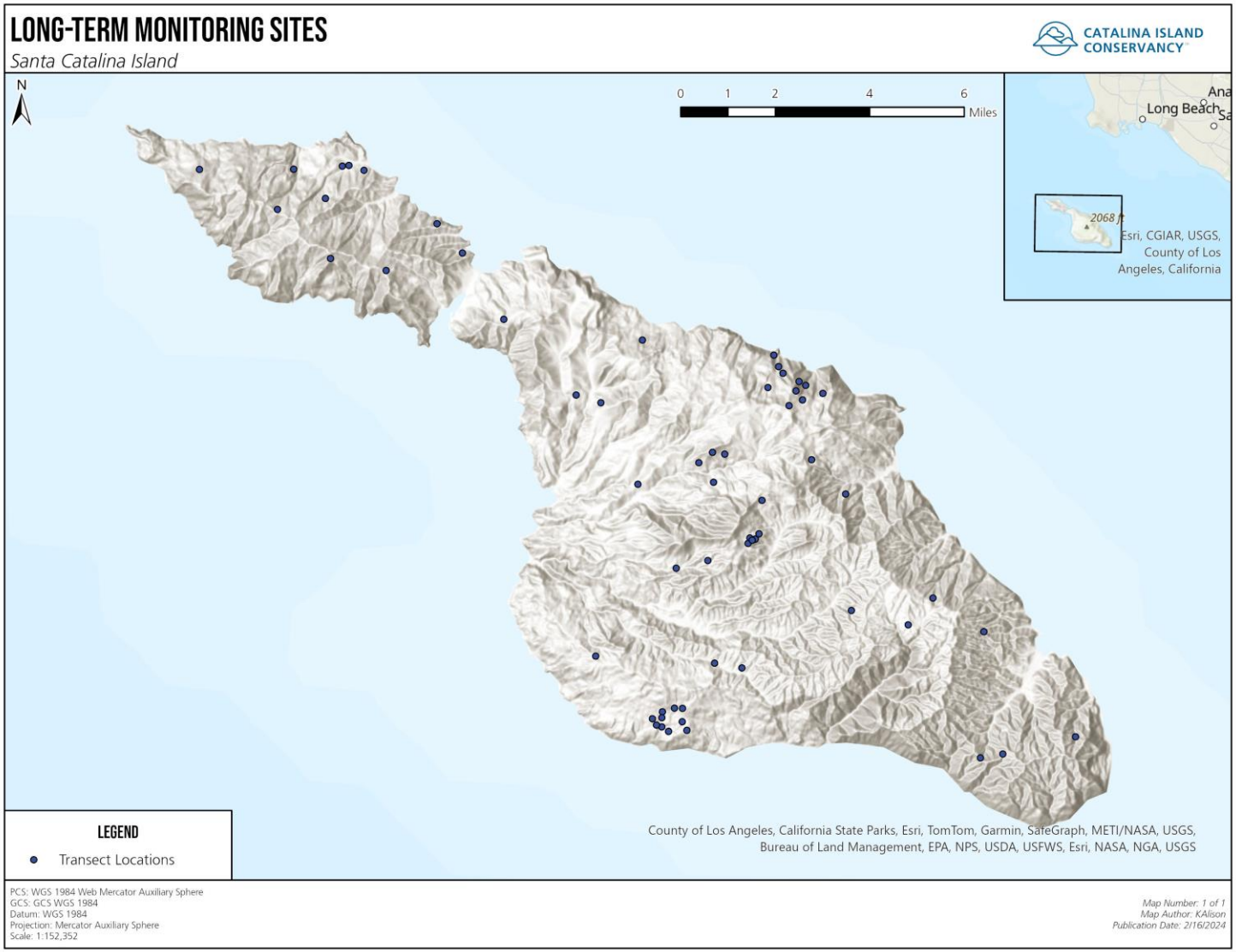


Figure 5-1 Long-Term Vegetation Monitoring Sites

Table 5-2 Long-Term Vegetation Monitoring—Primary Sites

Transect ID	Location	Plant Community Type
AB02	Airport Burn	Island chaparral & Coastal sage scrub
AB11	Airport Burn	Island chaparral & Coastal sage scrub
GH06	Goat Harbor	Scrub oak chaparral
GH12	Goat Harbor	Coastal Sage Scrub
GH20	Goat Harbor	Grassland
GH22	Goat Harbor	Catalina cherry stand
GH25	Goat Harbor	Ironwood groves
GH27	Goat Harbor	Ironwood groves
LB03	Land Bird	Grassland
LB11	Land Bird	Grassland
LB22	Land Bird	Coastal Sage Scrub/Grassland
LB36	Land Bird	Southern Oak Woodland
LB39	Land Bird	Grassland
LB49	Land Bird	Island Chaparral/Coastal Sage Scrub
LB56	Land Bird	Grassland
LB60	Land Bird	IW/Island Chaparral
LB79	Land Bird	Southern Oak Woodland
LB80	Land Bird	Coastal Sage Scrub/Grassland
WB01	Wild Boar Gully	Grassland
WB05	Wild Boar Gully	Coastal sage scrub
WB07	Wild Boar Gully	Scrub oak chaparral
WB13	Wild Boar Gully	Grassland
WB14	Wild Boar Gully	Grassland
WB17	Wild Boar Gully	Coastal sage scrub
WE02	West End	Island woodland - *Lyonothamnus floribundus*
WE05	West End	Island woodland - *Prunus ilicifolia*
WE08	West End	Island chaparral - *Adenostoma fasciculatum*
WE09	West End	Coastal Sage Scrub
WE10	West End	Island chaparral - *Quercus pacifica*
WE14	West End	Grassland

Table 5-3 Long-Term Vegetation Monitoring—Secondary Sites

Transect ID	Location	Plant Community Type	Sampling Cycle Group
MF01	Middle Fire	Coastal Sage Scrub - Burn site	1
MF02	Middle Fire	Coastal Sage Scrub - Burn site	1
MF03	Middle Fire	Coastal Sage Scrub - Burn site	1
MF04	Middle Fire	Coastal Sage Scrub - Burn site	1
MF05	Middle Fire	Coastal Sage Scrub - Burn site	1
AB04	Airport Burn	Island chaparral & Coastal sage scrub	1
FH18	Goat Harbor	Grassland	1
GH13	Goat Harbor	Coastal Sage Scrub	1
GH14	Goat Harbor	Scrub oak chaparral	1
GH7	Goat Harbor	Scrub oak chaparral	1
B/IC12	Island Fire	Bare/Island chaparral	2
GR/IC5	Island Fire	Grassland/ Island chaparral	2
GR/IC9	Island Fire	Grassland/ Island chaparral	2
IW5	Island Fire	Island woodland	2
NNS/IC1	Island Fire	Non-native scrub/ Island chaparal	2
29	Land Bird	Grassland	2
LB16	Land Bird	Island Chaparral/Grassland	2
LB21	Land Bird	NNH/Grassland	2
LB34	Land Bird	Southern Oak Woodland/Grassland	2
LB44	Land Bird	Island Chaparral/Coastal Sage Scrub/Grassland	2
LB48	Land Bird	Coastal Sage Scrub	3
LB71	Land Bird	Grassland	3
WE03	West End	Island woodland - Lyonothamnus floribundus	3
WE07	West End	Island chaparral - Adenostoma fasciculatum	3
WE13	West End	Grassland	3
WE17	West End	Coastal Sage Scrub	3
WB03	Wild Boar Gully	Grassland	3
WB06	Wild Boar Gully	Coastal sage scrub	3
WB11	Wild Boar Gully	Grassland	3
WB12	Wild Boar Gully	Scrub oak chaparral	3

At each point, monitors will identify each plant that touches the measuring rod, and for woody vegetation, the height and age class. The substrate of each transect will be recorded.

In addition to the point-intercept data, a list of all plant species observed within a one-meter buffer on the uphill slope of the 30-meter tapeline and any additional species within a five-meter buffer on either side will be recorded. For all rooted shrubs within one meter of the tapeline on the uphill side, the number of individuals will be recorded with notes on their various life stages. The same notes will be taken for rooted trees within five- meters on either side of the tapeline while also measuring the diameter-at-breast-height (DBH) of the largest size class trees in the established boundary. From this combined data, the Conservancy can accurately calculate and assess changes in the percent coverage of species, native and non-native plant species richness, plant community structure and composition, diversity, etc.

The selected sampling sites will be stratified by slope, elevation, vegetation type, distance from roads, and distance from other points. Samples will be divided between low elevation areas in drainages as well as ridge lines and hillsides. Additional sample points may be added as needed in areas with active restoration or if a particular habitat is underrepresented. It is recommended that each of the key vegetation habitat types is represented in the sample points, which include island chaparral, island scrub oak chaparral, coastal sage scrub, maritime cactus scrub and grassland.

Monitoring will be conducted in late winter to early summer depending on weather variables and plant phenology to capture the vegetation characteristics at the height of the growing season. The vegetation transect sampling techniques will align with the transect monitoring protocol used by the National Park Service and The Nature Conservancy on the Channel Islands to allow for a larger comparison among California Pacific Islands. Where appropriate, vegetation rapid assessments will be conducted in addition to transects and will follow the current California Native Plant Society – California Department of Fish and Wildlife Protocol for Combined Vegetation Rapid Assessment and Relevé, which was last updated April 2016.

5.3.3 PHOTO MONITORING

Like the vegetation transect data, a historical collection of photo monitoring sites have been established throughout the island. These sites were established in previous decades to visually interpret physical and biological aspects of the landscape over time. The Conservancy plan to use a subset of these photo monitoring points that will be used for the long-term monitoring by capturing repeated photos after removal of mule deer.

Three-foot metal rebars were pounded one foot into the ground and marked with metal identification tags at each photo monitoring sight. Photos will be taken digitally (e.g., using smartphones). A digital application may be used to transpose previously recorded photos with a transparent overlay feature to accurately match previous landscape photos of the same location.

Twenty-one photo monitoring sites were selected from a collection of sites previously established in 2005-2007 (Figure 5-2). The Conservancy plans to continue capturing photos from these sites every five years to visually monitor and assess changes and trends to the landscape over time. Imagery captured using unmanned aerial vehicles (UAV) can also augments photo monitoring documentation.

5.3.4 WILDLIFE MONITORING

As part of the Island-wide restoration project, the Conservancy has developed a long-term monitoring strategy for measuring the response of bird and bat species to deer removal and active restoration activities. The negative impact of high deer densities on bird species, particularly ground and mid-story nesting songbirds, is well documented (Crystal-Ornelas et al. 2021, Phillips and Cristol 2024). Deer can have an outsized effect on these bird species through reducing habitat structural diversity and foraging habitat quality, as well as directly through nest depredations (Phillips and Cristol 2024). The impact on bat species is less direct, but the reduction in vegetation diversity and structure can reduce insect availability, the primary prey of most bat species on Catalina (Stewart 2001, Allombert et al. 2005). To monitor the response of bird and bat species to the removal of deer and vegetation restoration initiatives, the Conservancy will use non-invasive acoustic recorders to look at species richness and occurrence across the island for both taxa.

The Conservancy will monitor birds with acoustic recorders set up at 30 to 35 locations annually for 8 weeks between May and June. In addition, the Conservancy will deploy an additional 10 to 15 acoustic recorders in areas with current or planned habitat restoration activities. The Conservancy will choose locations through a stratified random sampling of sites from a pool of locations with prior or future vegetation monitoring and may alter or add locations as needed based on access and habitat type. The Conservancy will also collect additional habitat data on vegetation structure and cover each year at each acoustic site. The Conservancy chose to collect data in late spring/early summer to coincide with vegetation sampling and to capture primarily breeding bird activity. The acoustic stations will include one AudioMoth (low-cost, full-spectrum acoustic logger designed to record a wide range of audible and ultrasonic frequencies) attached to the top of a pole approximately 6 ft high. The recorders will be set away from trees to avoid picking up rustling leaves and pointed to the most open area. These methodologies follow the protocol set up by the California Department of Fish and Wildlife (CDFW) for their biodiversity and climate sentinel monitoring sites.

The Conservancy will use the acoustic records to look at species richness throughout the island, as well as changes in specific species occurrence over time. The Conservancy will monitor 4 to 6 species for each nesting category: ground, midstory, and upper story/canopy. Possible species of interest include the San Clemente spotted towhee (ground nesting), chipping sparrow (mid-story nesting), and the Hutton's vireo (upper story/canopy nesting). The Conservancy predicts ground and mid-story nesters are impacted more by deer presence and will respond more quickly while canopy nesters are less affected and will respond more slowly or not at all (Chollet et al. 2014).

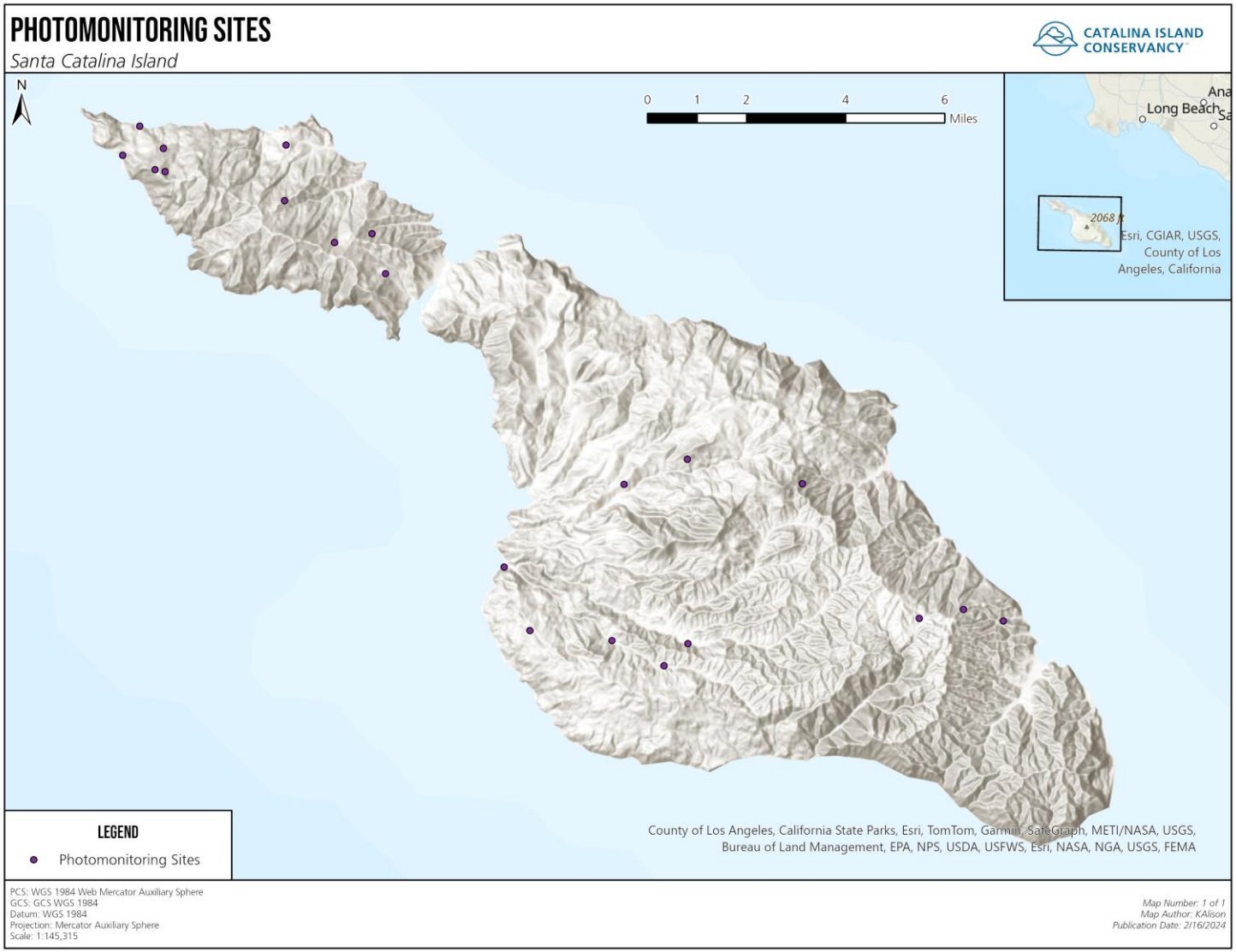


Figure 5-2 Long-Term Photo-Monitoring Sites

The bird acoustic data will be processed using the machine learning program BirdNET through Cornell University (Kahl et al. 2021).

The Conservancy will be monitoring bat species at 10 locations around the island. Two of the locations have had a permanent recording station deployed on site since 2019. The Conservancy will monitor an additional 8 sites for one month in the spring and one month in the fall. Because the Conservancy only has 4 acoustic devices, they will split up the monitoring so 4 sites will be monitored in May/September, and 4 sites will be monitored in June/October. This period will coincide with spring pupping activity and with fall migration. The additional 8 sites will be selected for high quality bat habitat to increase the chances of monitoring all 10 bat species on island. The acoustic records will be processed using the program SonoBat.

By monitoring bird and bat species from the initial stages of deer removal throughout the subsequent stages of the Project, they will be able to determine if the project goals and objectives are being met (Table 5-1). If the Conservancy are not seeing predicted species recovery that will be an indication for a review of the environmental and anthropogenic threats our island flora and fauna species are facing, then they can then address any shortcoming of the current habitat restoration efforts and implement appropriate changes to better address those threats.

5.3.5 INSECT MONITORING

As part of the long-term monitoring strategy, the Conservancy will track insects in addition to vegetation on the island. With this data, the Conservancy will incorporate insect relative abundance and diversity to assess the ecosystem health island wide. The Conservancy will collaborate with the California Insect Barcoding Initiative (CIBI) to collect and process genetic samples of insects on the island. The Conservancy plan to collect these samples every five to ten years to monitor changes beginning in 2024 as a baseline dataset.

To make these insect collections, the Conservancy will establish three insect monitoring sites using Townes' style malaise traps for six months (April to September) during the peak insect collecting months. The Conservancy will establish these three sites in areas with the greatest concentration of vegetation transects on the West End, Goat Harbor, and Wild Boar Gully. These traps are a netted system that funnels insects into pre-labeled collection bottles filled with 95% ethanol. The bottles capturing samples will be retrieved once per month for analysis using eDNA to genetically barcoded using eDNA. These samples will allow the Conservancy to collect and interpret insect diversity, species richness, biomass and relative abundance. All samples will be intact after sequencing, allowing for morphological and taxonomic data to be available for further entomological studies if desired.

5.3.6 SOIL MONITORING

Soil monitoring will consist of looking at key characteristics to determine if soil conditions are improving to provide for more stable and healthier native habitat. Soil characteristics will include monitoring soil stability and soil water retention. A key

component for restoration in steep areas is to improve upon soil stability and reduce the chances of soil erosion including rilling, landslides, and deposition of soil material at the toe of slopes or in drainages. Soil water retention is expected to improve with the conversion of degraded areas that were once dominated by nonnative weed species to native habitat and vegetation communities. UAVs can also be incorporated to monitor soil condition at landscape level.

SOIL STABILITY IN HIGHLY EROSIVE AREAS

Soil stability is critical for native habitat establishment and resilience. Disturbance from erosive actions generally decreases native vegetation thereby allowing for the increase in nonnative weed species that thrive and can outcompete natives through early and rapid establishment following disturbances.
Several applicable methods may be used to monitor soil stability in highly erosive areas. One method may be the Soil Stability Test (Herrick et al. 2017) that involves sampling surface and, in some cases, subsurface samples to determine the soil stability class ranking. Ideally sampling should occur at the vegetation sampling locations at the same time to provide a more robust data set. Sampling protocol including methods for sampling in conjunction with vegetation monitoring are described in the Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems Volume I by Herrick et al. (2017).

SOIL WATER RETENTION

Soil water retention and infiltration capacity are expected to improve through passive and active restoration activities with the increase in native perennial vegetation and lessening of nonnative vegetation cover. Improvement will help to reduce stormwater runoff, decrease erosion, and increase groundwater recharge, ultimately benefitting the island's freshwater supply. The deep-rooted nature of perennial species will allow for more water capture and storage deep in the soil thereby making it available for plants during times of drought and will increase soil stabilization making steep hillsides less prone to erosion. The reduction in runoff and erosion will decrease the amount of nitrogen and suspended sediments in stormwater runoff and into open water areas. Several methods may be used for monitoring soil water retention with one method being described in Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems Volume II by Herrick et al. (2005). The monitoring method includes field tests to determine the soil infiltration rate, or the measure of how fast water enters the soil. The method includes using a single-ring infiltrometer in the field under saturated conditions to determine the relative infiltration capacity. As with the soil stability test, for a more rigorous sampling effort the soil infiltration rate can be sampled in the same locations and coincident with the vegetation sampling points and transects.

5.3.7 INVASIVE SPECIES CONTROL MONITORING

Invasive species control has been a key component of island management for several decades and is incorporated as a key restoration action of this plan. The CIPP program has been implemented since 2004 with the mission of the program being to "ensure the

continued domination of the ecosystems of Catalina Island by native plants for the immediate and long-term future" (Appendix A). Since complete eradication is not possible for all invasive species a three-tiered approach is implemented that includes targeted invasive species control, (e.g., along roadsides or high value watershed management units), education of the public to stop the spread of invasive species on the island, and complete eradication from the island for long-term habitat benefits. Monitoring efforts for invasive species will follow the monitoring currently implemented for the Conservancy's CIPP program. Ad hoc surveys while en route or while conducting other monitoring activities can be done to increase chances of early detection of new invasive species or expansion of known invasive populations on the island. A mapping protocol has been developed for the island and is presented in the Appendix A. It is also a key component of the CIPP program to diligently monitor after weed treatment events to track the efficacy of control methods.

5.3.8 Other Monitoring Methods

The Conservancy is considering innovative monitoring approaches, including a collaboration with CALeDNA to conduct an eDNA study in conjunction with other vegetation and sampling at the same monitoring sites. This sampling would involve collecting approximately 5 to 10 small vials of soil from each monitoring site to test for DNA. This would assist the Conservancy in understanding the changes in the invertebrate and microbial communities at these locations and could provide valuable additional indicators for successful versus failed restoration efforts.

5.4 Assess and Adapt

Monitoring results will be used to compare against the decision support tool values, which are thresholds for when management actions are necessary to achieve the defined goals in the LTMP and the HRMP. The decision support tools, and management actions are different for passive and active restoration areas because of the level of effort and time scale of change for both methods.

5.4.1 Passive Restoration Areas

For passive restoration, the time span for reaching the Project goals will be longer since it will take some time for natural recovery to occur after releasing the areas from the browsing pressure of the mule deer and for vegetation recovery after a fire. The anticipated time frame is 5 to 10 years before monitoring should begin in passive restoration areas and every 5 to 10 years thereafter. If no detectable change is observed or native cover and/or species richness declines after 5 to 10 years, then management actions should be implemented based on the decision support tools to achieve the LTMP goals. The following are recommended remedial management actions that could be implemented to achieve native cover and species richness goals in passive restoration areas:

1. Changes in invasive species control intensity, extent, and/or methods

2. Implement weed control of other target competitive nonnative plant species that are inhibiting native plant establishment
3. Remedial seeding in areas where the native seed bank is lacking

5.4.2 ACTIVE RESTORATION AREAS

In active restoration areas, monitoring should occur annually during site-specific habitat restoration project implementation to prescribe management actions in a timely manner if goals are not being achieved to ensure more successful restoration outcomes and to not backslide on the amount of effort that has already been input into the restoration area. The following are recommended remedial management actions that could be implemented to achieve native cover and species richness goals in active restoration areas:

1. Changes in invasive species control intensity, extent, and/or methods
2. Implement weed control of other target competitive nonnative plant species
3. Remedial seeding in large areas that failed to establish after one season
4. In areas with failing container plants, modify irrigation application as needed
5. Remedial planting in areas with less than 80 percent survivorship of container plantings

5.5 REPORTING

Reports detailing monitoring methodology and results are essential as reference documents for future staff to be able to conduct monitoring using the same methodology and to document vegetation, wildlife, and soil changes on the island. It is vital to fully understand what has been done in the past to be able to manage adaptively in the future. Adaptive management is near impossible if it is unknown or unclear what was done in the past for management and what the outcomes were after implementing management actions.

The recommended minimum reporting requirements would include the following:

1. Documenting what, how, when, and where monitoring occurred
2. Raw data, data analysis procedures, data analysis results
3. Documentation of any changes or variations to the monitoring procedure
4. Management actions that were implemented if goals were not achieved
5. Recommendations for future monitoring and management actions

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Appendix A

Catalina Invasive Plant Program (CIPP) Guide

CATALINA ISLAND CONSERVANCY™

To be an exemplary steward of Island resources through a balance of conservation, education, and recreation.

Catalina Habitat Improvement and Restoration Program (CIPP) Guide

Updated March 2024

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1 Introduction

The mission of the Catalina Island Conservancy (Conservancy) is to be a responsible land steward through a balance of conservation, education, and recreation. The Conservancy owns and manages 88% (42,087 acres) of Catalina Island (about 48,000 acres). Invasive species are considered the second greatest threat to biodiversity worldwide and are the leading cause of species extinctions in island ecosystems (Kiehn 2011). Catalina Island, the third largest of the eight California Channel Islands off the coast of southern California, is no exception.

The Conservancy faces the challenge of managing invasive plants, which have thrived in novel habitats due to human-induced disturbances and the introduction of nonnative plants and animals (Baskin 2002). With over 700 plant species on Catalina Island, approximately 30% are nonnative. Over time, invasive plants have spread to varying degrees on the island, affecting flora, fauna, and ecosystem processes. Invasive plants are one of the greatest challenges facing the health of Catalina Island (Knapp 2007).

Invasive plants displace Catalina's native flora and do not provide suitable habitat for native wildlife, threatening the stability of the entire ecosystem. Invasive plants can form large stands dominated by one species, which lowers the biodiversity that ecosystems depend on. This is well displayed in areas such as Avalon Canyon with introduced flax-leaf broom (*Genista linifolia*). Almost half of the federally endangered and threatened species became listed due to the proliferation of invasive species (Babbit 1998). Invasive plants can interrupt the functioning of an ecosystem by competing with native vegetation for resources such as water, light, and nutrients, by altering soil chemistry and composition, flood patterns, and fire regimes, or by increasing soil erosion (Mullin et al. 2000, Colorado Natural Areas Program et al. 2000). Several invasive plants can also hybridize with native plant species, changing their descendants' genetic make-up. This is a particularly pronounced threat on Catalina Island. Hybrid descendants often become more invasive than the invasive parent plant because of a common phenomenon utilized by plant breeders called hybrid vigor (Randall and Hoshovsky 2000).

While the Conservancy has successfully eradicated some nonnative animals from the island to protect island biodiversity, such as the removal of invasive wild goats and pigs in the 1990s, the continued impact other invasive animals (e.g., mule deer and bison populations), existing established invasive plant populations, and ongoing human activities exacerbates plant invasions.

Catalina's proximity to southern California and high visitation rate elevates its vulnerability to new invasive species introductions or reintroduction of previously eradicated ones. To effectively halt and reverse the spread of invasive nonnative plants, the Conservancy must employ every appropriate tool and strategy, ensuring a comprehensive and adaptive approach to safeguarding the island's ecosystem (DiTomaso et al. 1999, Colorado Natural Areas Program 2000). The Conservancy’s multipronged approach to island restoration includes targeted control of existing invasive plants, monitoring for early detection of new invasions, active restoration of native plant communities, the development of biosecurity measures, and promoting public awareness to mitigate the risk of introducing new invasive species.

Invasive plant management with sufficient long-term funding is critical to the Conservancy's conservation mission. To meet this challenge, in 2003, the Conservancy developed an integrated science-based program to protect ecosystem health through monitoring and management of invasive plants, utilizing adaptive management techniques referred to as the Catalina Invasive Plant Program (CIPP) (Knapp 2007). Since the beginning of CIPP, 4 species have been functionally eradicated, over 1.4 million individual plants have been treated, nearly 30,000 acres have been surveyed, over 3,000 acres have been treated, over 200 species have been treated, and over 68,000 management hours have been invested (e.g., see Figure 1). Over the years, the Conservancy has contracted with conservation partners, such as American Conservation Experience (ACE), to help implement CIPP through conservation interns. Beginning in 2023, the Conservancy began contracting with the California Institute of Environmental Studies (CIES) for the majority of grant funded invasive plant management. CIES contractor crews come with experience and expertise in treating invasive plants across several of the California Channel Islands.

In 2023, the Conservancy and CIES surveyed 192 acres across 37 watershed management units. A total of 15 different species were treated, totaling 204,973 individual plants. Currently, the Conservancy targets over 40 invasive plant species for management (see Table 1).

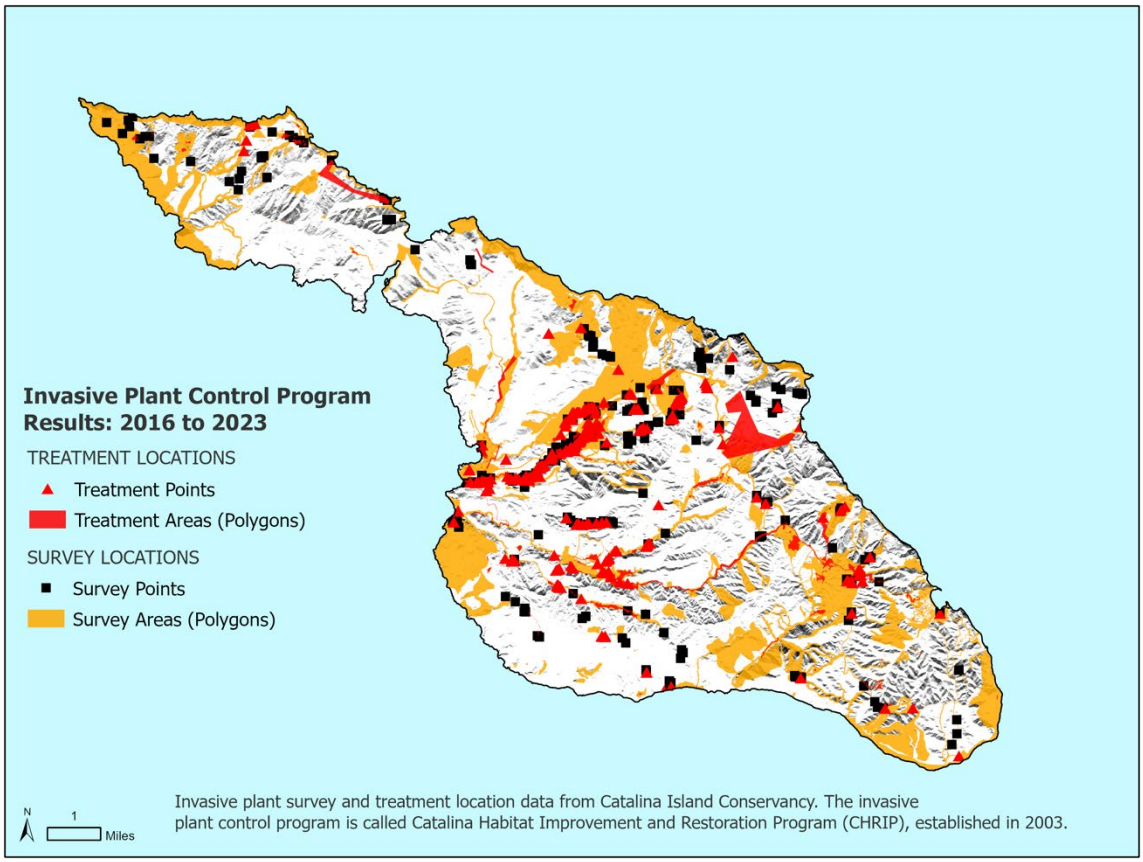

Figure 1. Location of Invasive Plant Surveys and Treatments from 2016 to 2023.

2 CIPP Goals

The goals of CIPP are as follows (Knapp 2007):

1. Prevent the reduction or loss of native Catalina Island flora and fauna, due to the direct or indirect impact(s) caused by invasive plants, by actively managing invasives with the safest, most effective and economical methods available.
2. Increase the Conservancy's and partner agencies knowledge regarding invasive plant distribution, impacts and management strategies.
3. Stop invasive plant introductions, establishment and spread on Catalina Island by increasing invasive plant awareness in staff, contractors, residents, and visitors through education programs, and improving cultural practices and partnerships.

3 Invasive Plant Management Objectives

Effectively managing well-established invasive species populations through long-term programs requires substantial financial investment and resource allocation, underscoring the importance of strategic prioritization in selecting which species to target for control efforts. To allocate limited resources effectively, the Conservancy focuses on species that pose the most significant threats to native ecosystems and have the greatest potential for successful management (Mullin et al. 2000).

Efficient management of invasive plants relies on accurately predicting susceptible species and locations, while employing robust control tools. This strategic prioritization requires understanding each species' ecological impact, distribution, and control potential. By focusing on high-impact, rapidly expanding species, land managers can effectively allocate resources to protect native habitats. A well-informed, data-driven prioritization process ensures efficient use of limited conservation resources, enabling professionals to make targeted decisions that preserve native ecosystems and promote long-term environmental health (APRS Implementation Team 2000).

The goal of active invasive plant management species is currently achieved through four objectives:

1. **Early Detection and Rapid Response (EDRR)** to detect, monitor, and eradicate new invasive plant introductions before it can spread.
2. **Eradication** of all known populations on the island, or from natural areas, of species that have significant ecological impacts and are feasible to eliminate.
3. **Control** of species too widespread to be eradicated by reducing invasive plant populations in high priority watersheds, restoration areas, and high use areas.
4. **Corridor Management** of species too widespread to be eradicated and commonly found along corridors, such as the roadways, that serve to spread invasive plant propagules.

The management priorities and objectives for over forty invasive plant species are presented in Table 1.

3.1 EDRR

The Early Detection and Rapid Response (EDRR) management strategy harnesses our ability to effectively eradicate emerging invasive plant populations during their early stages. By detecting invasive plants before they can spread and establish substantial seed banks, managers can intervene early enough in the invasion process to successfully eliminate the species from a particular area while the population remains small. This proactive approach of early detection and rapid response enables well-informed monitoring, ultimately mitigating the need for expensive and extensive long-term control measures.

3.2 Eradication

Focusing on the complete removal of invasive species from islands or natural areas holds the most substantial promise for enduring habitat improvement. This approach prioritizes the eradication of invasive species that possess a documented potential to become widespread. Most often, species identified with this goal are limited in their current distributions with few small populations, such as giant cane (*Arundo donax).* They are also often ranked with high California Invasive Plant Council (Cal-IPC) scores, meaning they have shown significant ecological impacts.

3.3 Control

Control refers to the management of invasive plant populations in high priority watersheds, restoration areas, and high use areas. Species with this goal are also usually too widespread for eradication to be feasible. For these species, they are usually not commonly found in corridors, such as Mediterranean broom (*Genista linifolia*), or they are so widespread that controlling them in high priority areas is the only manageable action, such as fennel (*Foeniculum vulgare*).

The Conservancy controls invasive plant populations in high priority areas with a strategic top-down approach. Starting at the top of watersheds, at the highest elevation, and working downwards reduces source populations and reintroduction. Twelve watersheds were identified by the Conservancy as priorities for invasive plant control to protect their high value biological and cultural resources (Knapp 2007). Corresponding Watershed Management Units (WMU) are identified and depicted in Figure 2.

1. Middle Canyon (WMUs 61b, 61e, and 61f)
2. Haypress (WMU 50b)
3. Cottonwood Canyon (WMUs 63a, 63c, and 63d)
4. Shark Harbor (WMU 64)
5. Little Harbor (WMU 66a)
6. White's Landing (WMU 32a)
7. Coffeepot Canyon (WMU 51)
8. Emerald (WMU 6)
9. Parson's Landing (WMU 4)
10. Goat Harbor (WMU 28)
11. Big Springs Canyon (WMU 65)
12. Empire Landing (WMU 20)

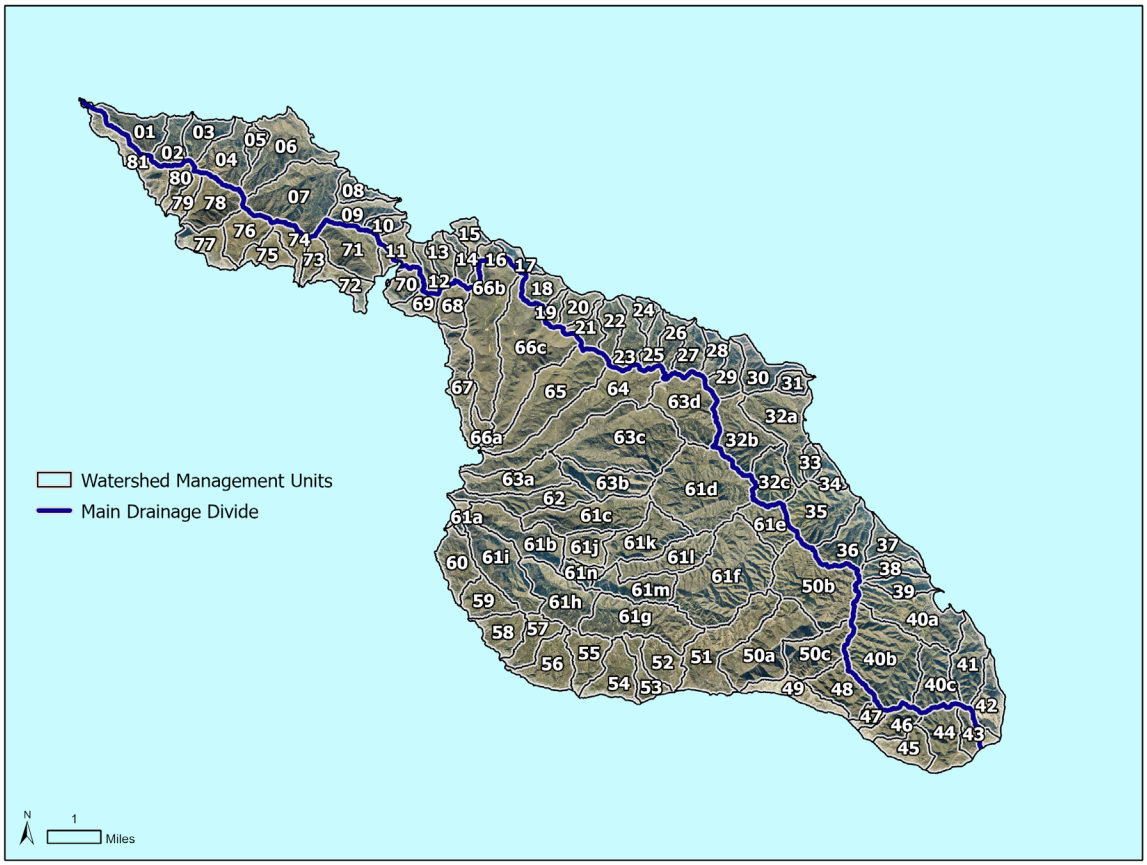

Figure 2. Catalina Island Watershed Management Units.

3.4 Corridor Management

Invasive plant management along corridors is crucial in controlling the spread of invasive plants. CIPP defines corridors as a 60-meter buffer along each side of a roadway (total management buffer of 120 meters) and a 10-meter buffer along each side of trails (total management buffer of 20 meters). Corridors are generally highly disturbed and highly trafficked areas which promote the establishment and spread of invasive plants (Cal-IPC 2012). It is understood that roadways are a major pathway in which invasive plant propagules spread. Vehicles can act as a secondary dispersal vector for many plant species which allows propagules to travel much further than their natural dispersal range (Lemke et al. 2019). For corridors, Conservancy staff concentrates on treating invasive plant species that are already degrading ecosystems and thrive in disturbed soils, such as castor bean (*Ricinus communis*). These species are often too widespread for eradication to be a feasible goal, so focusing on containing and stopping the spread is the best management action.

Table 1. Invasive Plant Management Priorities and Objectives.

Overall Priority Rank	2024 Priority Rank	Management Objectives	Scientific Name	Common Name	CAL-IPC Score	Notes
1	**1**	**Control**	*Genista linifolia*	Mediterranean broom	Watch	Red alert status
2	**2**	**Control**	*Foeniculum vulgare*	Fennel	Moderate	Threat with deer management
3	**1**	**Eradication-Island Wide**	*Pennisetum setaceum*	Fountain grass	Moderate	Watch pops by Hamilton and top of Wrigley
4	**2**	**Eradication-Island Wide**	*Cortaderia selloana*	Pampas grass	Moderate	New pop in Cottonwood Canyon
5	**1**	**Eradication-Natural Areas**	*Cynara cardunculus*	Artichoke thistle	Moderate	NRCS EQIP Target
6	**3**	**Control**	*Silybum marianum*	Milk thistle	Limited	NRCS EQIP Target
7	**2**	**Eradication-Natural Areas**	*Arundo donax*	Giant cane	High	Mostly Baker Dam, Palisades
8	**3**	**Eradication-Natural Areas**	*Spartium junceum*	Spanish broom	High	Only in Avalon right now, recently treated in Middle Canyon by pump house
9	**4**	**Control**	*Phalaris aquatica*	Harding grass	Moderate	NRCS EQIP Target
10	**5**	**Control**	*Carduus pycnocephalus*	Italian thistle	Moderate	Cottonwood Canyon, Garden to Sky, Bulrush
11	**3**	**Eradication-Island Wide**	*Tamarix ramosissima*	Tamarisk	High	Mostly Pacific side on West End, Palisades
12	**4**	**Eradication-Island Wide**	*Stipa tenuissima*	Mexican feathergrass	High	Removed from Avalon
13	**5**	**Eradication-Island Wide**	*Paspalum vaginatum*	Seashore Paspalum	Watch	Ben Weston Canyon, Two Harbors Dump

Overall Priority Rank	2024 Priority Rank	Management Objectives	Scientific Name	Common Name	CAL-IPC Score	Notes
14	**6**	**Control**	*Cirsium vulgare*	Bull thistle	Moderate	
15	**6**	**Eradication-Island Wide**	*Eriogonum fasciculatum*	California buckwheat	N/A	May hybridize w/ island *Eriogonum* spp.
16	**4**	**Eradication-Natural Areas**	*Vinca major*	Periwinkle	Moderate	Ben Weston Canyon, near pumphouse in middle canyon
17	**1**	**Corridors**	*Salsola tragus*	Russian thistle	Limited	Also *S. australis*; unsure ID @ all pops
18	**5**	**Eradication-Natural Areas**	*Hedera helix*	English ivy	High	
19	**6**	**Eradication-Natural Areas**	*Genista monspessulana*	French broom	High	Not seen in natural areas, known in town
20	**7**	**Eradication-Natural Areas**	*Genista stenopetala*	Sweet broom	N/A	Not seen in natural areas, known in town
21	**8**	**Eradication-Natural Areas**	*Cotoneaster sp.*	Silverleaf Cotoneaster	Moderate	Probably *C. pannosus*, Descanso Canyon
22	**7**	**Control**	*Asparagus asparagoides*	Bridal creeper	Moderate	Red alert, Thompson's Reservoir, Isthmus rd
23	**9**	**Eradication-Natural Areas**	*Centranthus ruber*	Jupiter's beard	Alert	Stage Road, seems to be spreading
24	**9**	**Control**	*Ficus carica*	Common fig	Moderate	
25	**7**	**Eradication-Island Wide**	*Delairea odorata*	Cape Ivy	High	Mostly Avalon, Quail Valley
26	**8**	**Control**	*Brassica nigra*	Black Mustard	Moderate	Little Harbor, West End, Cottonwood
27	**10**	**Eradication-Natural Areas**	*Pittosporum undulatum*	Mock Orange	Limited	Middle Canyon population, Toyon

Overall Priority Rank	2024 Priority Rank	Management Objectives	Scientific Name	Common Name	CAL-IPC Score	Notes
28	**11**	**Control**	*Phoenix canariensis*	Canary Island Date Palm	Limited	
29	**11**	**Eradication-Natural Areas**	*Caesalpinia spinosa*	Tara	N/A	Avalon
30	**2**	**Corridors**	*Ricinus communis*	Castor Bean	Limited	White's, Emerald
31	**12**	**Control**	*Washingtonia* species	Fan palm	Moderate	Score for W. robusta (CA non-native)
32	**13**	**Control**	*Pinus halepensis*	Aleppo pine	N/A	On CAL-IPC watchlist; not enough info
33	**8**	**Eradication-Island Wide**	*Asphodelus fistulosus*	Onionweed	Moderate	Alert; one pop at Hamilton
34	**14**	**Control**	*Eucalyptus* species	Eucalyptus	Limited	*E. globulus* naturalizes in coastal CA
35	**3**	**Corridors**	*Nicotiana glauca*	Tree tobacco	Moderate	
36	**13**	**Eradication-Natural Areas**	*Euphorbia lamarckii*	Milky spurge	N/A	Spreading in Avalon
38	**4**	**Corridors**	*Xanthium spinosum*	Spiny cocklebur	N/A	Consider other xanthium
39	**14**	**Eradication-Natural Areas**	*Carpobrotus* species	Iceplant	High	Empire, Avalon, Two Harbors
40	**10**	**Control**	*Cakile maritima*	Sea rocket	Limited	
41	**6**	**Corridors**	*Mesembryanthemum* species	Crystalline iceplant	Moderate	Mushroom flats, Pacific side
42	**5**	**Corridors**	*Marrubium vulgare*	Horehound	Limited	Widespread
43	**15**	**Control**	*Schinus molle*	Peruvian pepper tree	Limited	Camps (fox), Avalon
44	**12**	**Eradication-Natural Areas**	*Solanum elaegnifolium*	Silverleaf nightshade		Golf course

Overall Priority Rank	2024 Priority Rank	Management Objectives	Scientific Name	Common Name	CAL-IPC Score	Notes
		EDRR	*Tribulus terrestris*	Puncture Vine	Limited	Not detected 2021-2022
		EDRR	*Osteospermum calendulaceum*	Stinking Roger	Watch	Detected in Orange County
		EDRR	*Hypercium androsaemum*	Sweet amber	Watch	
		EDRR	*Arctotheca calendula*	Capeweed	Moderate	Alert - fertile forms
		EDRR	*Brassica tounefortii*	Saharan Mustard	High	CIES reported some near Empire and Ben Weston overlook
		EDRR	*Centaurea solstitialis*	Yellow starthistle	High	Eradicated from Middle Cyn
		EDRR	*Cytisus scoparius, C. striatus*	Scotch & Portuguese broom	High	C. striatus - moderate
		EDRR	*Euphorbia terracina*	Carnation spurge	Moderate	
		EDRR	*Lepidium draba*	Whitetop	Moderate	
		EDRR	*Malephora crocea*	Coppery mesembryanthemum	N/A	On CAL-IPC watchlist
		EDRR	*Oenothera xenogaura*	Dummond's gaura	N/A	
		EDRR	*Tribulus terrestris*	Puncture Vine	N/A	White's Landing historic pop.
		Identify & Map Populations	*Lathyrus latifolius, L. odoratus*	Everlasting, Sweet pea	N/A	L. latifolius on CAL-IPC watchlist

4 Invasive Plant Survey and Treatment Methods

4.1 Integrated Invasive Plant Management Toolbox

To effectively manage diverse invasive plant species, land managers must be equipped with a versatile range of tools and techniques to address the unique challenges posed by each species, site, or weather condition. A well-rounded "toolbox" enables professionals to adapt to an ever-changing environment, ensuring the successful control and eradication of invasive plants.

Documenting and monitoring management techniques is crucial in identifying the most efficient control methods and adapting or developing new strategies as needed. Utilizing the winter season, when fewer species require treatment, to evaluate the efficacy of past management efforts based on databased treatment records allows land managers to learn from past experiences, build on successes, and refine their approaches.

Innovative solutions can also be found by exploring techniques and tools from other disciplines and adapting them to the invasive plant management field. By embracing creativity and collaboration, conservationists can develop more effective methods for controlling invasive species, ultimately promoting the preservation and restoration of native habitats.

4.1.1 Cultural Control

Many troublesome invasive plants are highly dependent on ongoing disturbance, whether natural (e.g., fire, flood, or landslide) or artificial (e.g., browsing, grazing, mowing, disturbance by foot or vehicle traffic). Where appropriate, measures should be taken to protect areas with high biological values from further disturbance.

4.1.2 Physical and Mechanical Control

Physical and mechanical control methods such as pulling, grubbing, cutting, girdling, or mowing, can be used on species that do not resprout (e.g., annual grasses or brooms), or can be successfully killed without herbicide. For mechanical methods to be successful, treatments must occur prior to significant seed set in the population, or weed seed must be collected and disposed of properly. These methods utilize a wide array of hand and power tools, including weed wrenches, loppers, handsaws, cordless drills, brush cutters, chain saws, power hedgers, and tractors.

4.1.3 Chemical Control

Herbicide application is another tool that is utilized when mechanical or physical techniques are not effective alone or are not the best treatment option due to possible collateral damage, cost effectiveness, or weather conditions. Whenever feasible, techniques such as cut-stump, drill-and-squirt, hack-and-squirt, glove-of-death, and basal bark application will be used to reduce both drift and the amount of herbicide used in the environment. Herbicides with the lowest EPA rating, “caution” such as Glyphosate, will be preferred to minimize the recognized risks to the applicator. Selective herbicides will be used to treat populations of invasive dicots where native monocots are present. Similarly, herbicides selective for monocots only, will be used as appropriate where invasive grass species grow among desirable dicot plants. A selective

herbicide effective only on thistles (*Asteraceae*) and herbaceous taxa in the pea family *(Fabaceae)* can be used for such invasive plants as *Cynara cardunculus* (artichoke thistle) or *Lathyrus* spp. (sweet pea). Very low rates of a non-selective herbicide such as Glyphosate will be carefully applied to susceptible species found invading robust perennial native vegetation, which should not cause irreparable damage to the native species. Chemicals used to treat invasive plants include, but not limited to alkyl polyglycoside, ammonium sulfate, nitrate, aminopyralid, clopyralid, fluazifop-p-butyl, glyphosate, imazapyr, polydimethylsiloxane, and triclopyr. All herbicides are applied in accordance with the instructions on the product label to ensure safety, effectiveness, and regulatory compliance. All herbicide usage is tracked in an electronic database and reported to LA County on pesticide usage reports.

The three main herbicide delivery systems used by the Conservancy are truck-mounted spray rig, backpack sprayer, and spray or squeeze bottles. A truck-mounted sprayer (150 gallons) can be used when treating roadsides and other areas accessible to these vehicles. Small populations or those found further than the length of the spray-rig hose are usually treated with herbicide contained in a backpack sprayer (typically up to four gallons), lab-style squeeze bottles, or hand spray bottles, ranging in capacity from one-half ounce to one quart.

Handheld bottles are easy to carry and maneuver, especially in dense vegetation and on steep slopes, but they contain a very limited amount of herbicide. Backpack sprayers can carry considerably more herbicide than a spray bottle but are heavy and cumbersome when hiking over rough terrain and thick vegetation. A truck mounted spray rig can hold large amounts of herbicide to treat large infestations. The truck mounted spray rig hose is not as heavy as a backpack sprayer but has a limited range (< 600 feet) and is at times unwieldy. The best container will be selected based on a combination of terrain, vegetation, population size, and weather conditions to ensure safety and efficiency.

4.1.4 Invasive Plant Monitoring and Treatment Schedules

When working in a watershed that has known infestations of priority invasive plant species, weed workers should constantly conduct ad hoc surveys while en route to conduct a treatment. It is important to map all new invasive plant populations using the mapping protocol, and regularly monitor treated populations based on the reproductive life cycle and seasonality. Failing to monitor treated populations consistently will mostly likely result in wasted work if treated plants resprout or seedlings that have germinated from the soil seed bank are allowed to reach reproductive age. Soil seed banks for some species such as Mediterranean broom can remain viable for over 50 years. It is important to know how long each species' seed bank can last, and to monitor all treated populations for that duration of time or longer. Once all above-ground plants of a population have been completely removed, and the site yields no new seedlings, the monitoring schedule can be implemented for each species based on the time it would take a plant to reach reproductive maturity. For example, if it takes fennel (*Foeniculum vulgare*) only six months to produce seed following germination, then a six-month monitoring schedule should be implemented for all treated fennel populations. And a two-year monitoring schedule should be implemented for all treated populations of French broom (*Genista monspessulana*) since it would take two years or more for seedlings to reach reproductive maturity.

With each successive season as soil seed banks are depleted, monitoring of treated populations can be achieved in a shorter amount of time. Once all originally targeted sites have been monitored, new populations can then be addressed within the treatment schedule. It is important to note that consistently monitoring previously treated populations is a key component of an invasive plant management program. Unfortunately, it is often viewed as unnecessary or superfluous, especially when funding is tight, and as such, is usually the first program element to be eliminated. Without monitoring and follow-up treatment, all previous work can be wasted if propagules are allowed to grow and produce more seeds. This resets the "seed bank viability clock" back to zero.

4.2 Geospatial Data Collection SOP

Purpose

This standard operating procedure (SOP) describers how to properly use the Conservancy field smart phones to collect geospatial data in project related web maps using the ESRI ArcGIS Field Maps program.

Responsibilities

- GIS Program Manager: Writes and records data management related SOPS and training videos, notifies field phone users of when to re-download offline areas of web maps, manages web maps and data for QA/QC, provide technical support
- Plant Conservation Manager: Sets goals for plant program field work, distributes data management related SOPs and video trainings
- Plant Ecologist/Conservation Horticulturalist: Use SOP to collect data properly and keep web map offline areas up to date on assigned field phone, assist other staff in proper use of field phones and data collection
- Lead Plant Technician: Use SOP to collect data properly and keep web map offline areas up to date on all Plant Tech field phones, assist techs in proper use of field phones and data collection, ensure data collected is QA/QC checked

Procedure

Before leaving the office:

- Make sure phone is fully charged, bring fully charged portable power bank if possible.
- Sign-in to ArcGIS Field Maps with Conservancy ESRI account (sign in information is saved on a note on the phone home screen if you do not remember).
- Check that the following maps have offline areas downloaded, even if it is not the project you are going into the field for (*you never know when or where you will find a rare or invasive plant*):
    - Invasive Plant 2024 Collection for invasive treatments and surveys
    - Native Plant Master Collection 2024 for native plant surveys
    - Master Restoration Collection for exclosure work and plantings
- If one of the maps above does not have a recent offline area downloaded, hit the three dots next to the map name and choose "Add offline area", then next to "Level of detail" hit the blue text and change it to "Buildings", move the rectangle to cover the entire

island and hit “DOWNLOAD AREA”. NOTE: This may take a while and a few attempts due to slow/spotty internet so if it fails just try it again.

- Once the offline area is downloaded, hit the three dots next to the offline area’s name and choose “Rename area”, change the name to the current date (i.e., 7/25/2024) and remove older offline areas.
- Offline areas should be redownloaded at least once a week.

In the field:

- When beginning surveys, open the ArcGIS Field Maps app and turn on “My tracks”, this helps record what areas have been surveyed and acts as a source of negative data.
- To add data to one of the maps, open the relevant maps and tap the blue plus sign in the bottom right of the screen. This will open a list of feature classes that you can add new features to and changes depending on the map you have open.
- Once the type of feature you are adding to the map has been chosen, a form will present you with a list of forms to fill out, fill all the fields out to the best of your ability (Guidance on the meaning on fields for native and invasive plants will be explained in a separate SOP).
- Make sure the location of the feature you are collecting (particularly points) is centered on your location by hitting the cross hairs in the top right if they appear.
- When ending surveys, return to the main page of the Field Maps app and turn off “Tracks”.

After returning to the office:

- Once reconnected to internet, open each map you collected data in and make sure the data syncs by hitting the circling arrows in the top toolbar and pressing “SYNC NOW” when prompted. NOTE: this may take a while and a few attempts due to slow/spotty internet so if it fails just try it again.
- Close the Field Maps app, turn off the phone, and plug it back into its charger, make sure the portable power banks are plugged in as well.
- Lead Plant Tech should assign someone the duty of QA/QC checking the data through ArcGIS Online that day or on the next office day (QA/QC process is detailed in separate SOP).

Table 2. Feature Classes Available in the "Invasive Plant 2024 Collection" Map.

Feature Class	Use	Note
Invasive treatment point	Relatively small, centralized population of invasive species that have been treated	
Invasive survey point	Relatively small, centralized population of invasive species that have not been treated	
No target point invasive survey	Population of invasive species that was not found during a second targeted survey	
Breadcrumb invasives	Short, general comments concerning invasives not tied to a specific species	
Note point invasives	Specific comment about a single occurrence of an invasive species	
Survey effort line invasives	Records survey time and path	Essentially replaced with the "Tracks" feature for our purposes
Invasive treatment polygon	Larger, dispersed populations of invasive species that have been treated	
Invasive survey polygon	Larger, dispersed populations of invasive species that have not been treated	

Table 3. Feature Classes Available in the "Native Plant Master Collection 2024" Map.

Feature Class	Use	Note
CNPS Historical	Duplicate of "_species_CNPS_merge_2018" layer which shows location of historical plant observations	Do not add new features to this layer, it was added by mistake
Native species point	Relatively small, centralized population of native species	
Breadcrumb	Short, general comments concerning native plants not tied to a specific species	
Note Point	Specific comment about a single occurrence of a native species	
No Target Point	Population of native species that was not found during a second targeted survey	
Tissue Point	Collection of tissue samples from a native plant	
Survey effort line invasives	Records survey time and path	Essentially replaced with the "Tracks" feature for our purposes
Native species polygon	Larger, dispersed populations of native species	

Table 4. Feature Classes Available in the "Master Restoration Collection" Map.

Feature Class	Use	Note
Note Point	Specific comment about a single occurrence of a native species	
Point of Restoration Planting Maintenance Visit	Observations of native plants at restoration sites	
Point of Restoration Planting	Location of new plantings	
Exclosure Repair	Length of repaired sections of fence	
Exclosure need to be repaired	Length of damaged sections of fence	
Polygon of Past Plantings	Location of past plantings	
Polygon of Restoration Planting Maintenance Visit	Observations of native plants at restoration sites	
Polygon Restoration Planting	Location of new plantings	

4.3 Invasive Plant Survey and Treatment SOP

Purpose

This standard operating procedure (SOP) outlines the procedures for conducting safe, effective, and efficient plant surveys and treatments. It combines best management practices for field work with invasive plant management considerations for Conservancy staff and contractors in the field.

Responsibilities

- Plant Conservation Manager: responsible for the overall program workflow
- Plant Program Lead Technician: responsible for ensuring staff compliance with this SOP and that CIPP project staff is trained on this SOP
- Conservation Technicians and Interns: responsible for implementing the SOP

Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) is essential for ensuring the safety of individuals working with herbicides. PPE should be inspected before each use to verify its functionality. The following PPE is mandatory for herbicide application:

1. Sun protection: Sunscreen, sunglasses, and a hat are necessary to protect against harmful UV rays.
2. Eye protection: Use shaded or clear glasses to shield your eyes from potential splashes or debris.
3. Long-sleeved shirt: Reduce skin exposure to chemicals and plants by wearing a long-sleeved shirt.
4. Nitrile gloves: High-quality, flexible gloves with no holes; store dipped gloves and herbicide/nitrile gloves in a ziplock bag (consider bringing an extra pair as a backup).
5. Long pants: Choose pants made of sturdy material that allow for a full range of motion.
6. Sturdy closed-toed shoes: Opt for well-fitted shoes with 8-inch height for ankle protection, non-skid soles, and suitability for the field terrain.
7. Optional: Wear a buff, bandana, or other face covering for additional protection.

Proper use and maintenance of PPE are crucial for minimizing the risk of injury or exposure to chemicals during herbicide application. Always inspect PPE before use and replace any damaged or worn items to ensure maximum effectiveness.

Field Gear

When preparing for fieldwork, in addition to PPE, it is essential to bring the following equipment to ensure safety, efficiency, and data accuracy:

1. Navigation tools: Carry a map, compass, and GPS device for navigation and wayfinding.
2. Communication devices: Bring a cell phone and Walkie-talkie; 2 VHF per team, plus an extra battery; radio call signs. Bring back up signaling devices, including a small mirror and whistle, in case of emergency and other communication devices do not work.

3. First aid kit: Pack a well-stocked first aid kit (fully stocked, non-expired, clean, in Ziplock or H_2O proof baggie) to handle minor injuries and emergencies. Bring any personal medication that is necessary (e.g., Epinephrine autoinjector or EpiPen if you have severe allergies). Bring toilet paper with Ziplock bags to put used paper in, as needed.
4. Weather-appropriate gear: Prepare for various weather conditions with items such as rain gear, extra layers, and insect repellent.
5. Hydration and snacks: Carry ample water (2 liters of water is mandatory; 3 are recommended) and nutrient-dense snacks to maintain energy throughout the day.
6. Data collection tools: Bring any necessary instruments, such as a camera, binoculars, field guides, and data sheets or digital recording devices.
7. Herbicide treatment supplies: In addition to plant specific treatment equipment, bring flagging tape to mark areas where herbicide was used, and an herbicide spill kit. Bring hand wipes and cleaner.
8. Seed collection materials: Bring paper bags/envelopes, Ziploc bags, paper towel, handsaw, and pruners.

Ensuring that you are well-equipped for fieldwork will contribute to a successful and productive experience while promoting personal safety and comfort. Refer to the Conservancy Field Gear Checklist for more details.

General Vehicle Safety and Fire Prevention Precautions

Prioritize safety and vehicle maintenance during fieldwork by adhering to the following guidelines:

1. Vehicle inspection: Before leaving the base yard, ensure your vehicle is equipped with essential safety items such as a fire extinguisher and first aid kit.
2. Parking precautions: Avoid parking on dry grass to minimize fire risk. If necessary, clear the area using a weed whacker before parking.
3. Radio usage: Conserve vehicle battery life by turning on the radio only during extended drives and turning it off when parked.
4. Emergency preparedness: Park the vehicle in a way that allows for easy and swift exit in case of an emergency, avoiding the need for complicated maneuvers.
5. Travel documentation: Accurately record the beginning and end of each trip in the travel log.
6. Regular vehicle maintenance: Routinely check the car sun visor for repair mileage, and notify the Conservation Operations Coordinator when an inspection is due.

By following these procedures, you can help maintain the safety and reliability of our vehicles, ensuring a smooth and efficient fieldwork experience.

Pre-Work Procedure for Surveys or Treatments

To optimize fieldwork efficiency and minimize environmental impact, follow these pre-work procedures:

1. Plan survey routes and locations:
    - Review previous survey and treatment data (e.g., polygons, points, and track lines in the Conservancy geospatial database).
    - Utilize historical data from CIPP crews to inform your approach.
    - Identify potential sensitive native animals or plants and note any areas requiring special attention or avoidance.
    - Bring relevant plant identification guides to aid in accurate plant identification.
    - Prepare for possible seed or cutting collection, and native plant population mapping.
2. Study invasive species in the work area:
    - Ensure proper identification of target invasive species and their various life stages.
    - Consider plants' reproductive strategies, such as vegetative spread or seed/cutting production, and adapt treatment methods accordingly.
3. Review herbicide use:
    - Consult the Herbicide Use Standard Operating Procedure document to address concerns related to:
        - Target plants and appropriate herbicide use.
        - Proximity to riparian habitats and water sources.
        - Potential weather impacts (e.g., extreme temperatures, rain, wind speed, and direction).
        - Necessary personal protective equipment (PPE) for each herbicide.
4. Inspect equipment and vehicles:
    - Thoroughly examine clothes, equipment, and vehicles for invasive plant propagules to prevent accidental spread and cross-contamination.

By adhering to these pre-work procedures, you can contribute to the successful management of invasive species while ensuring the preservation of native plants and sensitive ecosystems.

Field Work Procedure for Surveys or Treatments

To ensure effective fieldwork execution, follow these guidelines:

1. Activate tracking in Field Maps:
    - Enable tracks upon arrival to the site to aid data management and estimate surveyed acres.

- Accurate tracking provides valuable information on areas without invasive species.

2. Assess environmental conditions:
    - Survey the area for potential entry points, water sources, sensitive vegetation, and historical/cultural resources.
    - Minimize adverse impacts by following Invasive Plant Management Principles:
        - Evaluate invasion stages (colonization, establishment, expansion) and population size.
        - Target large populations from the outside in to prevent re-expansion.
        - Begin at the top of watersheds or upwind areas to avoid reinfestation.
        - On steep slopes, start at the far end and work back towards the exit.
        - Avoid moving through infestations to prevent further spread.
3. Survey native and invasive species:
    - Use Field Maps to record point features for clustered or small single-species populations.
    - Provide patch size estimates for points (survey or treatment).
    - Use polygon features for dispersed populations, increased accuracy of dispersal extent, or multiple species in a defined area.
4. Document herbicide use:
    - Record herbicide application details in real-time to streamline data entry in Microsoft Teams.
5. Conduct photo monitoring:
    - Capture images to document vegetation changes and guide future management efforts.
    - Include both short-term (before and after) and long-term monitoring scenarios with dedicated GIS points, server folders, and standardized procedures.
6. Capture relevant photos:
    - Document invasive plant removal, fieldwork, browsing on native plants, and unique findings.
    - Upload general photos to the designated server folder.
    - Contribute species-specific images to appropriate plant photo folders.
7. Collect plant vouchers:
    - When properly trained on the Specimen Collection SOP, gather plant specimens for the herbarium.

- Refer to the server for a list of needed specimens and detailed collection instructions.
- Handle unknown invasive specimens carefully, storing them in an airtight Ziploc bag or documenting them with photos.

By adhering to these procedures, you can contribute to the successful management and monitoring of invasive species while minimizing environmental impact.

Post-Work Procedure for Surveys or Treatments

To maintain environmental safety and facilitate efficient follow-up work, follow these post-fieldwork procedures:

1. Site flagging:
    - Clearly mark treated areas, particularly if herbicides were applied near high-traffic locations.
    - This helps to prevent accidental exposure and alerts others to the recent treatment.
2. Inspect equipment and vehicles:
    - Thoroughly examine clothes, equipment, and vehicles for invasive plant propagules before leaving the site.
    - This precaution reduces the risk of spreading invasives to new locations.
3. Assess the need for follow-up work:
    - Document in Field Maps if additional surveys or treatments are required, considering factors such as:
        - The necessity of multiple monitoring surveys for specific species throughout the season.
        - Remaining plants or propagules in the survey area that need attention.
4. Deactivate tracking:
    - Turn off tracks upon returning to the vehicle to maintain accurate data and conserve battery life.

By adhering to these guidelines, you contribute to the safe and responsible management of invasive species while ensuring the effectiveness of ongoing monitoring and treatment efforts.

This SOP may be updated at any time during the year; minimally, the SOP should be reviewed annually by those whose work is covered by the SOP.

4.4 Invasive Plant Database Data Entry SOP

Purpose

This standard operating procedure (SOP) is to ensure accurate reporting of all Invasive Plant Project management activities. A database entry needs to be completed at the end of each field day. Much of the survey and treatment information can be completed prior to finishing the GIS data entry for the day, but some data, for example acreage, it will need to be filled in after the GIS data is completed. Failure to comply with this SOP will result in incomplete and incorrect data and reporting. If you have questions, please ask Plant Conservation Manager or Plant Program Lead Technician.

Responsibilities

- Plant Conservation Manager: Distributes SOP and trains staff, interns and volunteers on how to use database. Updates database with new data definitions as needed. Completes quality analysis and quality control in the database to ensure data entry protocols and procedures are being followed. Creates monthly, quarterly and annual reports using database data.
- Plant Program Lead Technician: Trains technicians and interns in Database SOP. Updates Database with new data definitions as needed. Completes quality analysis and quality control in the database to ensure proper entry by self and others.
- Conservation Technicians and Interns: At the end of each field day collect field notes from other interns/technicians. Complete daily database entry. Entries should be updated before the end of day to ensure no information is missed or forgotten.

Data Entry Protocol

The data entered in each invasive plant database form in Microsoft Access reflects data collected and entered into the geospatial database (e.g., ArcGIS Field Maps). The Access database allows for a flexible reporting function as well as more detail and interpretation of the work conducted, and data collected.

Please note: if work was conducted in multiple watersheds in the same day, then please create an entry for each watershed management unit.

- **Date:** the date the management activity took place (often the current day).
- **Location1:** drop down of watersheds, select correct one.
- **Specific location:** provide as much details of the area managed as possible. Reference roads, land marks, trails, or elevation or ridges. Ex: “Drainage from Cotton Dam Rd to Cottonwood beach” or “5th ridge SW of Disappoint Spur off U Coffeepot Rd”
    - Or if you worked in multiple WMUs that day list them here
- **Grant #:** is filled in to show what grant is funding the project work. If unsure of the whether or not it is a grant specific project, ask Plant Program Lead Technician or Plant Conservation Manager.
- **Survey Acres:** is the total number of acres surveyed within that specific watershed. If you surveyed in multiple watersheds you must make a survey polygon for each watershed in order to calculate survey acres for the individual watersheds.

- **Species 1:** primary target species for the day or the species with the highest density of plants and / or treatment effort.
- **Manual Treatment:** drop down selection. Select 'None" if no manual treatment occurred.
- **Herbicide 1:** drop down selection. Select 'None" if no chemical treatment occurred.
- **Herbicide Method 1:** drop down selection. Select 'None" if no chemical treatment occurred.
- **Oz Herbicide 1:** Herbicide amounts reflect the amount of mixed herbicide, not the total amount of concentrated herbicide used. You are estimating, so leaving the conversion to the hundredths implies an accuracy that isn't there! Insert a zero (0) if no herbicide was used or no treatment occurred.
- **Treatment 1 Acres:** calculate using the ArcMap All_Species attributes table data. The Statistics tool (right click on Acres column) tallies the acres for multiple lines per species if you use the selection function.
- **Mature 1:** tally of mature Species 1 individuals (mature plants are individuals with reproductive parts present: flowers, fruits, buds &/or very large specimens that have reproductive capacity in the past). Plant count is for treated plants ONLY.
- **Immature 1:** tally of immature Species 1 individuals (immature plants are individuals without reproductive parts present, sometimes with cotyledon leaves present). Plant count is for treated plants ONLY.
- Follow the instructions above for **Species 2, Species 3, etc**. The higher the number should represent less plants treated or even surveillance only work effort. If more than 6 plants were surveyed for and / or treated, create a new database entry for them.
- **Work hours**: account for hours spent on management for each watershed. Include prep time at base yard and commute time. PPLT = plant program lead technician. Split work hours b/w watersheds if crew worked in multiple WMUs during the day. *Do NOT forget to total the hours.*
- **Comments**:
    - Crew initials
    - Plants Found: six (6) letter species code for each plant that was found
    - For each species surveyed for and / or treated, please provide information on population, for example if the plants were heavily browsed, if they were seeding, or may need to retreated for some reason.
    - Provide details on the survey work – was the survey completed? Was the vegetation dense or fairly open? Do we need to resurvey soon? Was it sunny, raining, windy? Was there something you didn't have that should be brought the next time? Anything unusual like a squirrel attack? The comment section is a good place to mention other invasives or natives you noticed but did not work on.
    - Think about what you wish you would have known prior to the survey! Remember: these notes, along with GIS polygons and photos, are all future crews have to go off of!

    - Access point information: put in details of how to best access the survey site, where to park, safety issues to look out for. For example, “Do not attempt to walk back up South ridgeline because you will get cliffed out.”
    - Mention ALL safety issues, even if it wasn’t an issue for you. Drop GPS waypoints on “waterfalls” and other hazards then save in the “Misc” folder when you get back to the office.
- **Final step:** save your work! Save the database!

For reference, here are some example comments that might be entered in the database:

- BJD SO ORR JMC Plants Found: GENLIN, SILMAR
- GENLIN: Survey tx; numerous populations in and on either side of the main drainage that serves Cottonwood beach. Many matures already set seed. Otherwise, they were mostly saplings.
- SILMAR: Survey; a few populations near previous treatment polygons that had already set seed and died back. Some new populations were also treated.
- ARUDON: Survey; none found.
- TETTET: Survey; historic pops on cottonwood beach still thriving. Only one surveillance polygon was created although we did see it on both sides of drg where polygons were created in 2016.
- Notes: We left MR by 7:45am and started our survey around 8:15am. We parked one truck at Cottonwood Beach and then drove up and down into Cottonwood Dam Rd and parked there. That’s where we started our survey. We surveyed the drainage and surrounding area from Cottonwood Dam road going westward. We had to survey on either side of the drainage to get past the actual Cottonwood Dam, but that was not too difficult. There were, however, several areas of dense vegetation that we had to survey through, and several spots within the drainage area that were heavily infested with poison oak. Gaps in survey polygon were due to two factors: we surveyed the roadsides while walking to and from the drainage, and often could not see to our other survey line in the drg, and we ran into a bison in the middle of the drg and had to chase him out so we could continue towards the beach. Large CA sycamores were naturalized in the drainage, too, although we did not map them. Overall survey was pretty easy but the dense pockets and poison oak and bison threw some challenges our way. We finished the survey at Cottonwood Beach around 2:15pm, then drove back for the other truck in Cottonwood Dam Rd, then returned to MR by 3pm ish.

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Appendix B

Catalina Island Plant List

Table B-1. Catalina Island Plant List.

The list provided by the Catalina Island Conservancy in 2023 includes current known plant species found on Santa Catalina Island. This list excludes species native to the island but now extirpated, ornamental vegetation in developed areas, and invasive species without established populations that have been removed in past control efforts. Introduced species are marked with an asterisk (*) before their scientific names.

FERNS AND FERN ALLIES

Family	Scientific Name	Common Name
Azollaceae	*Azolla filiculoides* Lam.	Mosquito fern
Blechnaceae	*Woodwardia fimbriata* Sm.	Giant chain fern
Cyatheaceae	**Sphaeropteris cooperi* (Hook. ex F. Muell.) R.M. Tryon	Scaly tree fern
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Kuhn var. pubescens Underw.	Western bracken
Dryopteridaceae	*Dryopteris arguta* (Kaulf.) Maxon	Wood fern
Equisetaceae	*Equisetum hyemale* L. subsp. affine (Engelm.) Calder & Roy L. Taylor	Common scouring rush
	Equisetum laevigatum A. Braun	Smooth scouring rush
	Equisetum telmateia Ehrh. subsp. *braunii* (J. Milde) Hauke	Giant horsetail
Ophioglossaceae	*Ophioglossum californicum* Prantl	California adder's-tongue
Polypodiaceae	*Polypodium californicum* Kaulf.	California polypody
Pteridaceae	*Adiantum capillus-veneris* L.	Southern maidenhair
	Adiantum jordanii Müll. Hal.	California maidenhair
	Aspidotis californica (Hook.) Copel.	California lace fern
	Notholaena californica D.C. Eaton	California cloak-fern
	Pellaea andromedifolia (Kaulf.) Fée	Coffee fern
	Pellaea mucronata (D.C. Eaton) D.C. Eaton	Bird's-foot fern
	Pentagramma triangularis (Kaulf.) Yatsk. et al. subsp. *triangularis*	Goldback fern
	Pentagramma triangularis (Kaulf.) Yatsk. et al. subsp. *viscosa* (D.C. Eaton) Yatsk. et al.	Silverback fern
Selaginellaceae	*Selaginella bigelovii* Underw.	Bigelow's spike-moss

GYMNOSPERMS

Family	Scientific Name	Common Name
Cupressaceae	**Calocedrus decurrens* (Torr.) Florin	Incense cedar
	**Hesperocyparis macrocarpa* (Hartw.) Bartel	Monterey cypress
	**Hesperocyparis stephensonii* (C.B. Wolf) Bartel	Cuyamaca cypress
Pinaceae	**Cedrus deodara* (Roxb. ex D. Don) G. Don f.	Deodar cedar
	**Pinus attenuata* Lemmon	Knobcone pine
	**Pinus canariensis* C. Smith ex DC	Canary Island pine
	**Pinus coulteri* D. Don	Coulter pine
	**Pinus halepensis* P. Mill.	Aleppo pine
	**Pinus muricata* D. Don	Bishop pine
	**Pinus pinea* L.	Italian stone pine
	**Pinus radiata* D. Don	Monterey pine
	**Pinus torreyana* Carrière subsp. *insularis* J.R. Haller	Santa Rosa Island torrey pine

ANGIOSPERMS

Magnoliids

Family	Scientific Name	Common Name
Saururaceae	*Anemopsis californica* (Nutt.) Hook. & Arn.	Yerba mansa

Monocots

Family	Scientific Name	Common Name
Agavaceae	**Agave americana* L.	American century plant
	Chlorogalum pomeridianum (DC.) Kunth	Soap plant
Alliaceae	*Allium praecox* Brandegee	Wild onion, Early onion
Arecaceae	**Phoenix canariensis* Chabaud	Canary Island palm
	**Washingtonia robusta* H. Wendl.	Mexican fan palm
Asparagaceae	**Asparagus asparagoides* (L.) Druce	Asparagus
	**Asparagus officinalis* L. subsp. *officinalis*	Garden asparagus
Cyperaceae	*Bolboschoenus maritimus* (L.) Palla subsp. *paludosus* (A. Nelson) T. Koyama	Saltmarsh bulrush, Alkali bulrush
	Bolboschoenus robustus (Pursh) Soják	Seacoast bulrush
	Carex globosa Boott	Round-fruited sedge
	Carex praegracilis W. Boott	Freeway sedge
	Carex triquetra Boott	Trigonous sedge
	Carex tumulicola Mack.	Foothill sedge
	Cyperus eragrostis Lam.	Tall flatsedge
	Cyperus esculentus L. var. *leptostachyus*	Yellow nutgrass
	Cyperus odoratus L.	Fragrant flatsedge
	Eleocharis macrostachya Britton	Creeping spike-rush
	Schoenoplectus americanus (Pers.) Schinz & R. Keller	Olney's three-square bulrush
	Schoenoplectus pungens (Vahl) Palla var. *longispicatus* (Britton) S.G. Sm.	Common three-square bulrush
	Scirpus microcarpus J. Presl & C. Presl	Small fruit bulrush
Iridaceae	*Sisyrinchium bellum* S. Watson	Western blue-eyed-grass
Juncaceae	*Juncus acutus* L. subsp. *leopoldii* (Parl.) Snogerup	Southwestern spiny rush
	Juncus balticus Willd. subsp. *ater* (Rydb.) Snogerup	Baltic rush
	Juncus bufonius L. var. *bufonius*	Toad rush
	Juncus mexicanus Willd.	Mexican rush
	Juncus textilis Buchenau	Basket rush
	Juncus xiphioides E. Mey.	Iris-leaved rush
Liliaceae	*Calochortus albus* (Benth.) Benth.	Fairy-lantern
	Calochortus catalinae S. Watson	Catalina mariposa lily
	Calochortus splendens Benth.	Lilac mariposa
Orchidaceae	*Epipactis gigantea* Hook.	Stream orchid
	Piperia cooperi (S. Watson) Rydb.	Chaparral rein-orchid
	Piperia elongata Rydb.	Chaparral orchid
	Piperia unalascensis (Spreng.) Rydb.	Slender-spire orchid

Family	Scientific Name	Common Name
Poaceae	*Agrostis exarata* Trin.	Spike bent grass
	Agrostis pallens Trin.	Dune bent grass
	**Agrostis stolonifera* L.	Creeping bent
	**Aira caryophyllea* L.	Silver hair grass
	Andropogon glomeratus (Walter) Britton et al. var. *scabriglumis* C.S. Campb.	Southwestern bushy bluestem
	Aristida adscensionis L.	Sixweeks three-awn
	**Arundo donax* L.	Giant reed
	**Avena barbata* Link	Slender wild oat
	**Avena fatua* L.	Wild oat
	**Avena sativa* L.	Cultivated oat
	Bothriochloa barbinodis (Lag.) Herter	Cane bluestem
	**Brachypodium distachyon* (L.) P. Beauv.	False brome
	**Briza minor* L.	Annual quaking grass
	Bromus arizonicus (Shear) Stebbins	Arizona brome
	**Bromus berteroanus* Colla	Chilean chess
	Bromus carinatus Hook. & Arn.	California brome
	**Bromus catharticus* Vahl	Rescue grass
	**Bromus diandrus* Roth	Ripgut brome
	**Bromus hordeaceus* L.	Soft chess
	Bromus laevipes Shear	Woodland brome
	**Bromus madritensis* L. subsp. *rubens* (L.) Husn.	Red brome
	Bromus pseudolaevipes Wagnon	Coast range brome
	**Bromus sterilis* L.	Poverty brome
	**Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn.	Pampas grass
	**Crypsis vaginiflora* (Forssk.) Opiz	Modest prickle grass
	**Cynodon dactylon* (L.) Pers.	Bermuda grass
	**Dactylis glomerata* L.	Orchard grass
	**Dactyloctenium aegyptium* (L.) Willd.	Durban crowfoot
	**Desmazeria rigida* (L.) Tutin	
	Dissanthelium californicum (*Poa thomasii* Refulio)	California dissanthelium
	Distichlis littoralis (Engelm.) H.L. Bell & Columbus	Shore grass
	Distichlis spicata (L.) Greene	Salt grass
	**Ehrharta calycina* Sm.	Perennial veldt grass
	**Ehrharta erecta* Lam.	Panic veldt grass
	Elymus condensatus J. Presl	Giant wild-rye
	Elymus glaucus Buckley	Blue wild-rye, Western wild-rye
	Elymus multisetus (J.G. Sm.) Burtt Davy	Big squirreltail
	Elymus triticoides Buckley	Beardless wild rye
	**Festuca arundinacea* Schreb.	Tall fescue
	**Festuca bromoides* L.	Brome fescue
	Festuca microstachys Nutt.	Small fescue
	**Festuca myuros* L.	Rattail sixweeks grass
	Festuca octoflora Walter	Sixweeks grass

Family	Scientific Name	Common Name
Poaceae	**Festuca perennis* (L.) Columbus & J.P. Sm.	English ryegrass, Perennial ryegrass
	**Festuca temulenta* (L.) Columbus & J.P. Sm.	Darnel
	**Gastridium phleoides* (Nees & Meyen) C.E. Hubb.	Nit grass
	**Hainardia cylindrica* (Willd.) Greuter	Barb grass
	Hordeum brachyantherum Nevski subsp. *californicum* (Covas & Stebbins) Bothmer et al.	California barley
	Hordeum intercedens Nevski	Bobtail barley
	**Hordeum marinum* Huds. subsp. *gussoneanum* (Parl.) Thell.	Mediterranean barley
	**Hordeum murinum* L. subsp. *glaucum* (Steud.) Tzvelev	Smooth barley
	**Hordeum murinum* L. subsp. *leporinum* (Link) Arcang.	Hare barley
	**Hordeum murinum* L. subsp. *murinum*	Wall barley
	**Hordeum vulgare* L.	Common barley
	**Lamarckia aurea* (L.) Moench	Goldentop
	Melica imperfecta Trin.	Little California melica
	Muhlenbergia microsperma (DC.) Kunth	Littleseed muhly
	**Panicum capillare* L.	Witchgrass
	**Parapholis incurva* (L.) C.E. Hubb.	Sickle grass
	**Paspalum dilatatum* Poir.	Dallis grass
	Paspalum distichum L.	Knot grass
	**Pennisetum clandestinum* Chiov.	Kikuyu grass
	**Pennisetum setaceum* (Forssk.) Chiov.	Fountaingrass
	**Phalaris aquatica* L.	Harding grass
	**Phalaris canariensis* L.	Canary grass
	**Phalaris caroliniana* Walter	Carolina canary grass
	Phalaris lemmonii Vasey	Lemmon's canary grass
	**Phalaris minor* Retz.	Little-seeded canary grass
	**Phalaris paradoxa* L.	Hood canary grass
	**Poa annua* L.	Annual blue grass
	Poa secunda J. Presl subsp. *secunda*	One-sided blue grass
	**Polypogon interruptus* Kunth	Ditch beard grass
	**Polypogon monspeliensis* (L.) Desf.	Rabbitfoot grass
	**Polypogon viridis* (Gouan) Breistr.	Water beard grass
	**Schismus arabicus* Nees	Arabian grass
	**Schismus barbatus* (L.) Thell.	Mediterranean grass
	**Sorghum bicolor* (L.) Moench	Sorghum
	Stipa cernua Stebbins & Love	Nodding needle grass
	Stipa lepida Hitchc.	Foothill needle grass
	**Stipa miliacea* (L.) Hoover var. miliacea	Smilo grass
	Stipa pulchra Hitchc.	Purple needle grass
	**Stipa tenuissima* Trin.	Mexican feathergrass

Family	Scientific Name	Common Name
Potamogetonaceae	**Potamogeton crispus* L.	Crisp-leaved pondweed
	Stuckenia pectinata (L.) Börner	Fennel-leaf pondweed
Ruppiaceae	*Ruppia maritima* L.	Ditch-grass
Themidaceae	*Bloomeria crocea* (Torr.) Coville	Common goldenstar
	Brodiaea jolonensis Eastw.	Chaparral cluster-lily
	Dichelostemma capitatum (Benth.) Alph. Wood subsp. *capitatum*	Blue dicks
Typhaceae	*Typha domingensis* Pers.	Southern cattail
	Typha latifolia L.	Broad-leaved cattail
Zosteraceae	*Phyllospadix scouleri* Hook.	Surf-grass
	Phyllospadix torreyi S. Watson	Torrey's surf-grass
	Zostera marina L.	Eel grass
	Zostera pacifica S. Watson	Pacific eel grass
Eudicots		
Adoxaceae	*Sambucus mexicana*	Blue elderberry
Aizoaceae	**Aptenia cordifolia* (L. f.) Schwantes	Baby sun-rose
	**Carpobrotus chilensis* (Molina) N.E. Br.	Sea fig
	**Carpobrotus edulis* (L.) N.E. Br.	Freeway iceplant
	**Mesembryanthemum crystallinum* L.	Crystalline iceplant
	**Mesembryanthemum nodiflorum* L.	Slender-leaved iceplant
	**Tetragonia tetragonioides* (Pall.) Kuntze	New Zealand spinach
Amaranthaceae	**Amaranthus albus* L.	Tumbleweed
	**Amaranthus deflexus* L.	Low amaranth
Anacardiaceae	*Malosma laurina* (Nutt.) Abrams	Laurel sumac
	Rhus integrifolia (Nutt.) Rothr.	Lemonade berry
	Rhus integrifolia x *ovata*	Hybrid sugar bush
	Rhus ovata S. Watson	Sugar bush
	**Schinus molle* L.	Peruvian pepper tree
	**Schinus terebinthifolius* Raddi	Brazilian pepper tree
	Toxicodendron diversilobum (Torr. & A. Gray) Greene	Poison oak
Apiaceae	*Apiastrum angustifolium* Nutt.	Wild celery
	Bowlesia incana Ruiz & Pav.	Bowlesia
	Daucus pusillus Michx.	Rattlesnake weed
	**Foeniculum vulgare* Mill.	Fennel
	Sanicula arguta J.M. Coult. & Rose	Sanicle
	Sanicula crassicaulis DC.	Pacific sanicle
	**Torilis arvensis* (Huds.) Link	
	**Torilis nodosa* (L.) Gaertn.	knotted hedge-parsley
	Yabea microcarpa (Hook. & Arn.) Koso-Pol.	Caucalis
Apocynaceae	*Asclepias fascicularis* Decne.	Narrow-leaf milkweed
	Funastrum cynanchoides (Decne.) Schltr. var. *hartwegii* (Vail) Krings	Climbing milkweed
	**Vinca major* L.	Greater periwinkle

Family	Scientific Name	Common Name
Asteraceae	*Achillea millefolium* L.	Yarrow
	Achyrachaena mollis Schauer	Blow-wives
	Acourtia microcephala DC.	Perezia, Sacapellote
	Amblyopappus pusillus Hook. & Arn.	Coast weed, Pineapple weed
	Ambrosia acanthicarpa Hook.	Annual bur-sage
	Ambrosia chamissonis (Less.) Greene	Beach bur-sage
	Ambrosia psilostachya DC.	Western ragweed
	**Anthemis cotula* L.	Mayweed
	Artemisia californica Less.	California sagebrush
	Artemisia douglasiana Besser	Mugwort
	Artemisia dracunculus L.	Tarragon
	Baccharis glutinosa Pers.	Marsh baccharis
	Baccharis pilularis DC. subsp. *consanguinea* (DC.) C.B. Wolf	Coyote brush
	Baccharis salicifolia (Ruiz & Pav.) Pers. subsp. *salicifolia*	Mule fat
	Baccharis salicina Torr. & A. Gray	Emory baccharis
	Baccharis sarothroides A. Gray	Broom baccharis
	Brickellia californica (Torr. & A. Gray) A. Gray	California brickellbush
	**Carduus pycnocephalus* L. subsp. *pycnocephalus*	Italian thistle
	**Centaurea cineraria* L.	Dusty miller
	**Centaurea melitensis* L.	Tocalote
	**Centaurea solstitialis* L.	Yellow star-thistle
	Centromadia pungens (Hook. & Arn.) Greene subsp. *pungens*	Common spikeweed
	Cirsium occidentale (Nutt.) Jeps. var. *californicum* (A. Gray) D.J. Keil & C.E. Turner	California thistle
	Cirsium occidentale (Nutt.) Jeps. var. *occidentale*	Cobwebby thistle
	**Cirsium vulgare* (Savi) Ten.	Bull thistle
	Constancea nevinii (A. Gray) B.G. Baldwin	Nevin's woolly sunflower
	Corethrogyne filaginifolia (Hook. & Arn.) Nutt.	Cud-weed aster
	**Cotula australis* (Spreng.) Hook. f.	Australian brass-buttons
	**Cotula coronopifolia* L.	Brass-buttons
	**Crepis setosa* Haller f.	Bristly hawksbeard
	**Cynara cardunculus* L. subsp. *flavescens* Wiklund	Artichoke thistle
	Deinandra clementina (Brandegee) B.G. Baldwin	Island tarplant
	Deinandra fasciculata (DC.) Greene	Common tarplant
	**Delairea odorata* Lem.	German ivy
	Encelia californica Nutt.	Bush sunflower
	Ericameria palmeri (A. Gray) H.M. Hall var. *pachylepis* (H.M. Hall) G.L. Nesom	Palmer's goldenbush
	**Erigeron bonariensis* L.	Flax-leaved fleabane
	**Erigeron canadensis* L.	Horseweed
	Erigeron foliosus Nutt. var. *foliosus*	Leafy fleabane

Family	Scientific Name	Common Name
Asteraceae	*Eriophyllum confertiflorum* (DC.) A. Gray var. *confertiflorum*	Golden-yarrow
	Euthamia occidentalis Nutt.	Western goldenrod
	Gamochaeta ustulata (Nutt.) Holub	Purple cudweed
	**Glebionis coronaria* (L.) Spach	Garland, Crown daisy
	Gnaphalium palustre Nutt.	Lowland cudweed
	Grindelia camporum Greene	Robust gumplant
	Hazardia squarrosa (Hook. & Arn.) Greene var. *grindelioides* (DC.) W.D. Clark	Saw-toothed goldenbush
	**Hedypnois cretica* (L.) Dum. Cours.	Crete weed
	Helenium puberulum DC.	Sneezeweed
	**Helminthotheca echioides* (L.) Holub	Bristly ox-tongue
	Heterotheca grandiflora Nutt.	Telegraph weed
	**Hypochaeris glabra* L.	Smooth cat's-ear
	**Hypochaeris radicata* L.	Rough cat's-ear
	Isocoma menziesii (Hook. & Arn.) G.L. Nesom var. *decumbens* (Greene) G.L. Nesom	Decumbent goldenbush
	Isocoma menziesii (Hook. & Arn.) G.L. Nesom var. *menziesii*	Menzies coast goldenbush
	Isocoma menziesii (Hook. & Arn.) G.L. Nesom var. *sedoides* (Greene) G.L. Nesom	Prostrate coastal goldenbush
	Isocoma menziesii (Hook. & Arn.) G.L. Nesom var. *vernonioides* (Nutt.) G.L. Nesom	Coast goldenbush
	Jaumea carnosa (Less.) A. Gray	Jaumea
	**Lactuca saligna* L.	Willow lettuce
	**Lactuca serriola* L.	Prickly lettuce
	Laënnecia coulteri (A. Gray) G.L. Nesom	Coulter's horseweed
	Lasthenia gracilis (DC.) Greene	Common goldfields
	Layia platyglossa (Fisch. & C.A. Mey.) A. Gray	Tidy-tips
	Leptosyne gigantea Kellogg	Giant coreopsis
	Logfia arizonica (A. Gray) Holub	Arizona cottonrose
	Logfia filaginoides (Hook. & Arn.) Morefield	California cottonrose
	**Logfia gallica* (L.) Coss. & Germ.	Daggerleaf cottonrose
	Madia elegans D. Don	Common madia
	Madia exigua (Sm.) A. Gray	Threadstem madia/tarweed
	Madia gracilis (Sm.) Applegate	Gumweed
	Madia sativa Molina	Coast tarweed
	Malacothrix saxatilis (Nutt.) Torr. & A. Gray var. *tenuifolia* (Nutt.) A. Gray	Cliff aster
	**Matricaria discoidea* DC.	Pineapple weed
	Matricaria occidentalis Greene	Valley mayweed
	Micropus californicus Fisch. & C.A. Mey. var. *californicus*	slender cottonweed
	Microseris douglasii (DC.) Sch. Bip. subsp. *platycarpha* (A. Gray) K.L. Chambers	Small-flowered microseris
	Pentachaeta lyonii A. Gray	Lyon's pentachaeta
	Perityle emoryi Torr.	Emory's rock daisy

Family	Scientific Name	Common Name
Asteraceae	*Pluchea odorata* (L.) Cass. var. *odorata*	Saltmarsh fleabane
	Pluchea sericea (Nutt.) Coville	Arrow-weed
	Pseudognaphalium beneolens (Davidson) Anderb.	Fragrant everlasting
	Pseudognaphalium biolettii Anderb.	Two-tone everlasting, Bicolored everlasting
	Pseudognaphalium californicum (DC.) Anderb.	California everlasting, Green everlasting
	Pseudognaphalium canescens (DC.) Anderb.	
	**Pseudognaphalium luteoalbum* (L.) Hilliard & B.L. Burtt	Weedy cudweed
	Pseudognaphalium microcephalum (Nutt.) Anderb.	Felt-leaf everlasting, White everlasting
	Pseudognaphalium stramineum (Kunth) Anderb.	Cotton-batting
	Psilocarphus tenellus Nutt.	Slender woolly-marbles
	**Pulicaria paludosa* Link	False-fleabane
	Rafinesquia californica Nutt.	California chicory
	Senecio aphanactis Greene	Chaparral ragwort
	Senecio flaccidus Less. var. *douglasii* (DC.) B.L. Turner & T.M. Barkley	Douglas' threadleaf ragwort
	Senecio lyonii A. Gray	Island senecio
	**Senecio vulgaris* L.	Common groundsel
	**Silybum marianum* (L.) Gaertn.	Milk thistle
	Solidago velutina DC. subsp. *californica* (Nutt.) Semple	California goldenrod
	**Soliva sessilis* Ruiz & Pav.	Spur weed
	**Sonchus asper* (L.) Hill subsp. *asper*	Prickly sow thistle
	**Sonchus oleraceus* L.	Common sow thistle
	**Sonchus tenerrimus* L.	Slender sow thistle
	Stebbinsoseris heterocarpa (Nutt.) K.L. Chambers	Grassland silverpuffs
	Stephanomeria diegensis Gottlieb	San Diego wreath plant, San Diego milk-aster
	Stephanomeria exigua Benth. ssp. *coronaria*	White plume wirelettuce
	Stephanomeria virgata Benth. subsp. *virgata*	Wand chicory
	Stylocline gnaphaloides Nutt.	Everlasting neststraw
	Symphyotrichum subulatum (Michx.) G.L. Nesom	Annual saltmarsh aster
	**Taraxacum officinale* F.H. Wigg.	Common dandelion
	**Tragopogon porrifolius* L.	Salsify, oyster plant
	Uropappus lindleyi (DC.) Nutt.	Silverpuffs
	**Xanthium spinosum* L.	Spiny cocklebur
	**Xanthium strumarium* L.	Cocklebur
Bataceae	*Batis maritima* L.	Saltwort, Beachwort
Boraginaceae	*Amsinckia intermedia* Fisch. & C.A. Mey.	Common fiddleneck
	Amsinckia menziesii (Lehm.) A. Nelson & J.F. Macbr.	Small-flowered fiddleneck
	Cryptantha clevelandii Greene	Cleveland's cryptantha
	Cryptantha intermedia (A. Gray) Greene	White forgive-me-not
	Cryptantha maritima (Greene) Greene	Guadalupe cryptantha

Family	Scientific Name	Common Name
Boraginaceae	*Cryptantha microstachys* (A. Gray) Greene	Tejon cryptantha
	Cryptantha wigginsii I.M. Johnst.	Wiggins' cryptantha
	Harpagonella palmeri A. Gray	Palmer's grapplinghook
	Johnstonella micromeres (A. Gray) Hasenstab & M.G. Simpson	Minute-flowered cryptantha
	Pectocarya linearis (Ruiz & Pav.) DC. subsp. *ferocula* (I.M. Johnst.) Thorne	Narrow-toothed pectocarya
	Pectocarya penicillata (Hook. & Arn.) A. DC.	Northern pectocarya
	Plagiobothrys acanthocarpus (Piper) I.M. Johnst.	Adobe popcornflower
	Plagiobothrys canescens Benth.	Popcorn flower
	Plagiobothrys collinus (Phil.) I.M. Johnst. var. *fulvescens* (I.M. Johnst.) Higgins	Rough-stemmed popcornflower
	Plagiobothrys collinus (Phil.) I.M. Johnst. var. *gracilis* (I.M. Johnst.) Higgins	San Diego popcornflower
	Plagiobothrys nothofulvus (A. Gray) A. Gray	Rusty popcornflower
Brassicaceae	*Athysanus pusillus* (Hook.) Greene	Athysanus
	**Brassica nigra* (L.) W.D.J. Koch	Black mustard
	**Brassica rapa* L.	Yellow field mustard
	**Cakile maritima* Scop.	Sea rocket
	**Capsella bursa-pastoris* (L.) Medik.	Shepherd’s purse
	Cardamine californica (Nutt.) Greene	Milk maids
	**Cardamine oligosperma* Nutt.	Bitter-cress
	Caulanthus lasiophyllus (Hook. & Arn.) Payson	California mustard
	Descurainia pinnata (Walter) Britton	Tansy mustard
	Draba cuneifolia Torr. & A. Gray	Whitlow-grass
	**Erysimum cheiri* (L.) Crantz	Wallflower
	**Hirschfeldia incana* (L.) Lagr.-Fossat	Shortpod mustard
	**Lepidium didymum* L.	Lesser swine cress
	**Lepidium draba* L.	Hoary cress
	Lepidium lasiocarpum Nutt. subsp. *lasiocarpum*	Hairy peppergrass
	Lepidium latipes Hook.	Dwarf peppergrass
	Lepidium nitidum Nutt.	Shining peppergrass
	Lepidium oblongum Small	Island peppergrass, Lentejilla
	**Lepidium strictum* (S. Watson) Rattan	
	**Lepidium virginicum* L. subsp. *menziesii* (DC.) Thell.	Bird’s peppergrass
	**Lobularia maritima* (L.) Desv.	Sweet alyssum
	**Nasturtium officinale* W.T. Aiton	Water cress
	**Raphanus raphanistrum* L.	Jointed charlock
	**Raphanus sativus* L.	Radish
	Sibara filifolia (Greene) Greene	Santa Cruz Island rockcress
	**Sinapis arvensis* L.	Charlock
	**Sisymbrium altissimum* L.	Tumble mustard
	**Sisymbrium irio* L.	London rocket
	**Sisymbrium officinale* (L.) Scop.	Hedge mustard

Family	Scientific Name	Common Name
Brassicaceae	**Sisymbrium orientale* L.	Oriental mustard
	Thysanocarpus curvipes Hook.	Hairy lacepod
	Thysanocarpus laciniatus Nutt.	Fringepod, Narrow-leaved lacepod
	Tropidocarpum gracile Hook.	Dobie pod
	Turritis glabra L.	Tower mustard
Cactaceae	*Bergerocactus emoryi* (Engelm.) Britton & Rose	Velvet cactus
	Cylindropuntia prolifera (Engelm.) F.M. Knuth	Coast cholla
	Opuntia engelmannii Engelm. var. engelmannii	Engelmann prickly-pear
	**Opuntia ficus-indica* (L.) Mill.	Mission prickly-pear
	Opuntia littoralis (Engelm.) Cockerell	Coastal prickly pear
	Opuntia oricola Philbrick	Pancake prickly pear, Tall prickly pear
Campanulaceae	*Lobelia dunnii* Greene var. *serrata* (A. Gray) McVaugh	
	Triodanis biflora (Ruiz & Pav.) Greene	Venus looking-glass
Caprifoliaceae	*Lonicera hispidula* (Lindl.) Torr. & A. Gray	Hairy honeysuckle
	Lonicera subspicata Hook. & Arn. var. *denudata* Rehder	Wild honeysuckle
	Lonicera subspicata Hook. & Arn. var. *subspicata*	Santa Barbara honeysuckle
	Symphoricarpos mollis Nutt.	Creeping snowberry
Caryophyllaceae	**Cerastium glomeratum* Thuill.	Sticky mouse-ear chickweed
	**Herniaria hirsuta* L. var. *cinerea* (DC.) Loret & Barrandon	Rupturewort
	Minuartia douglasii (Torr. & A. Gray) Mattf.	Douglas' stitchwort
	Polycarpon depressum Nutt.	Prostrate polycarp
	**Polycarpon tetraphyllum* (L.) L. var. *tetraphyllum*	Four-leaved allseed
	Sagina apetala Ard.	Dwarf pearlwort
	Sagina decumbens (Elliott) Torr. & A. Gray subsp. *occidentalis* (S. Watson) G.E. Crow	Western pearlwort
	Silene antirrhina L.	Sleepy catchfly
	Silene coniflora Otth	Multinerved catchfly
	**Silene gallica* L.	Windmill pink
	**Spergula arvensis* L.	Stickwort
	**Spergularia bocconi* (Scheele) Graebn.	Boccone's sand-spurrey
	Spergularia macrotheca (Cham. & Schltdl.) Heynh. var. *macrotheca*	Sticky sand-spurrey
	Spergularia marina (L.) Besser	Saltmarsh sand-spurrey
	**Spergularia villosa* (Pers.) Cambess.	Hairy sand-spurrey
	**Stellaria media* (L.) Vill.	Common chickweed
	Stellaria nitens Nutt.	Shining chickweed
Chenopodiaceae	*Aphanisma blitoides* Moq.	Aphanisma
	Arthrocnemum subterminale (Parish) Standl.	Pickleweed
	Atriplex argentea Nutt. var. *expansa* (S. Watson) S.L. Welsh & Reveal	Silverscale
	Atriplex coulteri (Moq.) D. Dietr.	Coulter’s saltbush

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Chenopodiaceae	*Atriplex lentiformis* (Torr.) S. Watson	Big saltbush
	Atriplex leucophylla (Moq.) D. Dietr.	Beach saltbush
	Atriplex pacifica A. Nelson	South coast saltscale
	Atriplex patula L.	Spear orach
	Atriplex prostrata DC.	Fat-hen
	**Atriplex rosea* L.	Tumbling orach
	**Atriplex semibaccata* R. Br.	Australian saltbush
	Atriplex serenana Abrams var. *davidsonii* (Standl.) Munz	Davidson's saltscale
	Atriplex serenana Abrams var. *serenana*	Bractscale
	**Atriplex suberecta* I. Verd.	Sprawling saltbush
	Atriplex watsonii Abrams	Watson's saltbush, Matscale
	**Bassia hyssopifolia* (Pall.) Kuntze	Five-hook bassia
	**Beta vulgaris* L. subsp. *maritima* (L.) Arcang.	Sea beet
	Chenopodium berlandieri Moq.	Pitseed goosefoot
	Chenopodium californicum (S. Watson) S. Watson	California goosefoot
	**Chenopodium macrospermum*	Largeseed goosefoot
	**Chenopodium murale* L.	Nettle-leaf goosefoot
	**Dysphania ambrosioides* (L.) Mosyakin & Clemants	Mexican tea
	**Dysphania pumilio* (R. Br.) Mosyakin & Clemants	Australian goosefoot
	Extriplex californica (Moq.) E.M. Zacharias	California orach
	Salicornia pacifica Standl.	Pickleweed
	**Salsola australis* R. Br.	Russian thistle, Tumbleweed
	**Salsola tragus* R. Br.	Russian thistle, Tumbleweed
	Suaeda calceoliformis (Hook.) Moq.	Horned seablite
	Suaeda taxifolia (Standl.) Standl.	Woolly seablite
Cistaceae	*Crocanthemum scoparium* (Nutt.) Millsp.	Peak rush-rose
	Crocantheumum greenei (B.L. Rob.) Sorrie	Island rush-rose
	Helianthemum greenei x *scoparium*	Hybrid rush-rose
Cleomaceae	*Peritoma arborea* (Nutt.) H.H. Iltis	Bladderpod
Convolvulaceae	*Calystegia macrostegia* (Greene) Brummitt	Morning-glory
	Calystegia macrostegia (Greene) Brummitt subsp. cyclostegia (House) Brummitt	Coast morning-glory
	Calystegia macrostegia (Greene) Brummitt subsp. *intermedia* (Abrams) Brummitt	Intermediate morning-glory
	Calystegia macrostegia (Greene) Brummitt subsp. *macrostegia*	Morning-glory
	Calystegia soldanella (L.) R. Br.	Beach morning glory
	**Convolvulus arvensis* L.	Bindweed
	Convolvulus simulans L.M. Perry	Small-flowered morning-glory
	Cressa truxillensis Kunth	Alkali weed
	Cuscuta occidentalis Millsp.	California dodder

Family	Scientific Name	Common Name
Convolvulaceae	*Dichondra occidentalis* House	Western dichondra
Cornaceae	*Cornus glabrata* Benth.	Brown dogwood
Crassulaceae	*Crassula aquatica* (L.) Schönl.	Water pygmy weed
	Crassula connata (Ruiz & Pav.) A. Berger	Pygmy-weed
	Dudleya greenei Rose	Greene's dudleya
	Dudleya virens (Rose) Moran subsp. *hassei* (Rose) Moran	Catalina liveforever
	Dudleya virens (Rose) Moran subsp. *insularis* (Rose) Moran	Island green dudleya
Crossosomataceae	*Crossosoma californicum* Nutt.	Catalina crossosoma
Cucurbitaceae	*Marah fabacea* (Naudin) Greene	California man-root
	Marah macrocarpa (Greene) Greene	Wild cucumber
Elatinaceae	*Elatine californica* A. Gray	California waterwort
Ericaceae	*Arctostaphylos catalinae* P.V. Wells	Santa Catalina Island manzanita
	Comarostaphylis diversifolia (Parry) Greene subsp. *planifolia* (Jeps.) G.D. Wallace	Summer holly
	Xylococcus bicolor Nutt.	Mission manzanita
Euphorbiaceae	*Croton californicus* Müll. Arg.	California croton
	Croton setiger Hook.	Turkey-mullein
	**Euphorbia* aff. *maculata*	Spotted spurge
	Euphorbia crenulata Engelm.	Chinese caps
	Euphorbia misera Benth.	Cliff spurge
	**Euphorbia peplus* L.	Petty spurge
	Euphorbia serpyllifolia Pers.subsp. *serpyllifolia*	Thyme-leafed spurge
	Euphorbia spathulata Lam.	Warty fruit spurge
	**Ricinus communis* L.	Castor bean
Fabaceae	**Acacia decurrens* Willd.	Green wattle
	**Acacia melanoxylon* R. Br.	Blackwood acacia
	*Acmispon americanus (*Nutt.) Rydb. var. *americanus*	Spanish clover
	Acmispon argophyllus (A. Gray) Brouillet var. *argenteus* (Dunkle) Brouillet	Silver clover
	Acmispon brachycarpus (Benth.) D.D. Sokoloff	Hill lotus
	Acmispon dendroideus (Greene) Brouillet var. *dendroideus*	Island broom
	Acmispon grandiflorus (Benth.) Brouillet var. *grandiflorus*	Large-flowered lotus, chaparral lotus
	Acmispon heermannii (Durand & Hilg.) Brouillet	Heermann's lotus
	Acmispon maritimus (Nutt.) D.D. Sokoloff var. *maritimus*	Coastal lotus
	Acmispon micranthus (Torr. & A. Gray) Brouillet	Crab lotus, Small-flowered lotus
	Acmispon strigosus (Nutt.) Brouillet	Bishop's lotus
	Acmispon wrangelianus (Fisch. & C.A. Mey.) D.D. Sokoloff	California lotus
	Astragalus didymocarpus Hook. & Arn. var. *didymocarpus*	Two-seeded milkvetch
	Astragalus gambelianus E. Sheld.	Gambel milkvetch

Family	Scientific Name	Common Name
Fabaceae	*Astragalus trichopodus* (Nutt.) A. Gray var. *lonchus* (M.E. Jones) Barneby	Rattleweed, Southern California locoweed
	Astragalus trichopodus (Nutt.) A. Gray var. *trichopodus*	Santa Barbara milkvetch
	**Caesalpinia spinosa* (Molina) Kuntze	Tara
	**Genista linifolia* L.	Dyer's greenwold
	**Genista monspessulana* (L.) L.A.S. Johnson	French broom
	**Lathyrus tingitanus* L.	Tangier pea
	Lathyrus vestitus Nutt. var. *alefeldii* (T.G. White) Isely	Wine red wild sweetpea
	Lathyrus vestitus Nutt. var. *vestitus*	Wild sweet pea
	**Lotus corniculatus* L.	Bird's-foot trefoil
	Lupinus albifrons Benth. var. *albifrons*	Silver bush lupine
	Lupinus bicolor Lindl.	Miniature lupine
	Lupinus concinnus J. Agardh	Bajada lupine
	Lupinus hirsutissimus Benth.	Stinging lupine
	Lupinus succulentus K. Koch	Arroyo lupine
	Lupinus truncatus Nutt.	Collar lupine, Truncate lupine
	**Medicago polymorpha* L.	California burclover
	**Medicago sativa* L.	Alfalfa
	**Melilotus albus* Medik.	White sweetclover
	**Melilotus indicus* (L.) All.	Sourclover
	**Senna didymobotrya* (Fresen.) H.S. Irwin & Barneby	African senna
	**Spartium junceum* L.	Spanish broom
	Trifolium albopurpureum Torr. & A. Gray	Indian clover, Rancheria clover
	Trifolium ciliolatum Benth.	Foothill clover
	Trifolium depauperatum Desv. var. truncatum (Greene Isely)	Truncate sack clover
	Trifolium gracilentum Torr. & A. Gray	Pinpoint clover
	**Trifolium hirtum* All.	Rose clover
	Trifolium macraei Hook. & Arn.	Macrae's clover
	Trifolium microcephalum Pursh	Small-head clover
	Trifolium microdon Hook. & Arn.	Thimble clover
	Trifolium palmeri S. Watson	Souther island clover
	Trifolium willdenovii Spreng.	Tomcat clover
	**Vicia benghalensis* L.	Purple vetch
	Vicia hassei S. Watson	Slender vetch
	Vicia ludoviciana Torr. & A. Gray subsp. *ludoviciana*	Deerpea vetch
	**Vicia villosa* Roth subsp. *varia* (Host) Corb.	Hairy vetch
Fagaceae	*Quercus chrysolepis* Liebm.	Canyon live oak
	Quercus douglasii Hook. & Arn.	Blue oak
	Quercus engelmannii Greene	Engelmann oak
	Quercus lobata Née	Valley oak
	Quercus pacifica Nixon & C.H. Mull.	Island scrub oak

Family	Scientific Name	Common Name
Fagaceae	*Quercus tomentella* Engelm.	Island oak
	Quercus x *macdonaldii* Greene	Macdonald oak
Frankeniaceae	*Frankenia salina* (Molina) I.M. Johnst.	Alkali heath
Gentianaceae	*Zeltnera venusta* (A. Gray) G. Mans.	California centaury
Geraniaceae	*California macrophylla* (Hook. & Arn.) J.J. Aldasoro et al.	Round-leaved filaree
	**Erodium botrys* (Cav.) Bertol.	Big beak filaree, Broad-leaf filaree
	**Erodium brachycarpum* (Godr.) Thell.	Storkbill
	**Erodium cicutarium* (L.) Aiton	Redstem filaree
	**Erodium moschatum* (L.) Aiton	Greenstem filaree
	Erodium texanum A. Gray	Texas filaree
	Geranium carolinianum L.	Carolina cranesbill
	**Geranium pusillum* L.	Small-flowered geranium
	**Pelargonium* x *hortorum* L.H. Bailey	Fish geranium
	**Pelargonium peltatum* (L.) L'Hér.	Ivy geranium
Geraniaeae	**Geranium molle*	Woodland geranium
Grossulariaceae	*Ribes viburnifolium* A. Gray	Santa Catalina Island currant
Heliotropiaceae	*Heliotropium curassavicum* L. var. *oculatum* (A. Heller) Tidestr.	Alkali heliotrope
Hydrophyllaceae	*Emmenanthe penduliflora* Benth. var. *penduliflora*	Whispering bells
	Eriodictyon traskiae Eastw. subsp. *traskiae*	Trask's yerba santa
	Eucrypta chrysanthemifolia (Benth.) Greene	Eucrypta
	Phacelia cicutaria Greene var. *hispida* J.T. Howell	Caterpillar phacelia
	Phacelia distans Benth.	Fern-leaf phacelia
	Phacelia grandiflora (Benth.) A. Gray	Large-flowered phacelia
	Phacelia lyonii A. Gray	Lyon's phacelia
	Phacelia minor (Harv.) F. Zimm.	Wild canterbury bells
	Phacelia viscida (Lindl.) Torr. var. *viscida*	Sticky phacelia
	Pholistoma auritum (Lindl.) Lilja var. *auritum*	Fiesta flower
	Pholistoma racemosum (A. Gray) Constance	White fiesta flower
Juglandaceae	**Juglans californica* S. Watson	Southern California black walnut
Lamiaceae	*Clinopodium douglasii* (Benth.) Kuntze	Yerba buena
	Lepechinia fragrans (Greene) Epling	Fragrant pitcher sage
	**Marrubium vulgare* L.	Horehound
	**Mentha aquatica* L.	Watermint
	**Mentha spicata* L.	Spearmint
	**Mentha* x *piperita* L.	Peppermint
	Salvia apiana Jeps.	White sage
	Salvia apiana x *mellifera*	Hybrid sage
	Salvia columbariae Benth.	Chia
	Salvia mellifera Greene	Black sage
	Trichostema lanceolatum Benth.	Vinegar weed
Linaceae	*Hesperolinon micranthum* (A. Gray) Small	Dwarf flax

Family	Scientific Name	Common Name
Loasaceae	*Mentzelia affinis* Greene	Yellow comet, Hydra stick-leaf
	Mentzelia micrantha (Hook. & Arn.) Torr. & A. Gray	Blazing star, Small-flowered stick-leaf
Lythraceae	*Ammannia robusta* Heer & Regel	Red-stem
	**Lythrum hyssopifolia* L.	Loosestrife
	**Punica granatum* L.	Pomegranate
Malvaceae	*Eremalche exilis* (A. Gray) Greene	White mallow
	Malacothamnus fasciculatus (Torr. & A. Gray) Greene var. *catalinensis* (Eastw.) Kearney	Santa Catalina Island bush-mallow
	Malva assurgentiflora (Kellogg) M.F. Ray subsp. *glabra* (Philbrick) Guilliams in ed.	Island mallow, Malva rosa
	**Malva nicaeensis* All.	Bull mallow
	**Malva parviflora* L.	Cheeseweed
	Malvella leprosa (Ortega) Krapov.	Alkali-mallow
Montiaceae	*Calandrinia menziesii* (Hook.) Torr. & A. Gray	Red maids
	Cistanthe maritima (Nutt.) Hershk.	Seaside cistanthe
	Claytonia parviflora Hook. subsp. *parviflora*	Narrow leaved miner's lettuce
	Claytonia perfoliata Willd. subsp. *mexicana* (Rydb.) John M. Mill. & K.L. Chambers	Miner’s lettuce
	Claytonia perfoliata Willd. subsp. *perfoliata*	Miner’s lettuce
Moraceae	**Ficus carica* L.	Edible fig
Myrsinaceae	**Lysimachia arvensis* (L.) U. Manns & Anderb.	Scarlet pimpernel
Myrtaceae	**Eucalyptus camaldulensis* Dehnh.	River red gum
	**Eucalyptus globulus* Labill.	Blue gum
	**Eucalyptus polyanthemos* Schauer	Silver dollar gum
Nyctaginaceae	*Abronia maritima* S. Watson	Red sand-verbena
	Abronia maritima x *umbellata*	Hybrid sand verbena
	Abronia umbellata Lam. var. *umbellata*	Beach sand verbena
	Mirabilis laevis (Benth.) Curran var. *crassifolia* (Choisy) Spellenb.	Wishbone bush
Onagraceae	*Camissoniopsis intermedia* (P.H. Raven) W.L. Wagner & Hoch	Suncups
	Camissoniopsis micrantha (Spreng.) W.L. Wagner & Hoch	Mini suncups
	Camissoniopsis robusta (P.H. Raven) W.L. Wagner & Hoch	Robust suncups
	Clarkia epilobioides (Torr. & A. Gray) A. Nelson & J.F. Macbr.	Willow-herb clarkia
	Clarkia purpurea (Curtis) A. Nelson & J.F. Macbr. subsp. *quadrivulnera* (Lindl.) H. Lewis & M. Lewis	Wine cup clarkia
	Clarkia unguiculata Lindl.	Elegant clarkia
	Epilobium brachycarpum C. Presl	Panicled willow herb
	Epilobium canum (Greene) P.H. Raven subsp. *canum*	California fuchsia
	Epilobium ciliatum Raf. subsp. *ciliatum*	Willow herb
	Eulobus californicus Torr. & A. Gray	Mustard suncup

Family	Scientific Name	Common Name
Onagraceae	*Ludwigia peploides* (Kunth) P.H. Raven subsp. *peploides*	Floating primrose-willow
	**Oenothera sinuosa* W.L. Wagner & Hoch	Wavy-leaf gaura
Orobanchaceae	*Castilleja affinis* Hook. & Arn. subsp. affinis	Indian paintbrush
	Castilleja exserta (A. Heller) T.I. Chuang & Heckard	Purple owl's-clover
	Castilleja foliolosa Hook. & Arn.	Woolly paintbrush
	Orobanche bulbosa Beck	Chaparral broomrape
	Orobanche fasciculata Nutt.	Clustered broomrape
	Orobanche parishii (Jeps.) Heckard subsp. *brachyloba* Heckard	Short-lobed broomrape
Oxalidaceae	**Oxalis articulata* Savigny subsp. *rubra* (A. St.-Hil.) Lourteig	Windowbox wood-sorrel
	Oxalis californica (Abrams) R. Knuth	California wood-sorrel
	**Oxalis corniculata* L.	Weed oxalis, Creeping wood sorrel
	**Oxalis pes-caprae* L.	Bermuda buttercup
Papaveraceae	*Dendromecon harfordii* Kellogg	Channel island tree poppy
	Eschscholzia californica Cham.	California poppy
	Eschscholzia ramosa (Greene) Greene	Island poppy
	Papaver californicum A. Gray	Fire poppy
	Papaver heterophyllum (Benth.) Greene	Wind poppy
	**Papaver somniferum* L.	Opium poppy
	Platystemon californicus Benth.	Cream cups
Phrymaceae	*Diplacus brevipes* (Benth.) G.L. Nesom	Yellow field monkeyflower
	Diplacus puniceus Nutt.	Red bush monkeyflower
	Diplacus traskiae (A.L. Grant) G.L. Nesom	Santa Catalina Island monkeyflower
	Erythranthe cardinalis (Douglas ex Benth.) Spach	Scarlet monkeyflower
	Erythranthe floribunda (Douglas ex Lindl.) G.L. Nesom	Slimy monkeyflower
	Erythranthe guttata (Fisch. ex DC.) G.L. Nesom	Creek monkeyflower
Pittosporaceae	**Pittosporum undulatum* Vent.	Mock orange
Plantaginaceae	*Antirrhinum kelloggii* Greene	Blue twining snapdragon, Climbing snapdragon
	Antirrhinum nuttallianum A. DC. subsp. *subsessile* (A. Gray) D.M. Thomps.	Violet snapdragon, Nuttall's snapdragon
	Callitriche marginata Torr.	Water starwort
	Collinsia heterophylla Graham var. *heterophylla*	Chinese-houses
	Gambelia speciosa Nutt.	Showy island snapdragon
	Keckiella cordifolia (Benth.) Straw	Heart-leaved penstemon, Climbing penstemon
	**Kickxia elatine* (L.) Dumort.	Fluellin
	Nuttallanthus texanus (Scheele) D.A. Sutton	Blue toadflax
	**Plantago coronopus* L.	Rattail plantain

Family	Scientific Name	Common Name
Plantaginaceae	*Plantago erecta* E. Morris	California plantain
	**Plantago lanceolata* L.	English plantain
	**Plantago major* L.	Common plantain
	Plantago ovata Forssk. var. *insularis* (Eastw.) S.C. Meyers & A. Liston	Island plantain
	Veronica sp.	Speedwell
Platanaceae	**Platanus racemosa* Nutt.	Western sycamore
Plumbaginaceae	**Limonium sinuatum* (L.) Mill.	Statice
Polemoniaceae	*Allophyllum glutinosum* (Benth.) A.D. Grant & V.E. Grant	Stinky gilia
	Eriastrum filifolium (Nutt.) Wooton & Standl.	Threadstem wool star
	Gilia angelensis V.E. Grant	Chaparral gilia
	Gilia capitata Sims subsp. *abrotanifolia* (Greene) V.E. Grant	Bluehead gilia
	Gilia clivorum (Jeps.) V.E. Grant	Purplespot gilia
	Gilia nevinii A. Gray	Nevin's gilia
	Leptosiphon bicolor Nutt.	True baby stars
	**Leptosiphon parviflorus* Benth.	Variable linanthus
	Linanthus dianthiflorus (Benth.) Greene	Ground pink, Fringed linanthus
	Navarretia atractyloides (Benth.) Hook. & Arn.	Holly-leaved skunkweed
	Navarretia hamata Greene subsp. *leptantha* (Greene) H. Mason	Hooked skunkweed
Polygonaceae	*Chorizanthe staticoides* Benth.	Turkish rugging
	**Eriogonum fasciculatum* Benth. var. *foliolosum*	Coastal California buckwheat
	Eriogonum giganteum S. Watson var. *giganteum*	Santa Catalina Island Buckwheat/St. Catherine's lace
	Eriogonum grande Greene var. *grande*	Island buckwheat
	Lastarriaea coriacea (Goodman) Hoover	Leather-spineflower
	Persicaria amphibia (L.) Gray	Water smartweed
	**Polygonum argyrocoleon* Kunze	Persian knotweed
	**Polygonum aviculare* L. subsp. *depressum* (Meisn.) Arcang.	Common knotweed
	Pterostegia drymarioides Fisch. & C.A. Mey.	Woodland threadstem
	**Rumex conglomeratus* Murray	Green dock
	**Rumex crispus* L.	Curly dock
	Rumex fueginus Phil.	Golden dock
	Rumex salicifolius Weinm.	Willow dock
Portulacaceae	**Portulaca oleracea* L.	Purslane
Primulaceae	*Primula clevelandii* (Greene) A.R. Mast & Reveal var. *insularis* (H.J. Thomps.) A.R. Mast & Reveal	Island shooting star
Ranunculaceae	*Clematis ligusticifolia* Nutt.	Western virgin's bower
	Delphinium parryi A. Gray subsp. *maritimum* (Davidson) M.J. Warnock	Maritime larkspur
	Ranunculus californicus Benth. var. *cuneatus* Greene	California buttercup

Family	Scientific Name	Common Name
Ranunculaceae	*Ranunculus hebecarpus* Hook. & Arn.	Hebe buttercup
Resedaceae	*Oligomeris linifolia* (Hornem.) J.F. Macbr.	Oligomeris
Rhamnaceae	*Ceanothus arboreus* Greene	Feltleaf ceanothus
	Ceanothus megacarpus Nutt. var. *insularis* (Eastw.) Munz	Island ceanothus
	Ceanothus megacarpus Nutt. var. *megacarpus*	Bigpod ceanothus
	Rhamnus pirifolia Greene	Island redberry
Rosaceae	*Adenostoma fasciculatum* Hook. & Arn.	Chamise
	Aphanes occidentalis (Nutt.) Rydb.	Lady's mantle
	Cercocarpus betuloides Nutt. var. *blancheae* (C.K. Schneid.) Little	Island mountain-mahogany
	Cercocarpus traskiae Eastw.	Catalina Island mountain-mahogany
	**Cotoneaster pannosus* Franch.	Silverleaf cotoneaster
	Drymocallis glandulosa (Lindl.) Rydb. var. *wrangelliana* (Fisch. & Avé-Lall.) Ertter	Sticky cinquefoil
	Heteromeles arbutifolia (Lindl.) M. Roem.	Toyon
	Holodiscus discolor (Pursh) Maxim. var. *discolor*	Oceanspray
	Lyonothamnus floribundus A. Gray subsp. *floribundus*	Santa Catalina Island ironwood
	**Poterium sanguisorba* L. var. *polygamum* (Waldstein & Kitaibel) Visiani	Garden burnet
	*P*runus ilicifolia (Hook. & Arn.) D. Dietr. subsp. lyonii (Eastw.) P.H. Raven	Catalina cherry
	Rosa californica Cham. & Schltdl.	California rose
	**Rubus armeniacus* Focke	Himalayan blackberry
	Rubus ursinus Cham. & Schltdl.	California blackberry
Rubiaceae	*Galium angustifolium* A. Gray subsp. *angustifolium*	Narrowly leaved bedstraw
	Galium aparine L.	Goose grass
	Galium catalinense A. Gray subsp. *catalinense*	Santa Catalina Island bedstraw
	**Galium murale*	Tiny bedstraw
	Galium nuttallii A. Gray subsp. *insulare* Ferris	Nuttall's island bedstraw
	Galium nuttallii A. Gray subsp. *nuttallii*	San Diego bedstraw
	**Galium parisiense* L.	Wall bedstraw
	Galium porrigens Dempster var. *porrigens*	Climbing bedstraw
Salicaceae	*Populus fremontii* S. Watson subsp. *fremontii*	Fremont cottonwood
	Populus trichocarpa Hook.	Black cottonwood
	Populus xparryi Sarg.	Hybrid cottonwood
	Salix exigua Nutt.	Narrow-leaved willow, Coyote willow
	Salix laevigata Bebb	Red willow
	Salix lasiolepis Benth.	Arroyo willow
Saxifragaceae	*Jepsonia malvifolia (*Greene) Small	Island jepsonia
	Lithophragma affine A. Gray	Woodland star
Scrophulariaceae	*Scrophularia villosa* Pennell	Santa Catalina figwort
Solanaceae	*Datura wrightii* Regel	Jimson weed

Family	Scientific Name	Common Name
Solanaceae	*Lycium brevipes* Benth. var. *hassei (*Greene) C.L. Hitchc.	Santa Catalina Island desert-thorn
	Lycium californicum Nutt.	California box-thorn
	Nicotiana clevelandii A. Gray	Cleveland's tobacco
	**Nicotiana glauca* Graham	Tree tobacco
	Nicotiana quadrivalvis Pursh	Indian tobacco
	Solanum douglasii Dunal	White Douglas' nightshade
	**Solanum elaeagnifolium* Cav.	White horse-nettle
	**Solanum rostratum* Dunal	Buffalo berry
	Solanum wallacei (A. Gray) Parish	Wallace's nightshade
Tamaricaceae	**Tamarix parviflora* DC.	Smallflower tamarisk
	**Tamarix ramosissima* Ledeb.	Saltcedar
Tropaeolaceae	**Tropaeolum majus* L.	Garden nasturtium
Urticaceae	*Hesperocnide tenella* Torr.	Western nettle
	Parietaria hespera Hinton	Pellitory
	Parietaria hespera Hinton var. *californica* Hinton	Pellitory
	Parietaria hespera Hinton var. *hespera*	Pellitory
	Urtica gracilis Ait. subsp. *holosericea* (Nutt.) W.A. Weber	Hoary nettle
	**Urtica urens* L.	Dwarf nettle
Valerianaceae	**Centranthus ruber* (L.) DC.	Red valerian
Verbenaceae	*Phyla nodiflora* (L.) Greene	Mat-grass
	Verbena bracteata Lag. & Rodr.	Vervain
	Verbena lasiostachys Link	Western verbena
	Verbena lasiostachys Link var. *lasiostachys*	Vervain
	Verbena lasiostachys Link var. *scabrida* Moldenke	Vervain
Violaceae	*Viola pedunculata* Torr. & A. Gray	Johnny-jump-up
Vitaceae	*Vitis girdiana* Munson	Desert wild grape
Zygophyllaceae	**Tribulus terrestris* L.	Puncture vine

Table B-2. Summary of the Number of Santa Catalina Island Plants, including all Species, Subspecies, or Varieties, by Plant Family and Taxonomic Group.

	Native	Introduced	Total
PLANTS	**473**	**236**	**709**
FERNS AND FERN ALLIES	**18**	**1**	**19**
Azollaceae	1	0	**1**
Blechnaceae	1	0	**1**
Cyatheaceae	0	1	**1**
Dennstaedtiaceae	1	0	**1**
Dryopteridaceae	1	0	**1**
Equisetaceae	3	0	**3**
Ophioglossaceae	1	0	**1**
Polypodiaceae	1	0	**1**
Pteridaceae	8	0	**8**
Selaginellaceae	1	0	**1**
GYMNOSPERMS	**0**	**12**	**12**
Cupressaceae	0	3	**3**
Pinaceae	0	9	**9**
ANGIOSPERMS	**455**	**223**	**678**
Magnoliids	**1**	**0**	**1**
Saururaceae	1	0	**1**
Monocots	**68**	**60**	**128**
Agavaceae	1	1	**2**
Alliaceae	1	0	**1**
Arecaceae	0	2	**2**
Asparagaceae	0	2	**2**
Cyperaceae	13	0	**13**
Iridaceae	1	0	**1**
Juncaceae	6	0	**6**
Liliaceae	3	0	**3**
Orchidaceae	4	0	**4**
Poaceae	28	54	**82**
Potamogetonaceae	1	1	**2**
Ruppiaceae	1	0	**1**
Themidaceae	3	0	**3**
Typhaceae	2	0	**2**
Zosteraceae	4	0	**4**
Eudicots	**386**	**163**	**549**
Adoxaceae	1	0	**1**
Aizoaceae	0	6	**6**
Amaranthaceae	0	2	**2**
Anacardiaceae	5	2	**7**

	Native	Introduced	Total
Apiaceae	6	3	**9**
Apocynaceae	2	1	**3**
Asteraceae	76	34	**110**
Bataceae	1	0	**1**
Boraginaceae	15	0	**15**
Brassicaceae	14	20	**34**
Cactaceae	5	1	**6**
Campanulaceae	2	0	**2**
Caprifoliaceae	4	0	**4**
Caryophyllaceae	9	8	**17**
Chenopodiaceae	18	11	**29**
Cistaceae	3	0	**3**
Cleomaceae	1	0	**1**
Convolvulaceae	9	1	**10**
Cornaceae	1	0	**1**
Crassulaceae	5	0	**5**
Crossosomataceae	1	0	**1**
Cucurbitaceae	2	0	**2**
Elatinaceae	1	0	**1**
Ericaceae	3	0	**3**
Euphorbiaceae	6	3	**9**
Fabaceae	34	16	**50**
Fabaceae	7	0	**7**
Frankeniaceae	1	0	**1**
Gentianaceae	1	0	**1**
Geraniaceae	3	7	**10**
Geraniaeae	0	1	**1**
Grossulariaceae	1	0	**1**
Heliotropiaceae	1	0	**1**
Hydrophyllaceae	11	0	**11**
Juglandaceae	0	1	**1**
Lamiaceae	7	4	**11**
Linaceae	1	0	**1**
Loasaceae	2	0	**2**
Lythraceae	1	2	**3**
Malvaceae	4	2	**6**
Montiaceae	5	0	**5**
Moraceae	0	1	**1**
Myrsinaceae	0	1	**1**
Myrtaceae	0	3	**3**
Nyctaginaceae	4	0	**4**
Onagraceae	11	1	**12**
Orobanchaceae	6	0	**6**
Oxalidaceae	1	3	**4**

	Native	Introduced	Total
Papaveraceae	6	1	**7**
Phrymaceae	6	0	**6**
Pittosporaceae	0	1	**1**
Plantaginaceae	10	4	**14**
Platanaceae	0	1	**1**
Plumbaginaceae	0	1	**1**
Polemoniaceae	10	1	**11**
Polygonaceae	8	5	**13**
Portulacaceae	0	1	**1**
Primulaceae	1	0	**1**
Ranunculaceae	4	0	**4**
Resedaceae	1	0	**1**
Rhamnaceae	4	0	**4**
Rosaceae	11	3	**14**
Rubiaceae	6	2	**8**
Salicaceae	6	0	**6**
Saxifragaceae	2	0	**2**
Scrophulariaceae	1	0	**1**
Solanaceae	7	3	**10**
Tamaricaceae	0	2	**2**
Tropaeolaceae	0	1	**1**
Urticaceae	5	1	**6**
Valerianaceae	0	1	**1**
Verbenaceae	5	0	**5**
Violaceae	1	0	**1**
Vitaceae	1	0	**1**
Zygophyllaceae	0	1	**1**

Plant Species: A group of individual plants with similar characteristics, such as appearance, reproductive traits, and genetic makeup, that are capable of interbreeding and producing fertile offspring. Species represent the basic taxonomic unit of biological classification, sharing a common ancestry and occupying specific ecological niches.

Subspecies (subsp.): A geographic or ecological subdivision of a species that exhibits distinct characteristics from other individuals of the same species but is still capable of interbreeding. Subspecies are often isolated from other populations, allowing them to develop unique traits while maintaining their connection to the broader species.

Varieties (var.): A taxonomic category within a species or subspecies that displays minor differences in morphological or physiological features from the more typical members. Varieties often result from genetic mutations or environmental factors, and they can be naturally occurring or selectively bred by humans for desired traits, such as increased pest resistance or improved taste.

Appendix C

Land Cover Change Analysis from 1985 to 2022

Native Island Vegetation Recovery Following Feral Goat and Pig Removal and the Interaction of Impacts from Large Fires, Invasive Mule Deer Browse, and Precipitation Variability

Prepared for

CATALINA ISLAND CONSERVANCY™

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APRIL 2024

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EXECUTIVE SUMMARY

Catalina Island's distinct evolutionary history has fostered a unique ecosystem with many endemic plant species due to its isolation, Mediterranean climate, and the absence of ungulates (hoofed animals that eat plants, like pigs, goats, sheep, cattle, bison, and deer). The removal of the Indigenous population, followed by the introduction of ungulates for ranching in the early 1800s and later for sport hunting, significantly altered the island's vegetation cover. Native woody vegetation and endemic plants declined, and nonnative Eurasian plant cover increased. However, with the successful eradication of invasive pigs and goats by the Catalina Island Conservancy beginning in the 1990s, native habitat has shown signs of recovery.

Despite high interest in vegetation dynamics, no recent island-wide assessments of land cover have been conducted, with the most recent vegetation map dating back to 2005. A more frequent and cost-effective method for tracking significant changes in vegetation is needed. Utilizing the US Forest Service's Landscape Change Monitoring System (LCMS) product, this report generates a time series of vegetation form maps from 1985 to 2022 at a 30 m resolution. While other land cover models may perform better in specific contexts, the LCMS offers a consistent methodology for time series analysis, ensuring reliable results without systematic bias. By analyzing land cover by watershed management unit, slope, geology, orientation of main drainage, fire history, and precipitation, we explore the influence of invasive ungulate removal, fire, drought, and other landscape factors on vegetation dynamics.

Six land cover classes in LCMS predominate on Catalina Island: Trees, Grass/Forb/Herb & Tree Mix, Shrubs, Grass/Forb/Herb & Shrub Mix, Grass/Forb/Herb, and Barren or Impervious. For the whole island, Tree cover (a combination of Island Woodland and Island Chaparral) increased from 43.0% in 1985 to 51.8% in 1998, where it remained stable until the 2006 Empire Fire and 2007 Island Fire, which burned a combined 12% of the island. Following the large fires, Tree cover decreased to 47.9% in 2007 and decreased further to 43.5% in 2022. Barren cover has decreased consistently over the past 37 years, replaced largely by Shrubs and Grass/Forbs/Herbs cover classes.

By 2022, the burned areas had recovered somewhat but not completely. Periods of drought (2011 to 2016 and 2020 to 2022) and the continued presence of introduced herbivores complicated post-fire recovery of island vegetation such that Tree cover was only 0.5% above 1985 levels, even as Barren cover had decreased to 8.5%.

The results align with known observations, such as the expansion of woody vegetation following invasive goat and pig removal, and the negative effects of deer browsing on island tree cover. Large fires, combined with deer browsing pressure, appear to contribute to the decline in natural chaparral and woodland vegetation. This highlights the importance of effective management strategies, such as invasive species eradication and fire ignition prevention, to protect and restore Catalina Island's biodiversity.

1 INTRODUCTION

Catalina Island has a unique evolutionary history as an offshore island, with no land connection for at least 5 million and probably more years (Vedder and Howell 1980). The vegetation therefore had millions of years of evolution without mid-sized or large herbivores. The only land mammals arguably native to Catalina Island are a deer mouse, ornate shrew, island fox (introduced 6kya) (Sacks et al. 2022), harvest mouse, California ground squirrel (Rick et al. 2012). The maritime-moderated Mediterranean climate and isolation led to evolution of many island endemic plant species, all evolved in the absence of larger herbivores.

Indigenous settlements on Catalina Island are dated using ^{14}C to 6,165 to 5,745 years before present (Radde et al. 2024). San Clemente Island has documented settlement sites from ~8,500 cal BP (Gusick et al. 2021), and San Nicolas ~8,400 cal BP (Rick et al. 2005). Researched settlement sites are found throughout the coast and terraces of Catalina (Figure 1) and more sites are submerged given that the island is slowly sinking and sea level into the modern era has been rising (Porcasi et al. 1999).

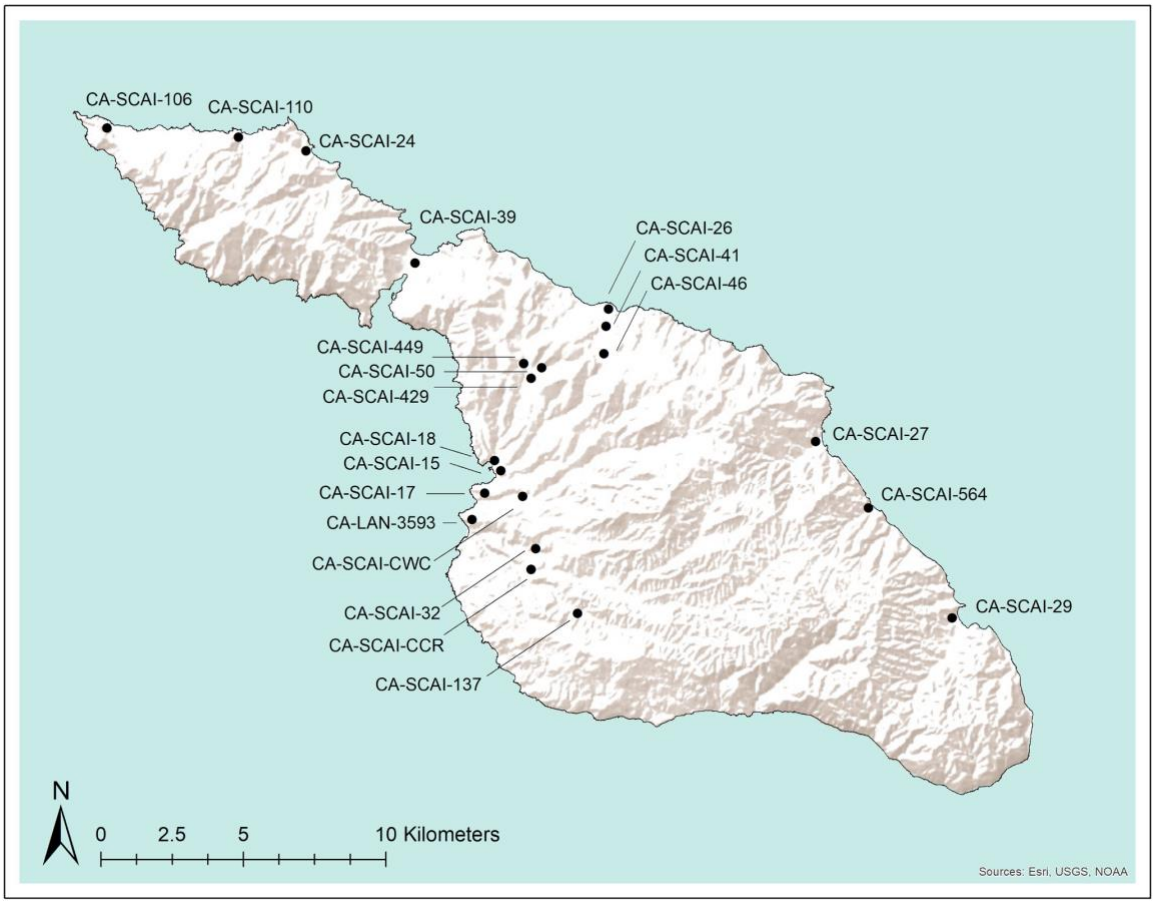

Figure 1 *Location of indigenous settlement locations from which ^{14}C dates have been analyzed.*
(Radde et al. 2024)

Vegetation management through fire was a part of Indigenous culture on the Channel Islands (Hardiman et al. 2016), but all indications, including massive shell mounds, are that staple foods on Catalina were marine in origin. The Indigenous population was present when the island was visited by Vizcaino in 1602 (Williamson 1903) and subsequently suffered through conflicts with Russian fur traders (Mead 1899) and enslavement by the Spanish during the Mission period.

By the 1830s, the Indigenous population had been killed or removed to the San Gabriel Mission. European ranchers and small-lot farmers settled, and an era of extensive and eventually uncontrolled grazing and browsing by introduced herbivores began (Figure 2). Sheep (*Ovis aries*), cattle (Bos taurus), and goats (*Capra hircus*) were introduced in the 1820s and persisted for a century. Sheep were removed in the 1920s and were replaced by pigs (*Sus scrofa*). Bison (*Bison bison*) were added in the 1920s as well, followed by mule deer in 1928 (Landis 2000). Goats and pigs were controlled in the 1990s through about 2000 and bison kept in check through fertility management starting in 2009 (Duncan et al. 2017). Prior to 2009, bison were periodically shipped off the island until it was determined that they had hybridized with cattle prior to introduction on the island and were no longer good candidates for reintroductions on the mainland (Vogel et al. 2007). Pigs were fully eradicated by 2004 and goats by 2005.

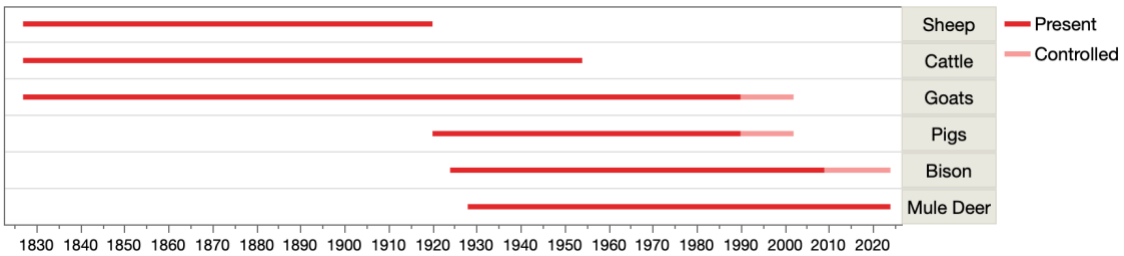

Figure 2 Timeline of presence of exotic herbivores on Catalina Island.

Vegetation has responded to the exotic herbivores. They reduced biomass so much that naturally occurring fire was quite uncommon through the 1980s (Minnich 1982). Comparison of aerial photography revealed a decline in the extent of oak trees from 1943 to 2005 (Knapp 2010). Notwithstanding high interest in vegetation dynamics in response to land management, no recent island wide assessments of land cover have been undertaken. The most recent vegetation map was published in 2005 (Knapp 2005). Preliminary work on an updated map has been started but no new map has been produced. Field mapping at the scale of vegetation alliances is expensive and time consuming and therefore only occurs periodically. It would be useful to have an assessment that can be repeated more often to track major changes in vegetation form, even if not providing the taxonomic resolution of proper vegetation maps.

Remote sensing products can provide insight on vegetation form over time even if not providing definitive information about. The US Forest Service has developed a product

that maps vegetation cover based on growth form (grass/forb/herb, shrub, tree) at a 30-meter resolution nationally with an annual cadence since 1985. Classification by growth form is consistent with the US National Vegetation Classification Standard, in which the highest levels of classification (Formations) are determined based on growth form, and global macroecological factors such as latitude and altitude. Growth form classification of land cover on Catalina on an annual basis presents a unique opportunity to understand vegetation dynamics with high spatial resolution to track the influence of herbivore removal, fire, and other landscape factors such as soils (parent material), slope, and aspect.

In this report, we document the use of the USFS Landscape Change Monitoring System product to create a time series of maps of vegetation characterized by form, summarize land cover by watershed management unit, slope, geology, aspect, and fire history, and to explore land cover trajectories over 37 years (1985 to 2022).

2 METHODS

We mapped and calculated the long-term trends in land cover types within management units on Catalina, classified the Catalina Island Conservancy (Conservancy) watershed management units by shared characteristics, and analyzed the resulting trends with respect to slope, aspect, parent material, fire history, and grazing history.

2.1 DATA

The Landscape Change Monitoring System (LCMS) is operated by the U.S. Forest Service to monitor long-term trajectories of different vegetation cover types across vast areas (USDA Forest Service, 2023) (Platt et al. 2023). It is available for Catalina Island for the period 1985 to 2022 at 30 m resolution. The LCMS product uses a combination of remote sensing data, machine learning algorithms, and expert knowledge to map and monitor land cover changes.

We loaded the LCMS v2022.8 data through the Google Earth Engine Data Catalog. The data define the land cover in each 30 by 30 m pixel each year as one of 11 categories for Catalina: Trees, Shrubs & Trees Mix, Grass/Forb/Herb & Trees Mix, Barren & Trees Mix, Shrubs, Grass/Forb/Herb & Shrubs Mix, Barren & Shrubs Mix, Grass/Forb/Herb, Barren & Grass/Forb/Herb Mix, Barren or Impervious, or Water. We later eliminated some categories from annual summaries because they had a negligible number (<0.5 ha) of classified pixels per management unit (e.g., Barren & Trees Mix, Shrubs & Trees Mix).

Watershed Management Units were provided as polygons by the Conservancy (Figure 3). Elevation and associated values (e.g., slope, aspect) were calculated from a Digital Elevation Model (DEM) derived from 2002/2003 Interferometric Synthetic Aperture Radar (IfSAR) (NAVD88 vertical datum). The generalized geology is from Schumann et al. (2012) based on the Preliminary Geologic Map of Santa Catalina Island (Bohannon and Reiss 2004). Fire perimeters and dates were obtained from the Conservancy. Weather data was obtained from the Western Regional Climate Center (WRCC 2024). We used

Long Beach Airport data to define drought periods because the Catalina precipitation record is missing data. We defined a drought as three consecutive years of below-average precipitation, which yielded the following time periods: 1987 to 1990, 2011 to 2016, 2020 to 2022.

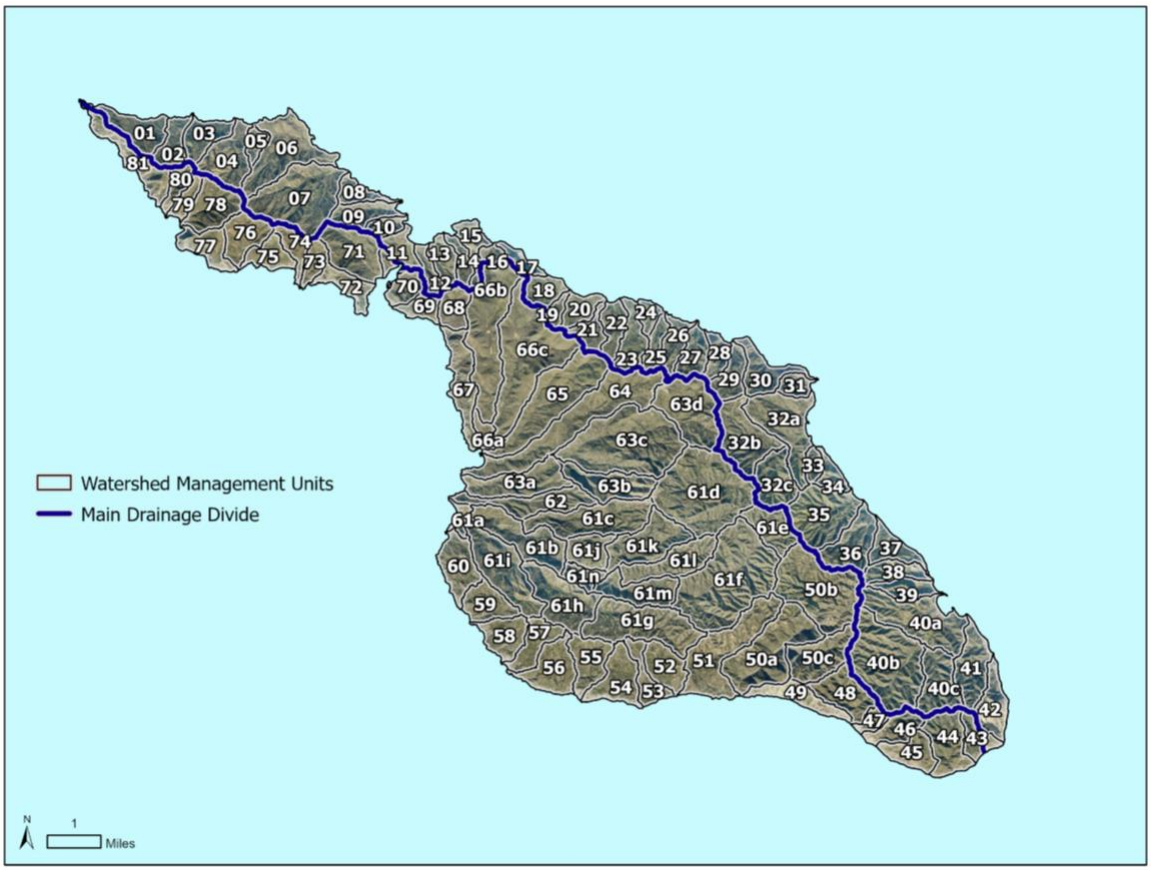

Figure 3 *Watershed management units and the main drainage divide between leeward and windward sides.*

2.2 LAND COVER HISTORY AND TRENDS

Using the land cover classification data as inputs for each year, we used the ArcGIS Zonal Statistics (count option) tool to compute the number of pixels of each land cover in each management unit each year. We also used map algebra to calculate change from year to year by multiplying the land cover code for year(x) by 100 and adding it to the code for year(x+1) so that the resulting integer could be interpreted as a land cover change between two identifiable categories (e.g., Grass/Forb/Herb & Trees to Trees). We also used Zonal Statistics (count option) to summarize the land cover changes within each management unit for each year (except the first year of 1985).

Then, we visualized the influence of landscape factors on land cover. Time series of land cover by watershed management unit (n=105) were plotted. Then overall land cover as an average of all watershed management units (each weighted equally) were graphed

as time series. These time series were also subsequently divided by landscape factors of orientation (windward/leeward), underlying geology (schist or volcanic), steepness (moderate, steep, very steep, extremely steep, and excessively steep calculated as the most common category in the management unit), and fire history (no major fire since 1985, burned in Empire, Goat, or Island fires). Time series were depicted with the mean and standard error of the values by land cover classification across watershed management units.

Spatial data acquisition and analysis were undertaken in Google Earth Engine and ESRI ArcGIS Pro, while time series analysis were performed in JMP Pro 17.

3 RESULTS

The land cover on Catalina is classified predominantly into six classes (Trees, Grass/Forb/Herb & Tree Mix, Shrubs, Grass/Forb/Herb & Shrub Mix, Grass/Forb/Herb, and Barren or Impervious). Some pixels were unclassified, and a few other categories were present but in such low numbers that they were excluded from further analysis but are included in the symbology of the land cover maps in Section 3.1 for completeness. The dataset provides time series classifications by watershed management unit and then summarized by dominant features in watershed (slope and aspect, fire history, orientation, and geology). Overall trends, cross-cutting influences, and patterns arising from groups of watershed management units with shared characteristics are presented below.

Before considering the result, please note that there is not a one-to-one correspondence between the LCMS classifications and vegetation types previously mapped on Catalina. The “Trees” category contains Island Chaparral, Island Woodland, Non-native Woodland, and Riparian Woodland. The Shrubs category contains Coastal Bluff Scrub, Maritime Cactus Scrub, Coastal Sage Scrub. Transitions between Trees and Shrubs, Grass/Forb/Herb & Shrub Mix, and Grass/Forb/Herb & Tree Mix could reflect either a change in vegetation vigor and canopy density or actual changes in vegetation composition.

3.1 LAND COVER MAPS

Land cover maps were produced for each year from 1985 to 2022. General trends are apparent from the maps, which are quantified in the next section. The 1985 map shows a landscape that is 43% Trees (a combination of Island Woodland and Island Chaparral) and 13.8% Barren (Figure 4). By 1998, the year before the first significant fire in the analysis period, Trees had increased to 51.8% and Barren decreased to 10.9% (Figure 5).

The two fires in 2006 (Empire Fire; Figure 6) and 2007 (Island Fire; Figure 6) define the subsequent land cover assessments, dramatically reducing the area of the landscape assessed to be predominated by land cover containing Trees and resulting in a concomitant increase in Grass/Forb/Herb cover. Together these fires burned close to 5,800 acres of the island (roughly 12%).

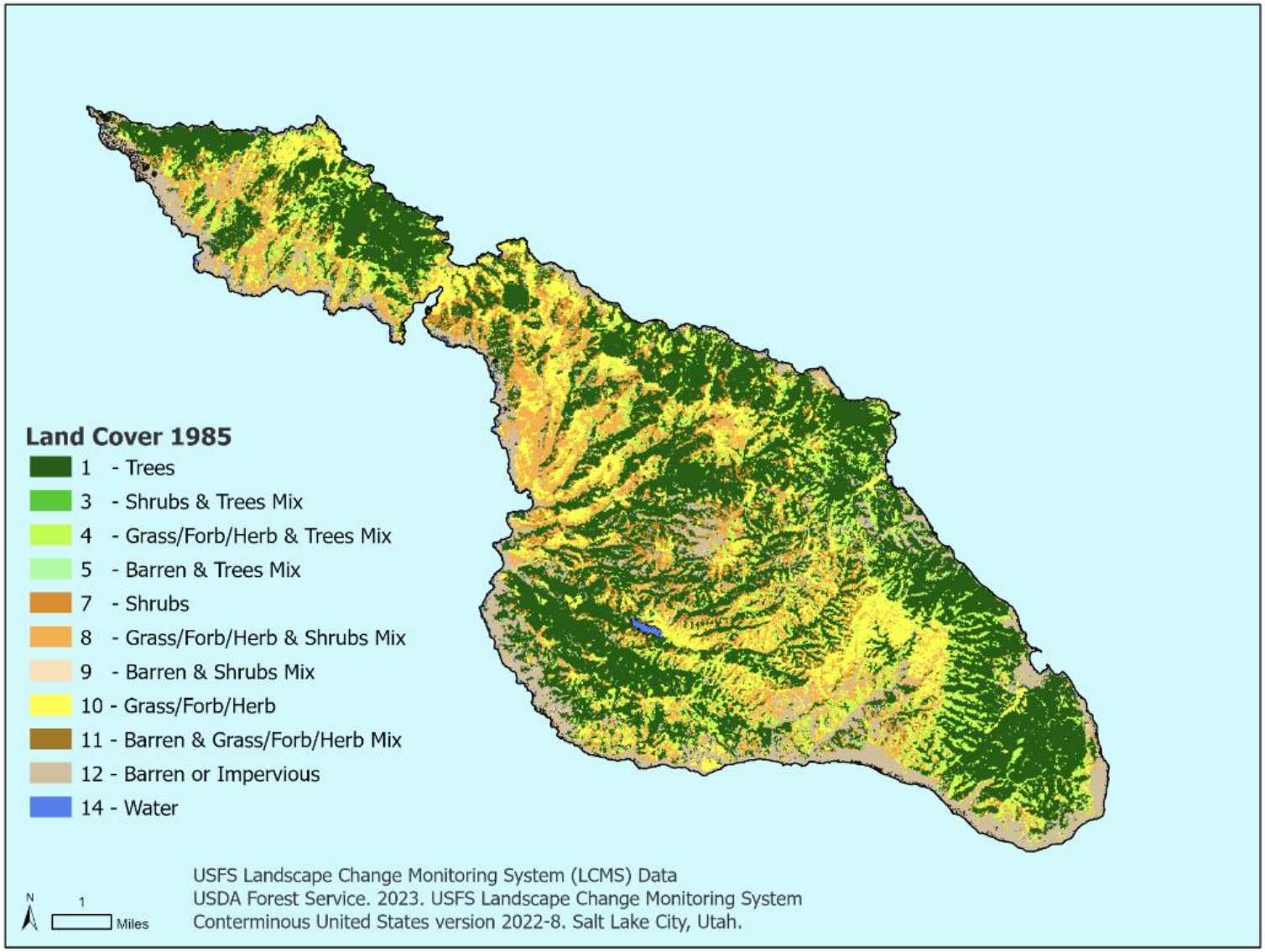

Figure 4 1985 Land Cover.

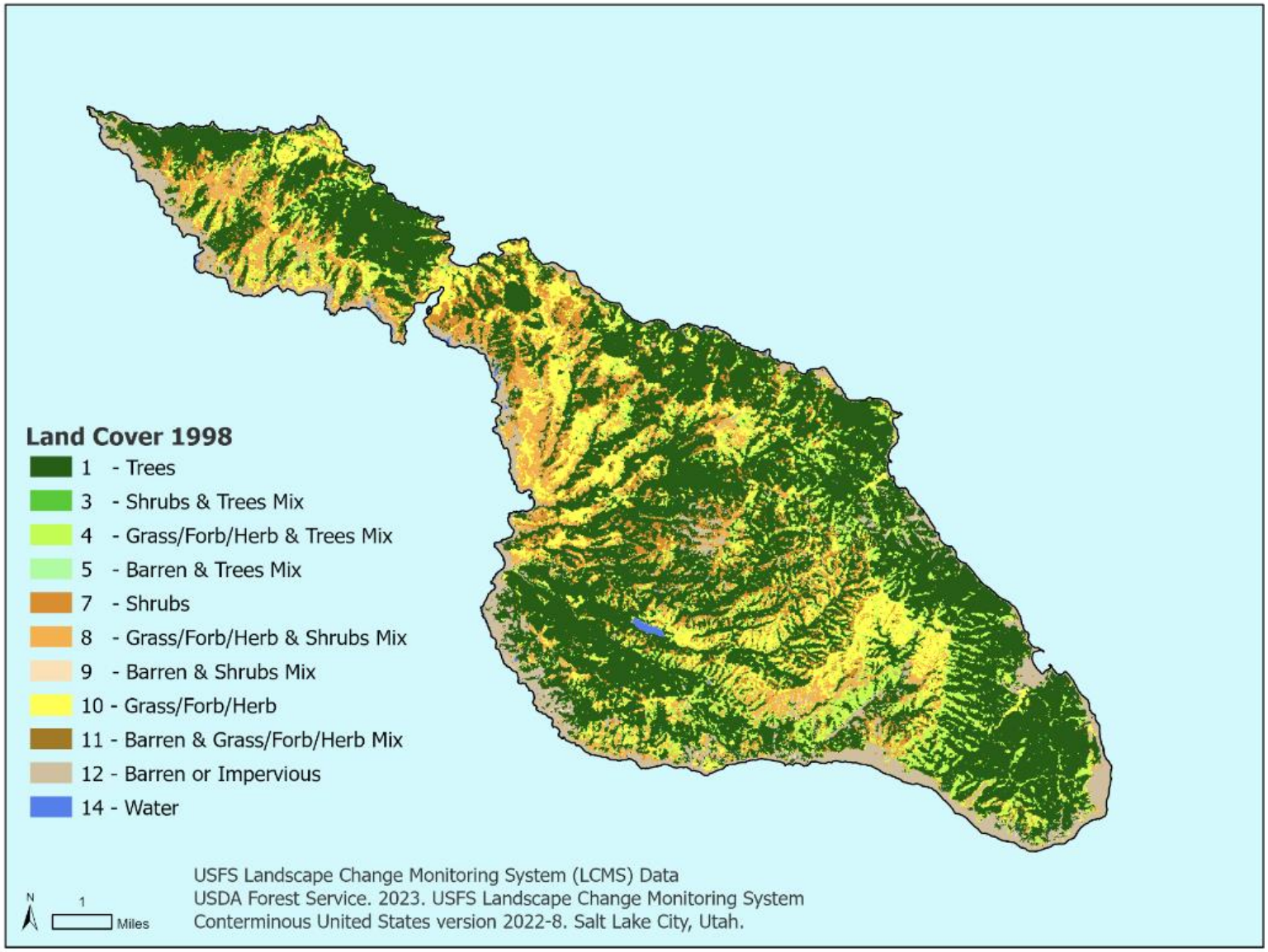

Figure 5 1998 Land Cover.

Figure 6 2007 Land Cover with extent of the 2006 Empire Fire and 2007 Island Fire.

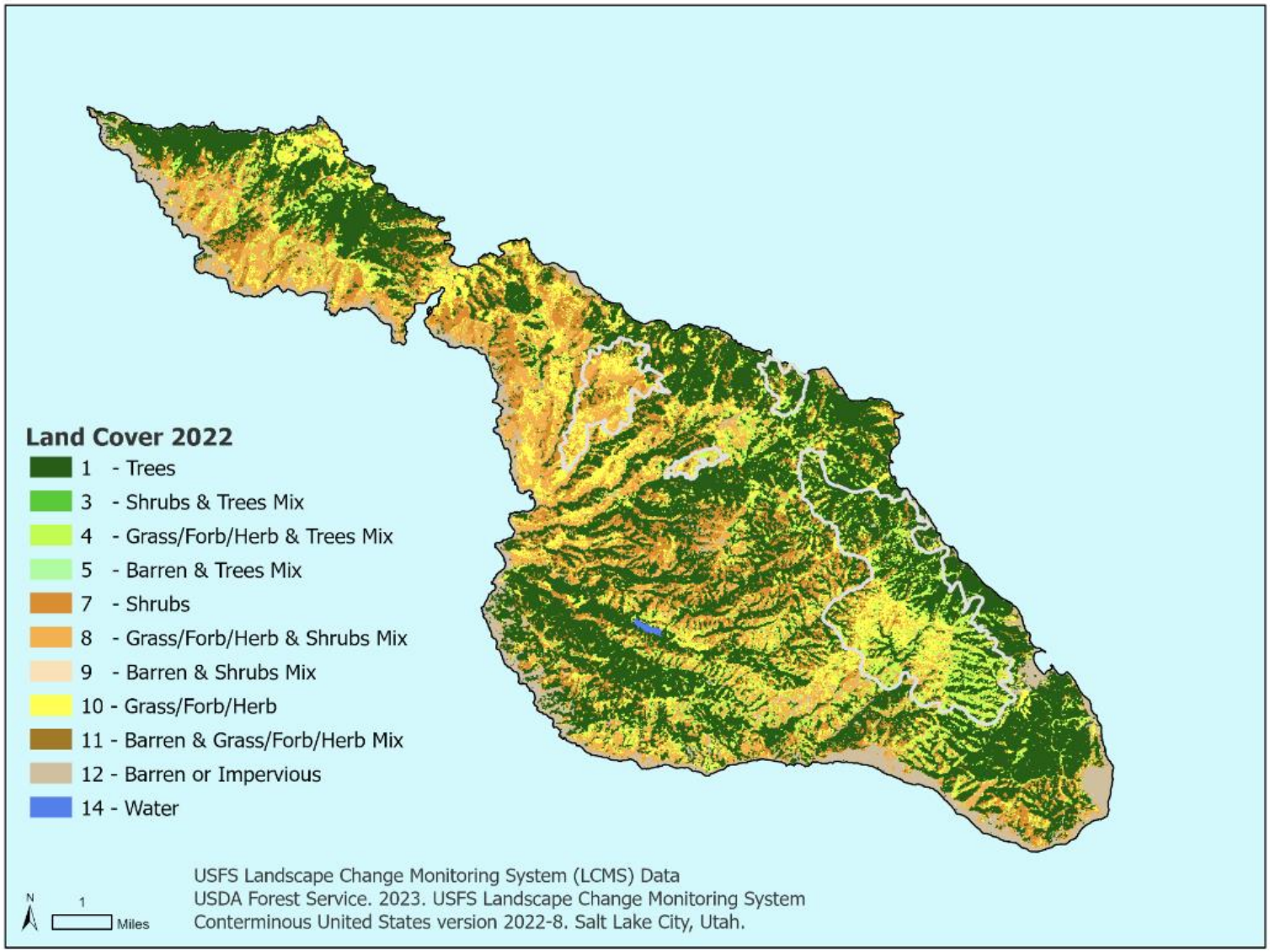

Figure 7 2022 Land Cover extent of the 2006 Empire Fire and 2007 Island Fire.

By 2022, the burned areas had recovered somewhat but not completely (Figure 7). Drought and continued presence of exotic herbivores complicated post-fire recovery such that overall Tree cover was only 0.5 percentage points above 1985 levels, even as Barren cover had decreased to 8.5%.

3.2 LAND COVER TRENDS

For overall trends in watershed characteristics, we summarized the data by averaging by watershed management units. Most of these units are roughly similar in size, so this analysis does not differ from a raw area analysis, except for slighting over emphasizing small management units and under emphasizing larger units.

The general trends in land cover since 1985 at the scale of the entire island are apparent (Figure 8). Most dramatically, barren and impervious area decreased consistently from 14.5% in 1985 to 10.0% in 2006. It increased slightly following the large fires and then remained basically stable, ending up at 9.0% in 2022. Tree cover started at 43.0% in 1985, increased to 51.8% in 1998, where it remained stable, then decreased to 47.9% in 2007 following the fires, and decreased further to 43.5% in 2022. Shrubs increased consistently from 6.4% in 1985 to 10.3% in 2006, jumped to 12.4% by 2008, and slowly increased to 14.0% in 2022. Grass/Forbs/Herb cover started at 11.8% in 1985, decreased to 9.7% in 2006, increased to 12.3% after the fires, and declined to 11.0% in 2022.

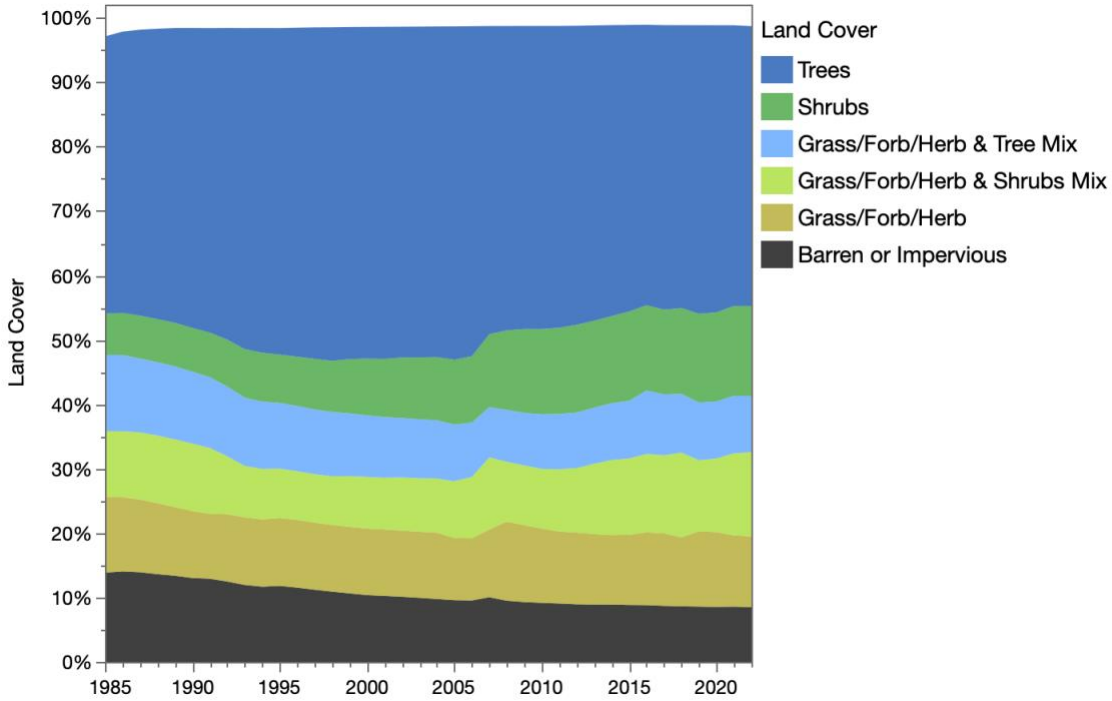

Figure 8 Land Cover trends from 1985 to 2022.

3.3 CROSS-CUTTING INFLUENCES

3.3.1 SLOPE

Across all years, barren soil was most prevalent in watershed management units that were excessively steep (22.9% at 1:1 average slope) and decreasing consistently to 1.3% in moderately sloped units (4:1) (Figure 9). Grass/Forb/Herb cover was influenced most consistently by steepness, fire history, and orientation, with geology influences less consistent but still highly significant. Cover of grass/forb/herb vegetation was lowest on the steepest slopes (4.9% median) and increased to 8.7% in very steep watershed (2:1), 11.6% in steep watershed (3:1), and 38.1% in moderately steep watershed (4:1).

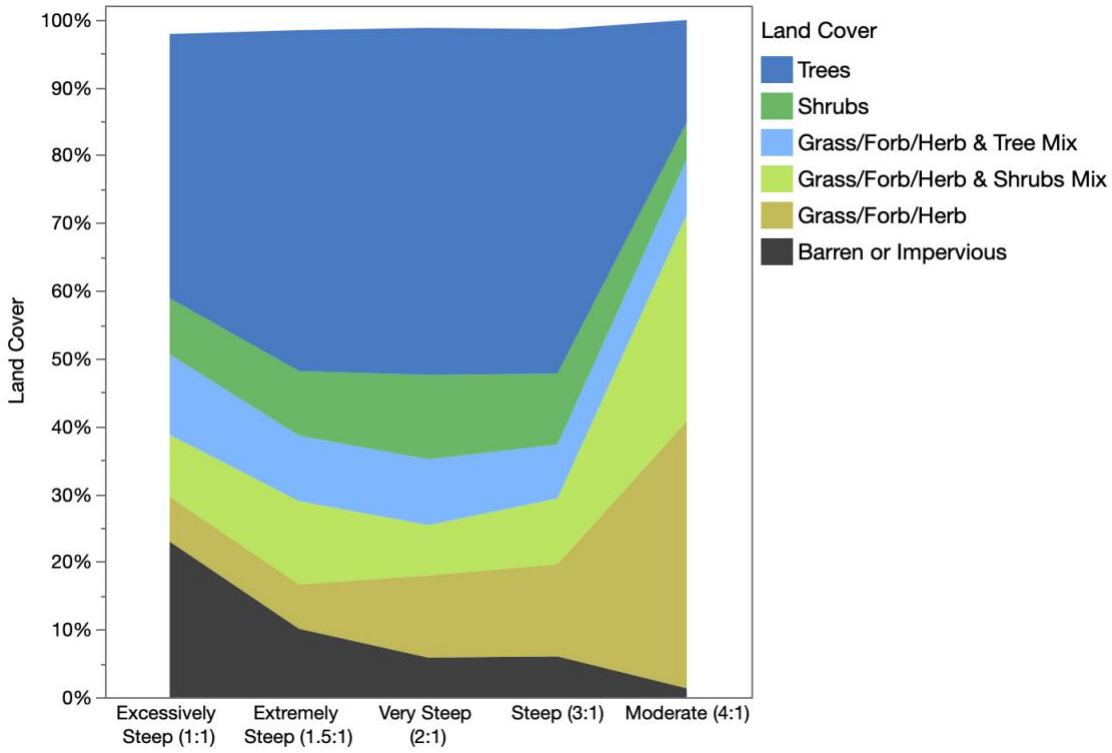

Figure 9 Influence of slope on land cover.

Grass/Forb/Herb & Shrubs mix was influenced most consistently by drainage orientation, steepness, and geology, with fire history also influencing cover during the period. This cover class was below 10% for watersheds with average slope of 1:1 to 3:1 and jumped to 29.7% in watersheds of moderate slope. Although driven somewhat by outliers, the prevalence of Grass/Forb/Herb & Tree cover was greatest (11.9%) in the steepest watershed management units (1:1) and was slightly less in steep watersheds (9.7% for 1.5:1, 2:1; 7.9% for 3:1) and lowest at moderate steepness (8.1% at 4:1). Shrubs had the highest cover in watershed management units with intermediate slope for the range on the island, 12.4% at 2:1 slope. Cover was less at both steeper and

shallower slows, at 8.2% in units with 1:1 average slope and 4.5% in units with moderate (4:1) slope. Tree cover is similar across the intermediate slope categories at 50.3 to 51.2% for the range from 1.5:1 to 3:1. Greater average slopes reduced tree cover to 39% (at 1:1) and flatter units to 15% (4:1).

3.3.2 Geology

The major geological distinction on Catalina Island is between soils derived from schist and those derived from volcanic parent material. These categories influenced land cover in consistent ways. All else being equal, tree cover was greater (52.2%) on volcanic as opposed to schist (46.4%) soils (Figure 10). Similarly, Grass/Forb/Herb & Tree mix was greater on volcanic soils (13.4% vs. 7.6% on schist). Barren soil was slightly lower (9.8%) on volcanic soils compared to schist (10.1%) but this difference was not significant. Shrubs were higher on schist soils (11.1%) compared to volcanics (8.1%). The related Grass/Forb/Herb & Shrub classification was also higher on schist (12.1%) compared to volcanic soils (6.4%). Grass/Forb/Herb was higher as well on schist (11.2% vs. 8.8%). Overall, grass and shrubs give way to more tree cover when moving from schist to volcanic soils.

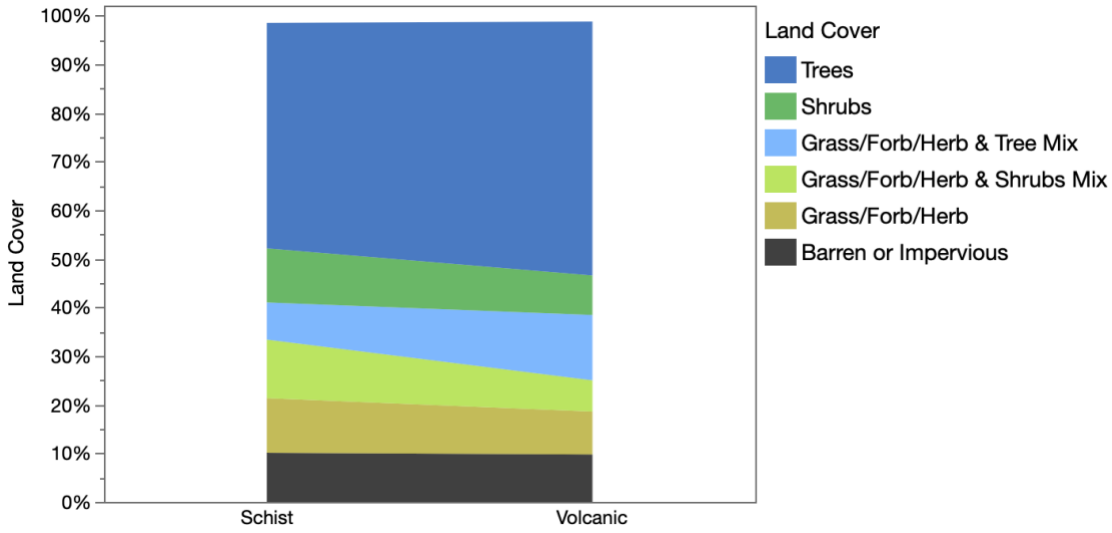

Figure 10 Influence of parent material on land cover.

3.3.3 Orientation of Main Drainage

Location on the leeward (NE side of the island) or windward side of the island, as classified by the main drainage in each watershed management unit, is highly influential for land cover. This influence results from the greater precipitation, north and north-eastern aspect, and lower windspeeds. We compiled available meteorological data to illustrate this difference. Weather stations on the leeward side had average windspeeds of 1.8 to 2.5 mph, while those on the windward side were as high as 6.9 mph average (Figure 11). The airport location, although technically on the leeward side, is located at the exposed ridge of the island and has higher average windspeeds than typical leeward locations.

Precipitation records from stations across the island show lower average totals on the extreme windward side (8.2 to 8.5 inches per year) compared with leeward side stations at 9.6 to 10.5 inches per year or more (Figure 12). The range in average precipitation on the island (8.2 to 10.5 inches) is lower than in coastal southern California region, which ranges from 9.5 to 13 inches (240 to 330 mm) (Okin et al. 2018).

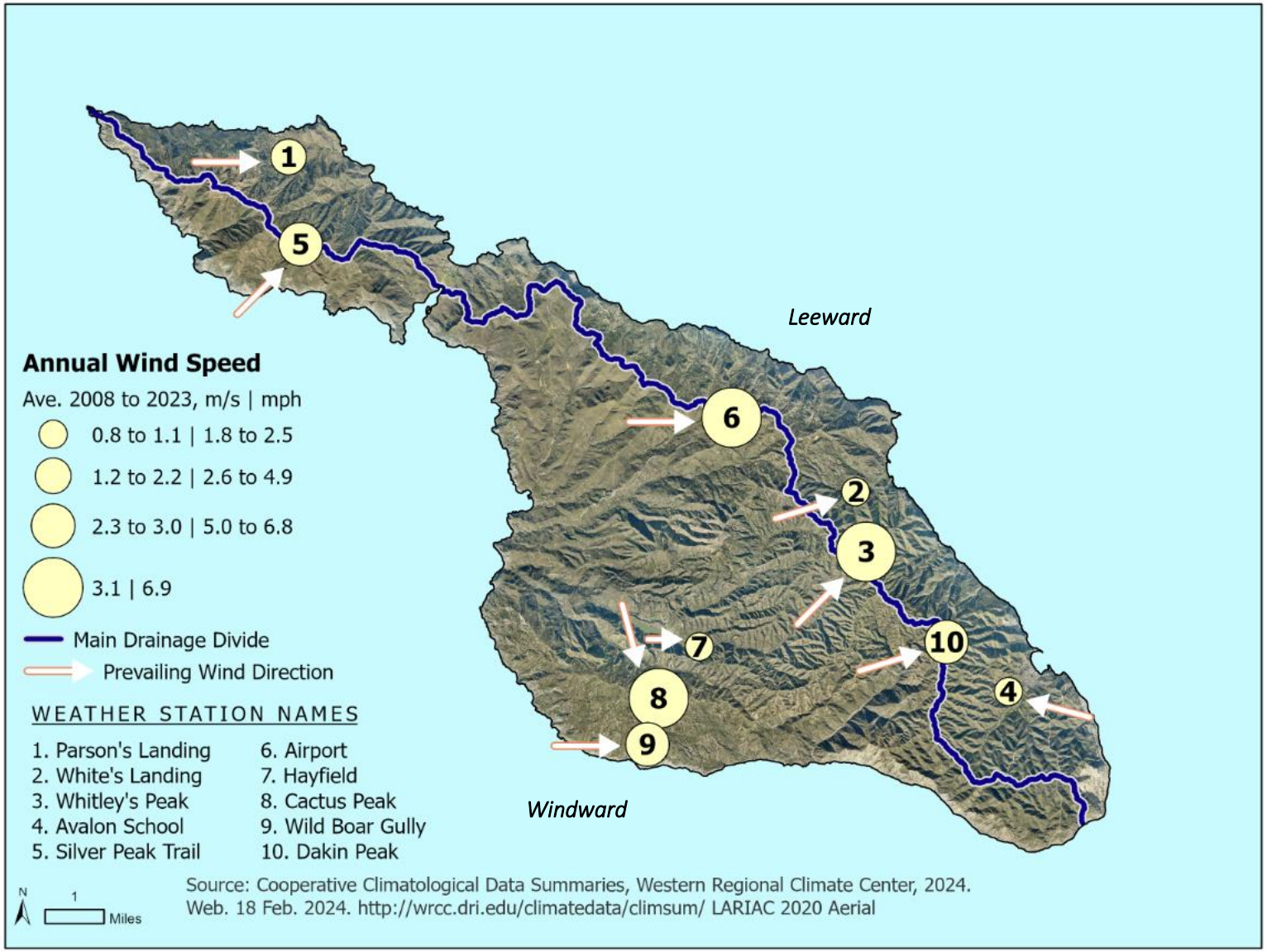

Figure 11 Average annual wind speed.

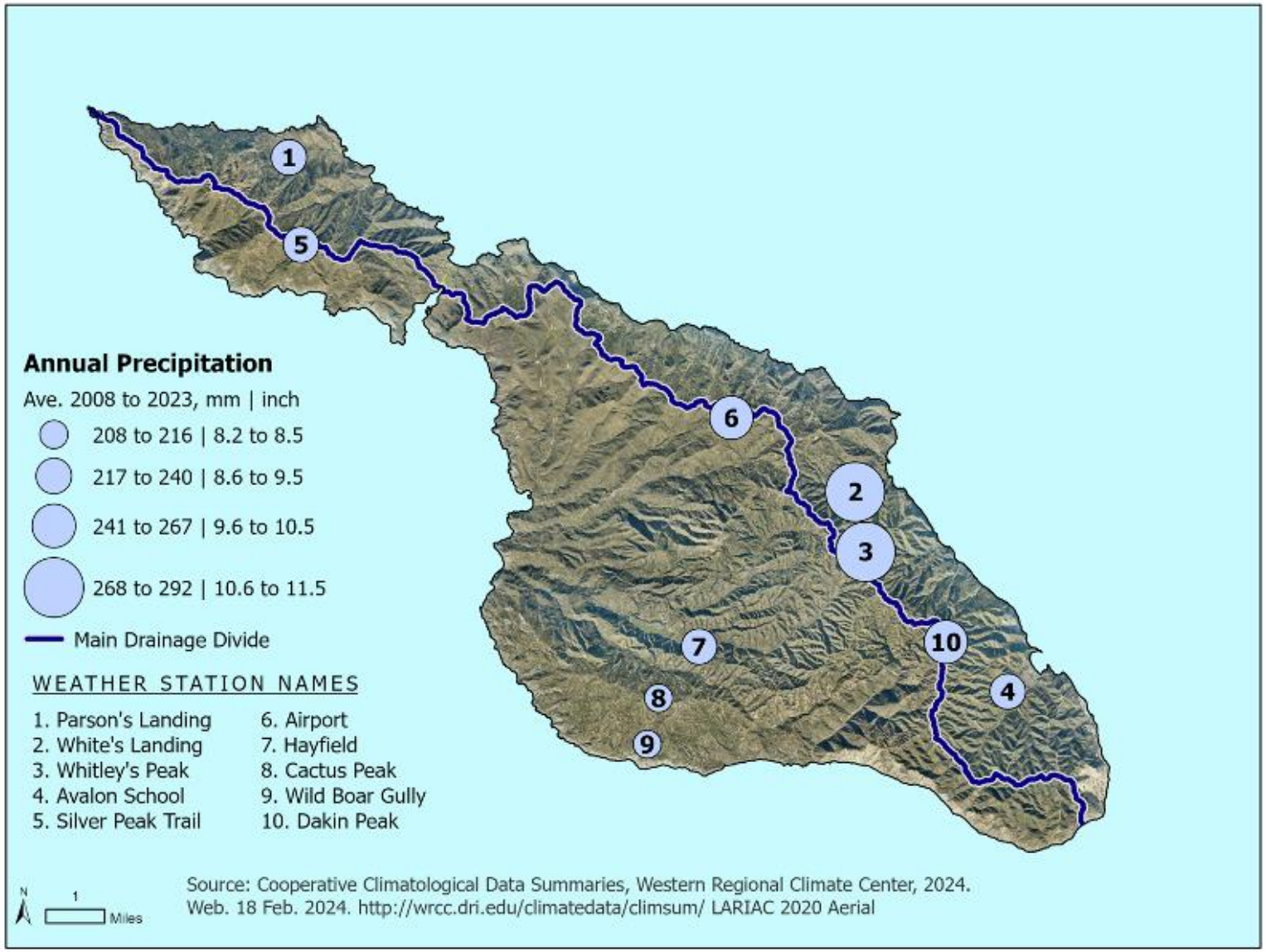

Figure 12 Average annual precipitation.

A gradient of north-eastness (correlating with overall landscape orientation) is established as a proxy measure for wetness on the Channel Islands (Paudel et al. 2016). The most dramatic influence of leeward compared with windward orientation on Catalina is that the Tree cover is almost twice as great on the leeward (61.8%) compared to the windward side (36.5%) (Figure 13). Grass/Forb/Herb & Tree Mix is even on both sides (9.6%). All other cover classes are greater on the windward side than the leeward side, including shrubs (11.8% vs. 8.2%), Grass/Forb/Herb & Shrubs Mix (15.1% vs. 3.0%), Grass/Forb/Herb (11.6% vs. 9.8%), and Barren or Impervious (13.8% vs. 6.3%). Urban development, found more on the leeward side, increases the impervious cover there.

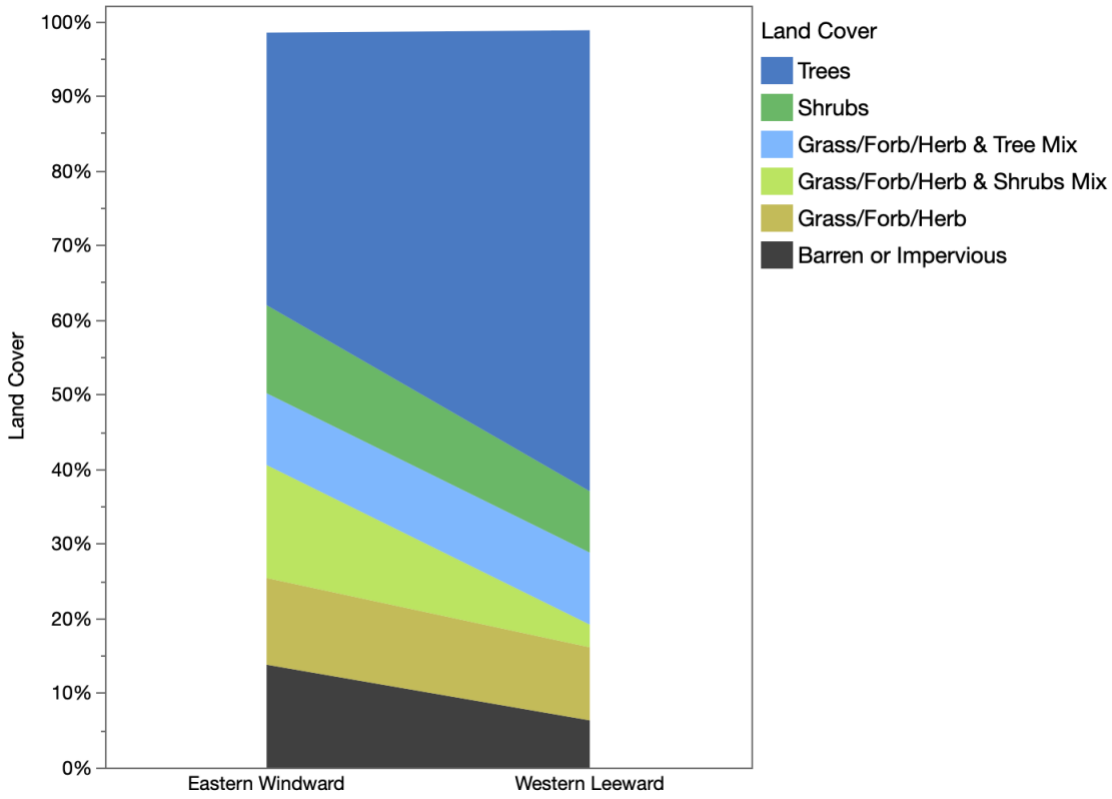

Figure 13 Influence of orientation of the main drainage on land cover.

These patterns are consistent through the time series (Figure 14). Even the total Tree cover following fires on the leeward side is greater than the maximum Tree cover on the windward side.

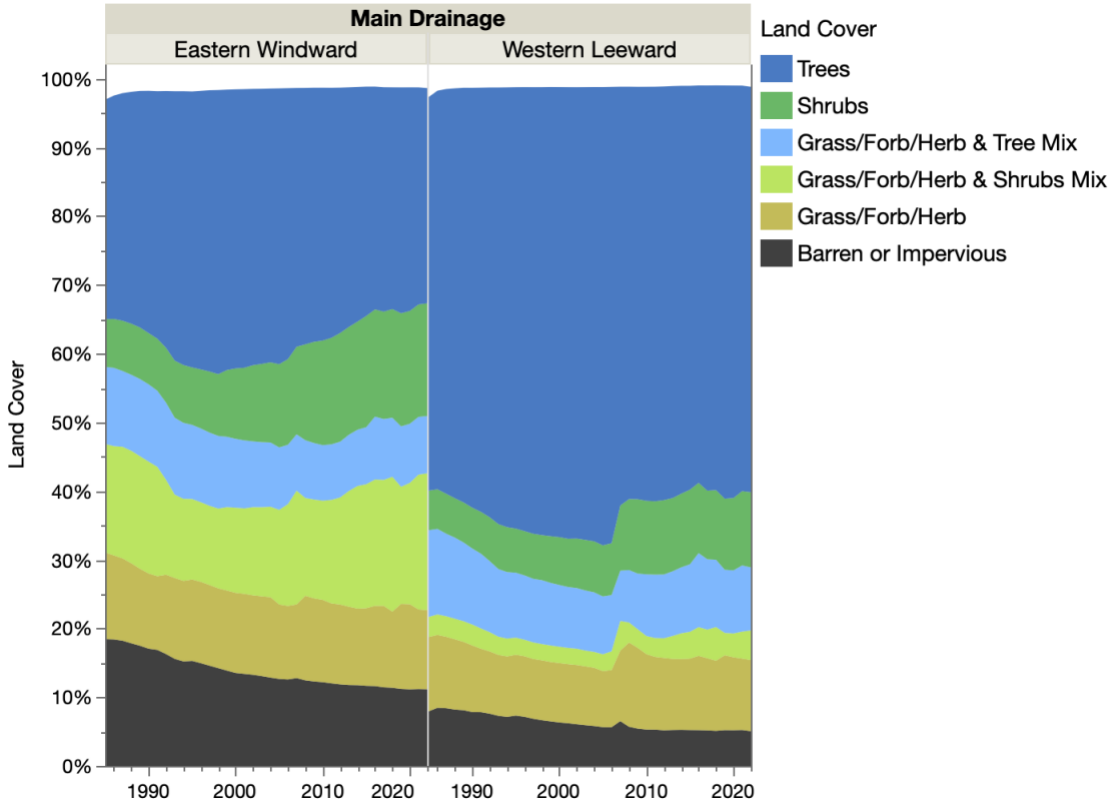

Figure 14 *Relative land cover by orientation of the main drainage of the watershed management unit.*

3.3.4 Fire History

Classifying watershed management units by whether they had any fires in the period 1985 to 2022 segregates long-term trends attributable to other factors from the influence of fire. During the period of analysis, unburned watersheds started with tree cover of 40.2%, which increased to a maximum of 48.7% in 1998 then declined from that point through to a low of 40.1% in 2022 (Figure 15). During this period, barren soil decreased (15.5% to 10.3%), shrubs more than doubled (6.9% to 15.0%), Grass/Forb/Herb was stable at 11.0 to 12.1%, and Grass/Forb/Herb & Shrubs Mix increased from 11.1% to 14.7%.

Management units that burned at all during this period show immediate responses to fire and evidence of succession following it. Tree cover started at 52.0% in 1985 and increased until just before the Empire fire (63.2% in 2005). Tree cover declined to 49.5% in 2008 and then stayed stable for 8 years and increased slightly into 2022 to 54.0%.

Barren soil started at 8.6% in 1985, decreased to 4.0% before the Empire Fire, increased to 5.7% with the Island Fire, then decreased to 2.7% in 2022. Grass/Forb/Herb showed a significant response to fire, having been stable between 10.9% and 9.2% from 1985 to 2005, it increased to 18.1% following the Island Fire, and declined to 10.7% in 2022.

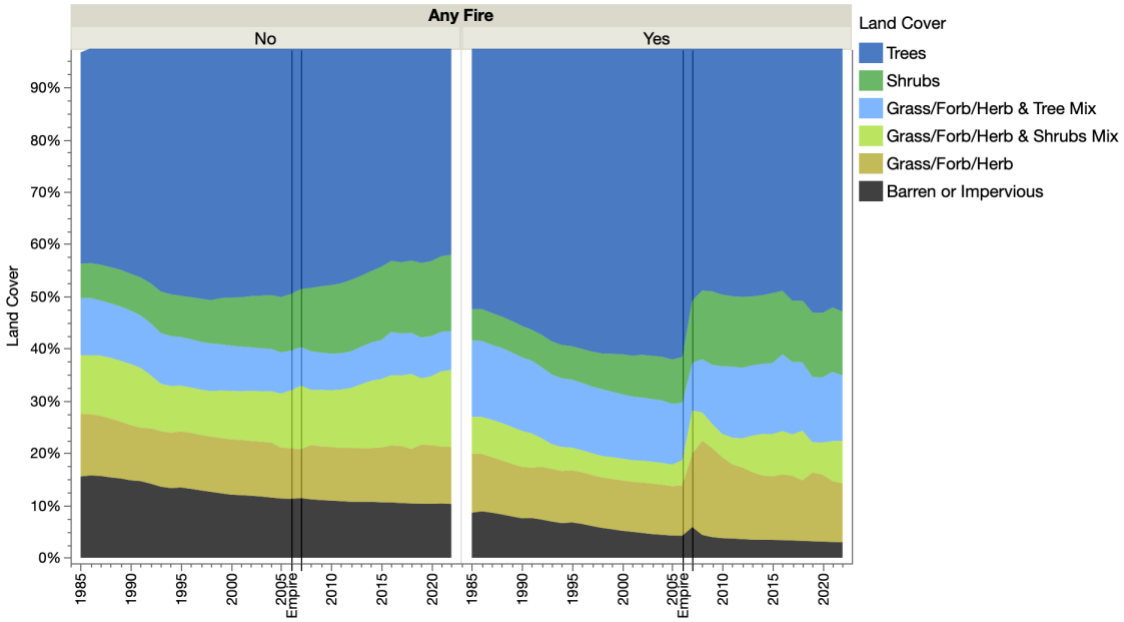

Figure 15 Land cover trends in watershed management units with and without fires from 1985 to 2022.

3.3.5 Precipitation and Drought

The weather data for Catalina are incomplete, with a period from the early-1990s through 2000 missing (Figure 16). The remaining record shows typical oscillations of a Mediterranean climate, with the influence of the El Niño/La Niña oscillation and the Pacific Decadal Oscillation apparent in the yearly extremes and the cycling between wet and dry periods. Temperature has been trending upwards and is projected to continue to do so. We graphed the land cover trends with drought periods for areas that either had a large fire in the WMU since 1985 or did not to better visualize the effect of drought.

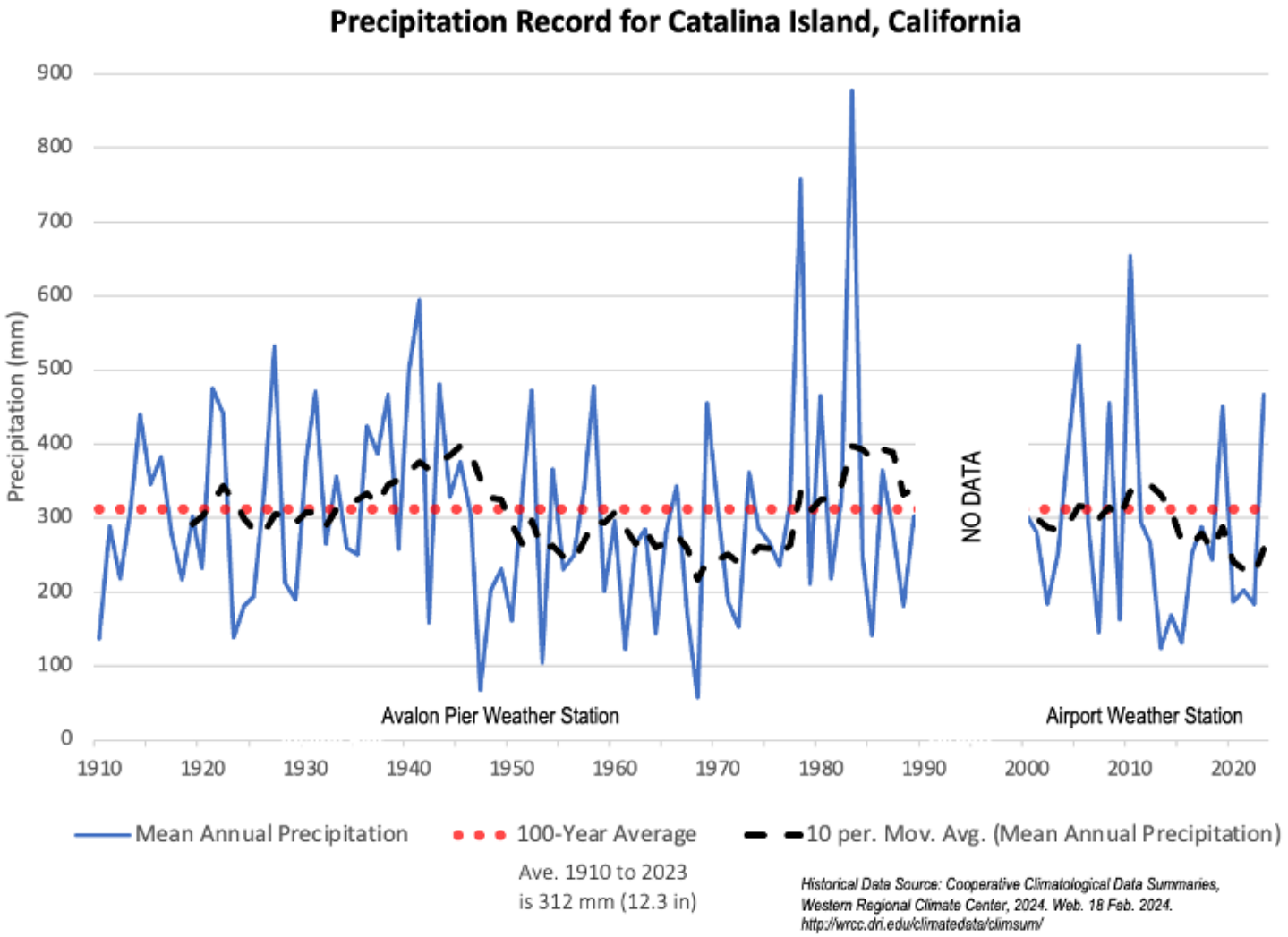

Figure 16 Precipitation record from 1910 to 2022.

Inspection of the overall land cover trends during 1985 to 2022 suggest the influence of drought on vegetation trends. Tree cover was increasing in the period 1985 to 1990 even though this period contained a 3-year period of below average rainfall for Long Beach (our proxy because of the missing data from Catalina). The Catalina record, however, shows that this was still a period where the 10-year average of precipitation was significantly above normal. It also corresponds with the period when the vegetation was first recovering from the initial partial removal of goats and pigs. Tree cover declined slowly through the period 1998 to 2010 in those areas that did not burn without there being a significant drought event (Figure 17). However, for those areas that burned in 2006 and 2007, recovery of Tree cover increased in recovery but then declined during the 2011 to 2016 drought period. This was true across both burned and unburned areas (see next section, 3.4). Further drought in 2020 through 2022 was similarly associated with reductions in the Tree classification in the cover maps.

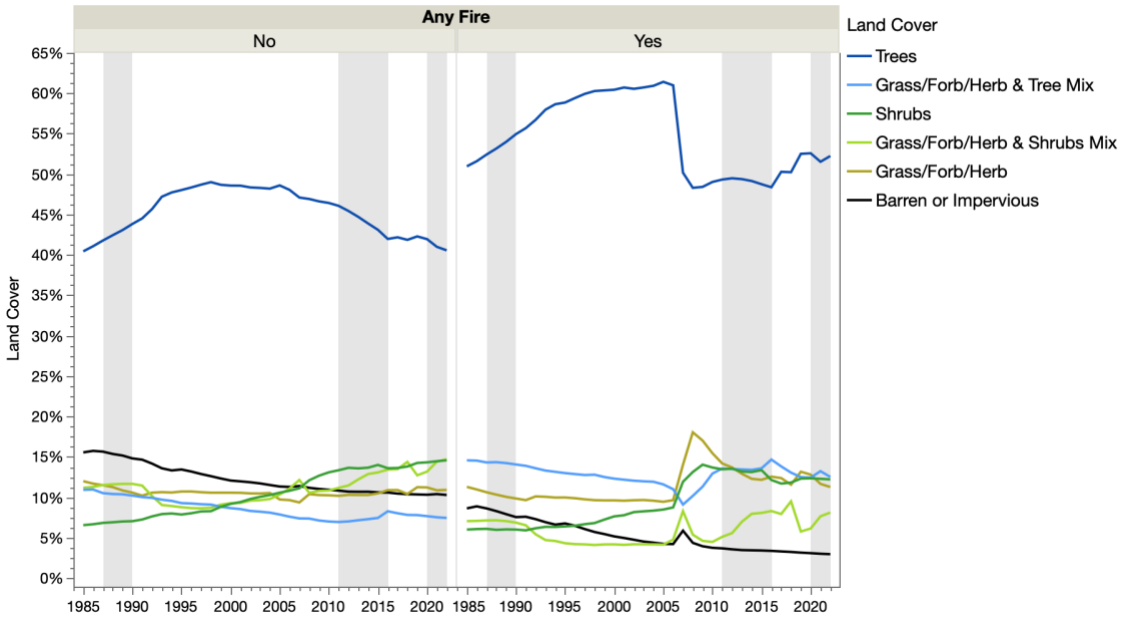

Figure 17 *Trends in land cover on Catalina Island 1985 to 2022 as an average of watershed management units that either did or did not have a significant fire during the period, with drought periods (3 or more consecutive years with under average precipitation) marked in gray.*

3.4 SYNTHETIC ANALYSIS

3.4.1 TYPOLOGY

Our review of the changing land cover patterns and associations with slope, orientation, geology, and fire history resulted in a proposed classification that assigns the 105 watershed management units used by the Conservancy into a hierarchical system of 13 groups. The top level combines drainage, geography, and land use into five groups:

Group 1. Leeward side of the West End

Group 2. Windward side of the West End and near Isthmus

Group 3. Leeward side of main island

Group 4. Windward side of main island

Group 5. Dominated by development

Then, Group 3 is divided into areas with schist geology (3a) and volcanic geology (3b). Group 4 is similarly divided by geology into schist (4a) and volcanic (4b). Finally, fire history is added as a subgroup for 3 and 4 within each of the geology classifications and depending on the fire. The result is a system with 13 categories that isolate different influences on vegetation and their trajectories over time (Figure 18).

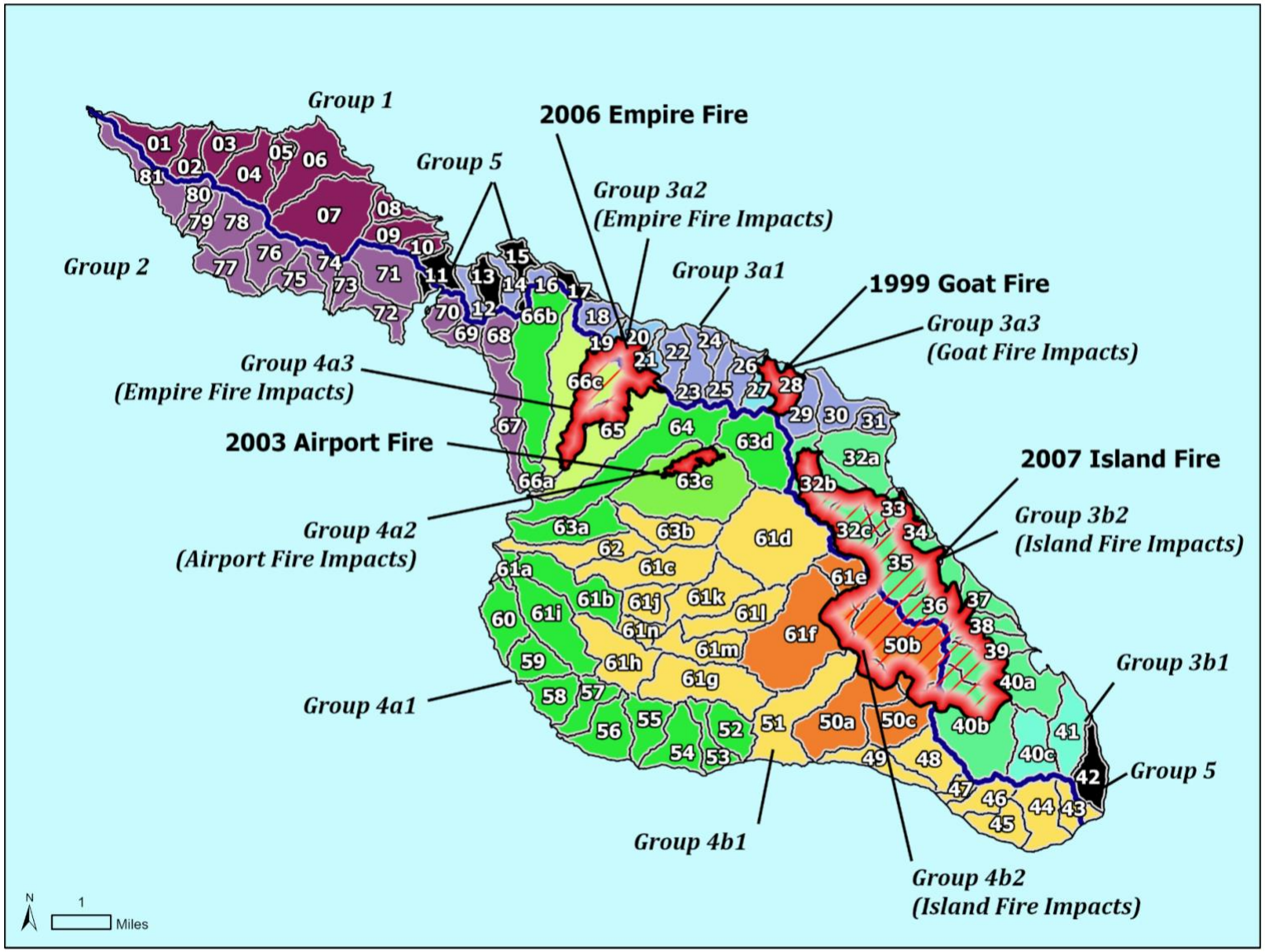

Figure 18 Groups for analysis of land cover trends.

3.4.2 GROUP 1 – EASTERN LEEWARD SIDE OF WEST END

The leeward side of the West End contains 10 watershed management units (1 to 10). It has had no significant fires and soils are primarily derived from Catalina Schist and Landslide parent material. Tree cover has ranged from 56.7% in 1985 to 65.1% in 2006 to 60.4% in 2022. Grass/Forb/Herb & Tree Mix increased from 7.7% in 2006 to 9.1% in 2022, indicating that some of the reduction in tree cover is dieback and thinning (Figure 19). Shrubs increased from 6.4% in 1985 to 9.2% in 1993, remained stable through 2006 and then increased to 12.3% in 2022. Grass/Forb/Herb started at 13.8% in 1985, declined to 10.6% in 1994 and has remained stable since, ending at 10.4% in 2022. Barren soil declined from 3.9% in 1986 to 2.3% in 2022.

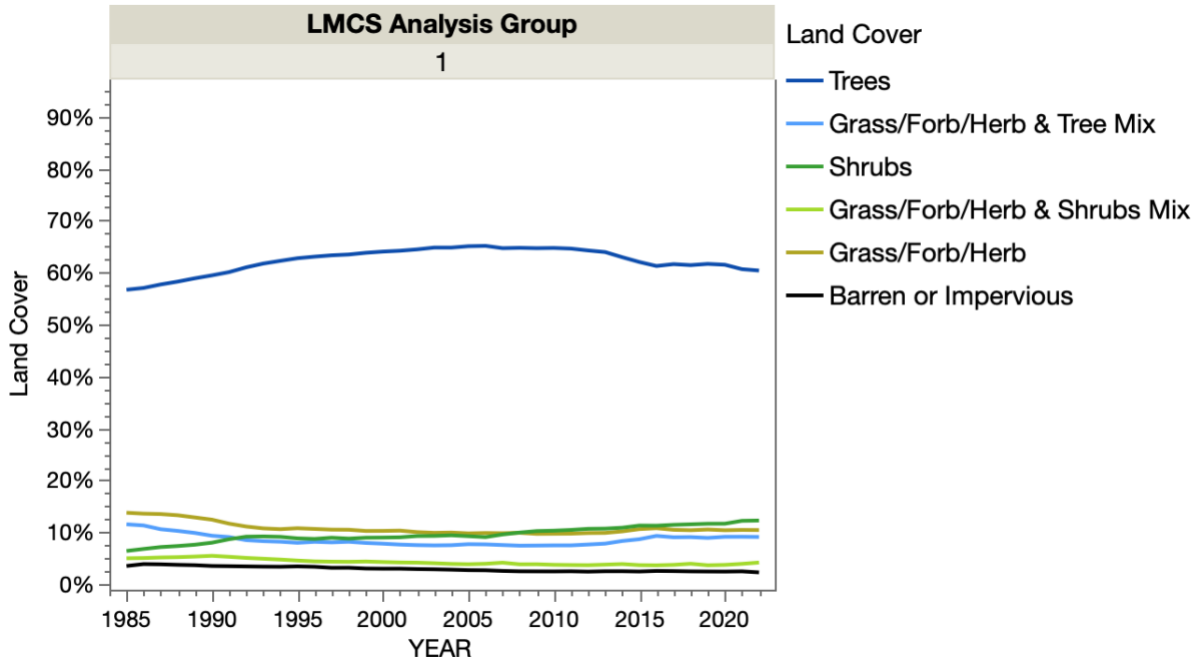

Figure 19 Group 1 land cover trends, 1985 to 2022.

3.4.3 Group 2 – Windward Side of West End and Near Isthmus on East End

The windward side of the west end and nearby management units on and next to the isthmus make up Group 2. The parent material is primarily Catalina Schist and Landslide. All these units are very steep and they have the most sustained fog cover into the summer months. It has less island scrub oak because of the fog and indeed the tree cover is quite low in comparison with other groups. It has large areas of grassland and patches of black sage and other low-growing shrubs.

For the group (units 67 to 81), tree cover started in 1985 at 20.9%, increased to 26.6% in 1998, then declined consistently to 9.4% in 2022 (Figure 20). Shrub cover increased consistently from 7.4% in 1985 to 24.4% in 2012 and has remained stable for the past decade. Grass/Forb/Herb class increased from 8.5% in 1985 to 11.4% in 1995 and has remained reasonably stable since then, ending at 11.3% in 2022. Barren land was at a maximum of 24.7% in 1987 and since then declined to 17.9% in 2022.

Individual watershed management units had variations on this theme, including influence by some smaller fires. Unit 67 (Euphorbia Haven) has a high cover of the Grass/Forb/Herb & Tree Mix, which has been steadily declining and replaced by more shrub classes. Units 68, 69, and 71 have seen an increase in the Grass/Forb/Herb & Shrubs Mix at the expense of Tree cover. Unit 70 (Ballast Point) has also seen a decrease in trees in favor of shrubs; it burned in 1982 and partially burned in 2011. Variability is highest in units 72 to 81, but also show a loss of trees in favor of shrubs and the Grass/Forb/Herb & Shrub Mix class.

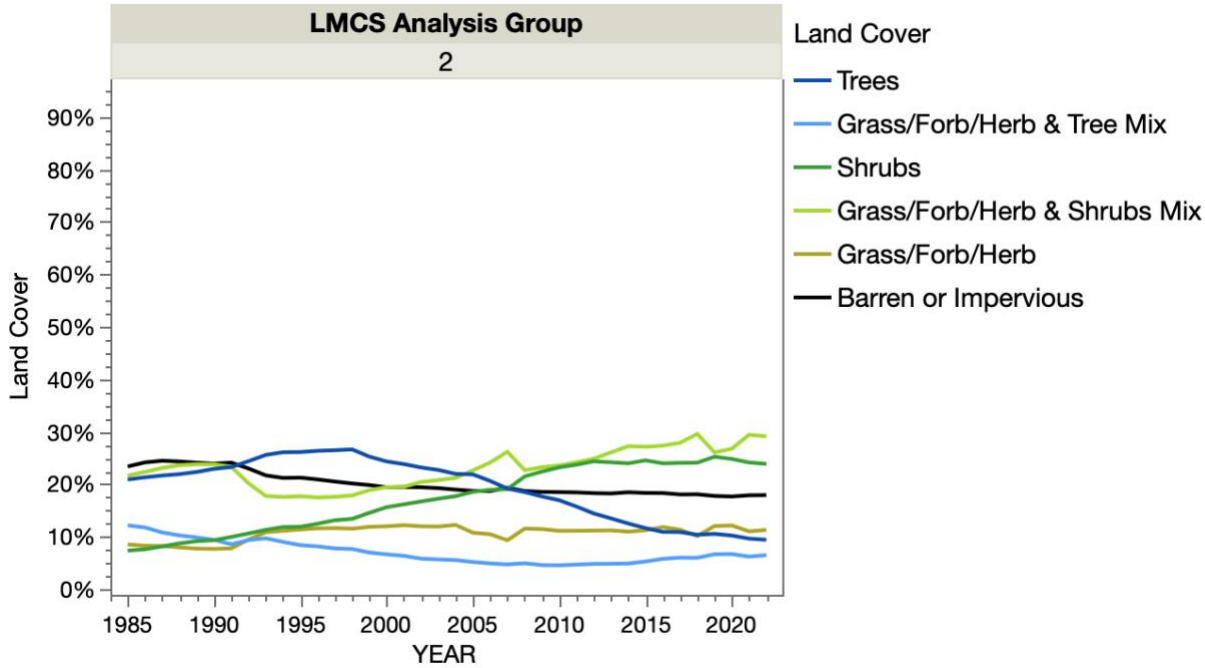

Figure 20 Group 2 cover trends, 1985 to 2022.

3.4.4 Group 3a1. Eastern Leeward Side of East End without Recent Large Fire - Catalina Schist

Group 3 is the leeward side of the main island (east of the isthmus). Within it, 3a are units with primarily schist geology and 3a1 are those units without large fires, and include watershed management units 12, 14, 16, 18, 22, 23, 24, 25, 26, 29, 30, and 31. These are primarily very steep channel facing drainages with primarily Catalina Schist parent material with other Landslide Deposits and volcanic derived soils.

Overall, these units have seen a steady gradual increase in tree cover following goat/pig removal, but with a decrease following the extended drought in the 2010s. Tree cover was at 59.3% in 1985, increased to 69.0% in 2005 and decreased to 62.9% in 2022 (Figure 21). Shrub cover increased some from 1985 to 2005 (8.9% to 9.5%) and then relatively more from then until 2022 (12.3%). Grass/Forb/Herb cover remained stable; (12.0% in 1985, 11.3% in 2022). Barren cover decreased from 5.1% in 1986 to 2.4% in 2022.

Within the group, units 12, 14, and 16 had small increases in tree and shrub cover from 1985 to 1998. Units 18, 22, 23, and 24 also had gradual tree increases but dropped following the 2010s drought. Units 25, 26, 29, 30, and 31 remained quite stable but with some small increases in tree cover. This group is the best comparison with group 3a2, which burned in the Empire Fire and had a drop in tree cover but no recovery afterward.

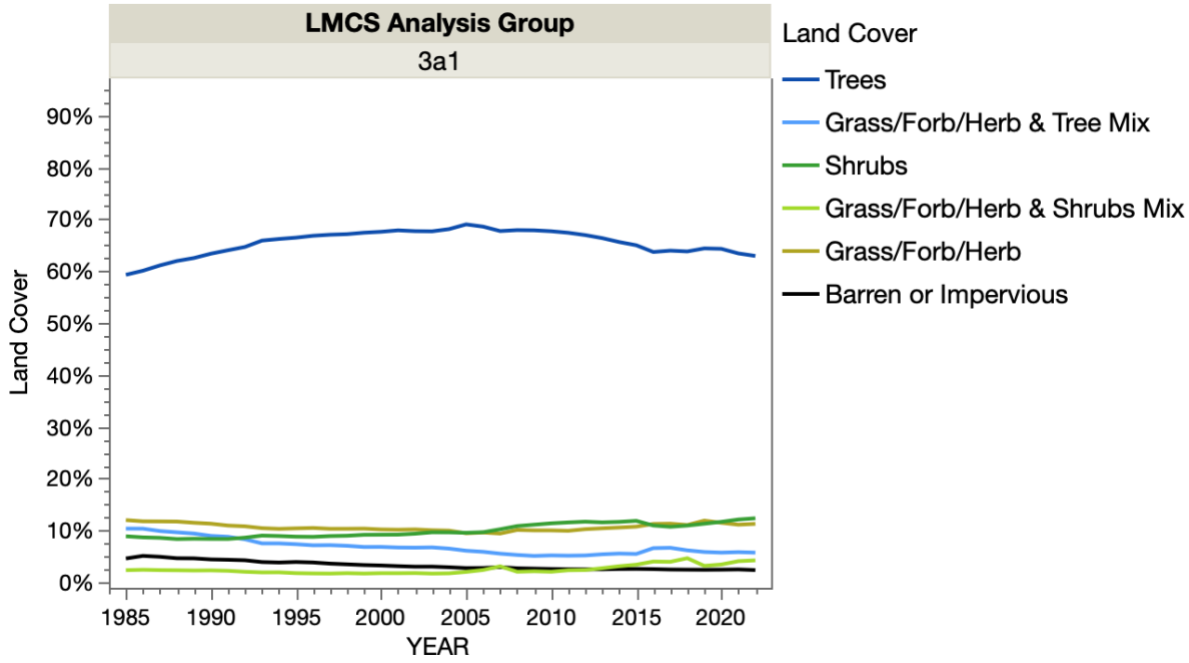

Figure 21 Group 3a1 land cover classification over time.

3.4.5 GROUP 3A2. EASTERN LEEWARD SIDE OF EAST END IMPACTED BY 2006 EMPIRE FIRE - CATALINA SCHIST

Group 3a2 includes leeward management units with Catalina Schist as the predominant parent material that were affected by the 2006 Empire Fire. It includes management units 19, 20, and 21.

Similar fire impacts in management units on both leeward and windward sides of the main drainage divide (compare with Group 4a3). Tree cover increased following goat and pig removal from 68.3% in 1985 to a maximum of 79.2% in 2005 (Figure 22). Since the fire in 2006, tree cover has declined and not recovered (63% in 2007; 60.4% in 2022), being replaced by more shrub cover and grassland. Shrub cover declined from 1985 (7.5%) to 2006 (5.2%) and then increased dramatically after the fire to a maximum of 21.5% in 2012, followed by a decline to 15.5% in 2022. Grass/Forb/Herb class was mostly stable from 1985 (9.7%) to 2006 (7.5%) and since then increased to 12.5% in 2022. Shifts from tree cover to shrub cover do not necessarily mean a change in species composition; island scrub oak can recover but be at a smaller stature during an extended recovery period in a drier climate. Lack of tree recovery following the 2006 fire is attributable to both extended drought in the 2010s and mule deer foraging in areas with resprouting vegetation.

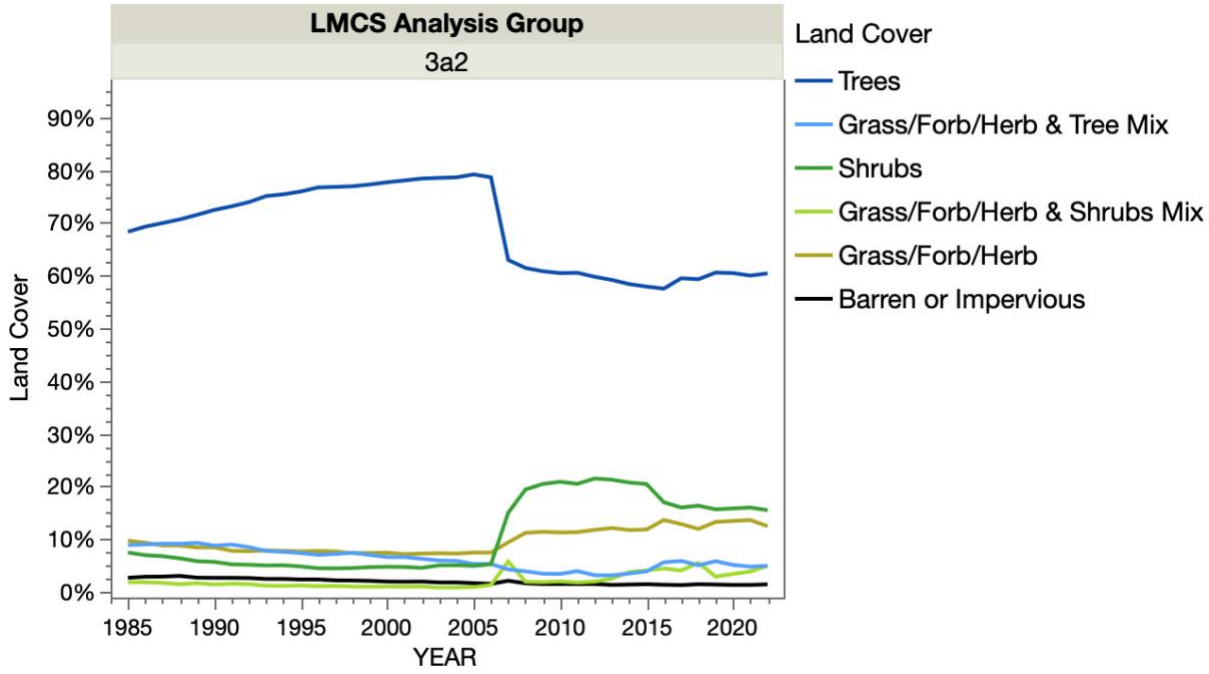

Figure 22 *Land cover trajectories in leeward management units with schist parent materials affected by the 2006 Empire Fire.*

3.4.6 GROUP 3A3. EASTERN LEEWARD SIDE OF EAST END IMPACTED BY 1999 GOAT FIRE - CATALINA SCHIST

Group 3a3 shares all characteristics with 3a2 except it includes those areas affected by the 1999 Goat Fire instead. It includes management units 27 and 28. Tree cover reached a maximum (64.8%) in these units in 1997, declining to 62.7% by the time of the fire and then continuing to a low of 55.9% in 2002 (Figure 23). It subsequently has increased to 61.4% (2022). Shrub cover shows a complementary trend, stable from 1985 (6.0%) to 1997 (7.0%), then increasing to 13.0% in 2002 and to 14.6% by 2015, after which it decreases to 10.4% in 2022. Barren cover decreased through the whole period from 8.7% in 1986 to 2.9% in 2022. Grass/Forb/Herb remained reasonably stable, from 7.5% in 1985 to 8.7% in 2022.

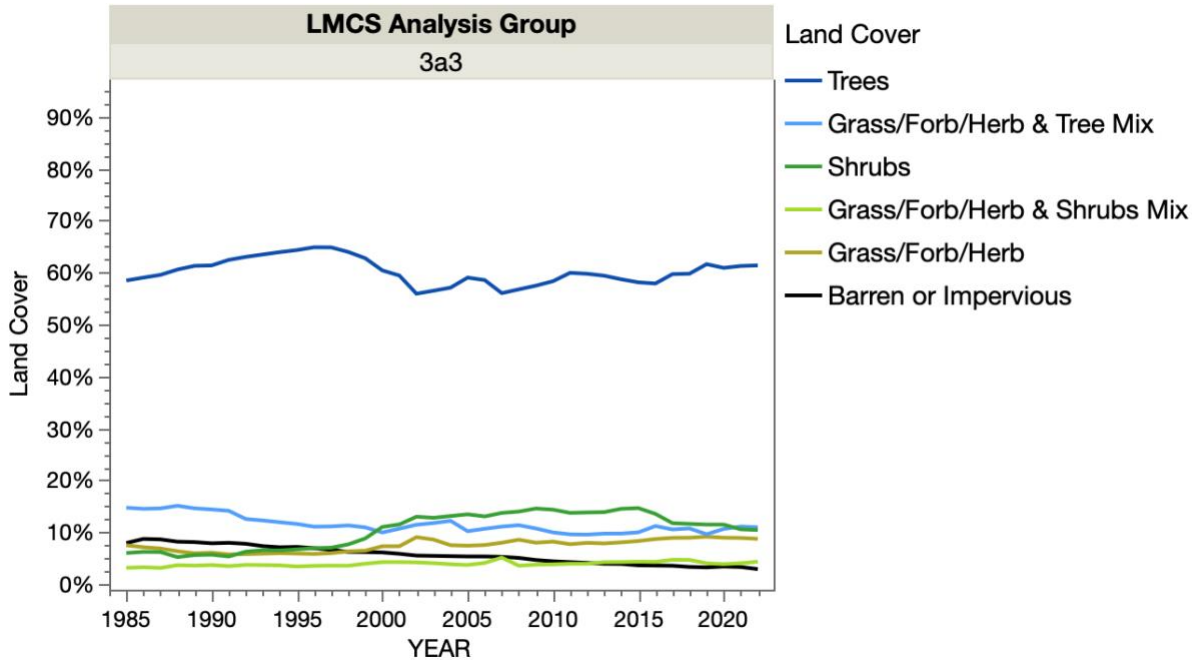

Figure 23 Land cover trajectories in leeward management units with schist parent materials affected by the 1999 Goat Fire.

3.4.7 GROUP 3B1. EASTERN LEEWARD SIDE OF EAST END WITHOUT RECENT LARGE FIRE - VOLCANIC ROCK

Group 3b1 consists of leeward management units with volcanic parent material (Tv or Tmqd) on the main island that have not had a large recent fire. These units are steep with landslide deposits common. They have higher annual rainfall and lower windspeeds than on the windward side of the island and slopes are North-Northwest to East facing, increasing the available moisture. This contrasts with most of the western windward side of the island that has slope aspects that typically range from South-Southeast to West facing. The exception is Bullrush Canyon, which has dominant North-Northeast facing slopes, due to the northwest to southeast alignment of the canyon, which parallels the orientation of the main axis of the island and the leeward, channel-facing watersheds. The rest of the canyons on the western windward side, generally are aligned from the southwest to the northeast, which also roughly aligns with the prevailing westerly wind direction off the open ocean. The unburned units in this category include 40c and 41 and serve as a comparison for Group 3b2, which burned in the 2007 Island Fire.

For this group, tree cover is high, between 84.5% and 87.3% from 1985 to 2015, with a dip in 2016 and decline to 82.9% in 2022 (Figure 24). The Grass/Forb/Herb & Tree Mix increases in 2016 associated with the Tree dip. Shrub cover increased from 0.5% in 1985 to 2.3% in 2022, replacing some of the tree cover. Barren cover declined very slightly from 4.7% in 1985 to 4.0% in 2022.

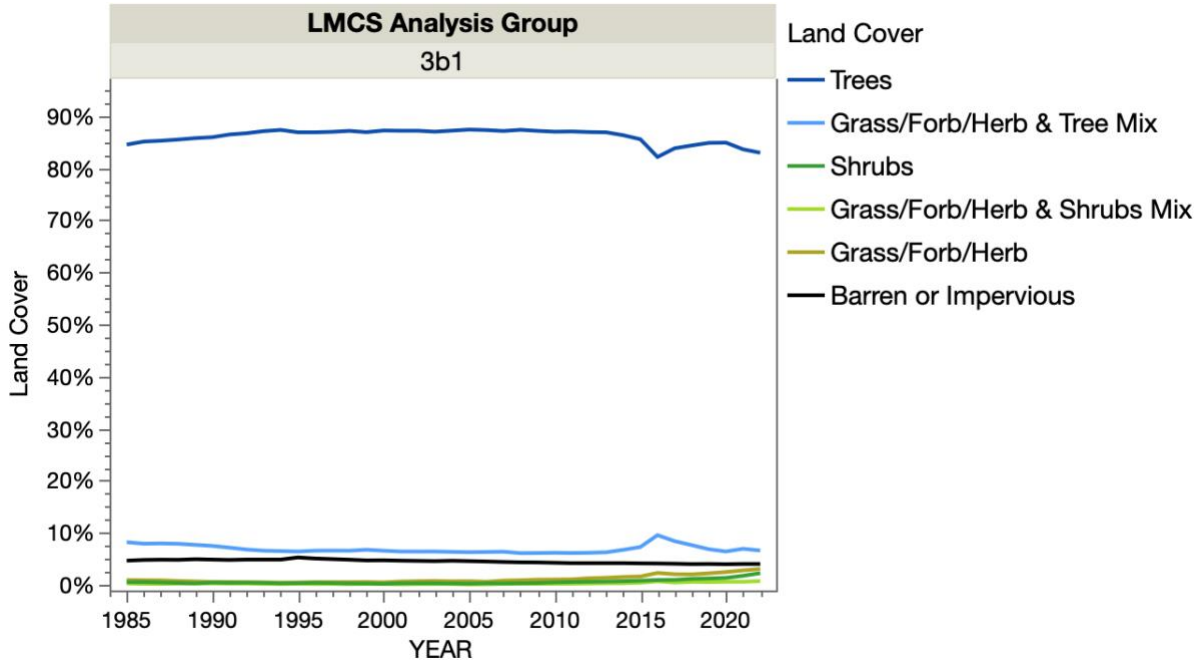

Figure 24 *Land cover trajectories in leeward management units with volcanic parent materials affected by any large fires.*

3.4.8 Group 3b2. Eastern Leeward Side of East End Impacted by 2007 Island Fire - Volcanic Rock

These areas on the leeward side on volcanic soils have higher tree cover in general (see analysis above) and are affected by the 2007 Island Fire. They show substantial gains in tree cover following goat removal, increasing from 61.8% in 1985 to 74.7% in 2006 (Figure 25). The fire reduced tree cover by a quarter to 56.2% in 2008, after which it has somewhat recovered to 64.9%. Grass/Forb/Herb & Tree Mix had declined with Tree increases from 1985 to 2006, decreased immediately after the fire and increased to a persistently higher level during the drought from 2010 to 2017 and decreased slightly into 2022. Barren areas have a long-term decline from 11.7% in 1987 to 4.4% in 2022 with a spike in 2007 to 9.5%. Grass/Forb/Herb cover spiked from 3.2% in 2006 to 16.1% in 2008 and remains well above 1985 to 2006 levels at 6.3% in 2022. Grass/Forb/Herb & Shrub Mix also remains above its 1985 to 2006 levels (2.3% in 2022 vs. 1.3% in 1985). Post-fire recovery appears to be hampered by both drought (2010s) and browsing.

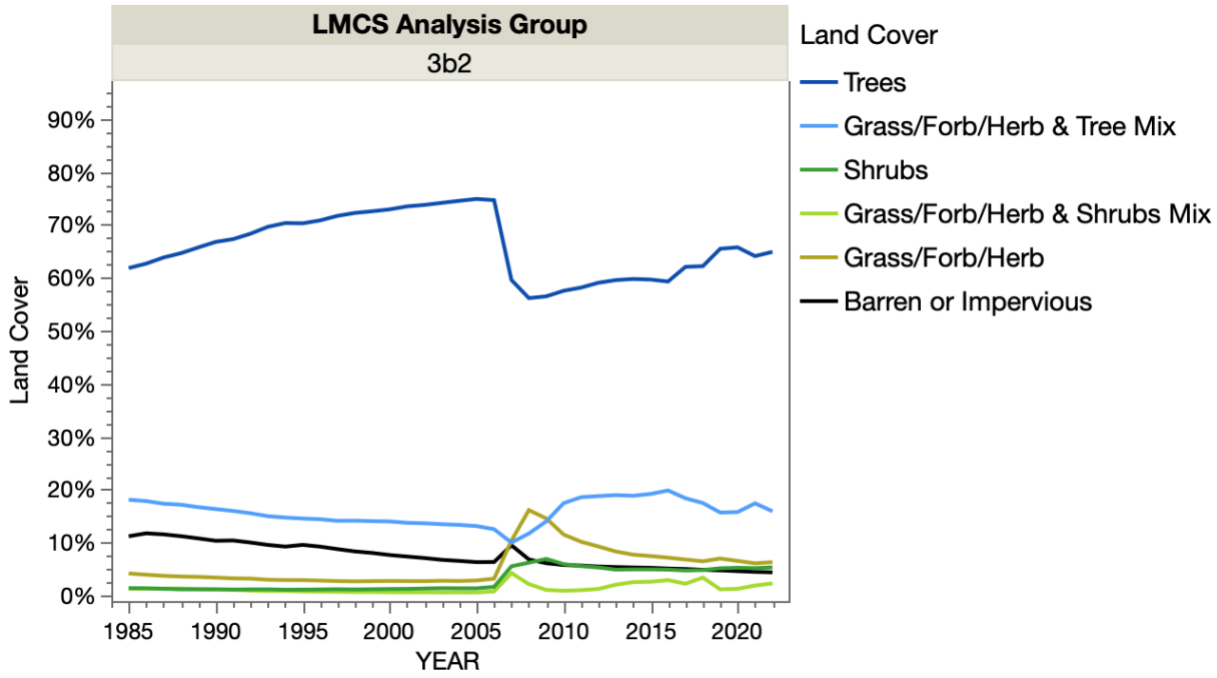

Figure 25 *Land cover trajectories in leeward management units with volcanic parent materials affected by the 2007 Island Fire.*

Within this group unit 32a has both volcanic parent material and schist parent material. The portion that burned had volcanic patient material. This unit increased in tree cover from 1985 to 2007, lost significantly in 2007, and had continued declines into 2022. Unit 32b is like 32a but has had some recent gains in tree cover. It has some luff/silty loam soils, which differ from other volcanic soils in this group which have loam (Tv parent) to

gravelly loam (Tmqd parent) soils. It is also the unit where White's exclosure is located, which eliminates the effect of mule deer browsing on regeneration. Unit 32c also saw increased tree cover from 1985 to 2007, which has also recovered following the 2007 fire. This is similarly attributable to the luff/silty loam soils. Both 33 and 34 were less affected by the fire and have stable and increasing tree cover. Finally, units 35 to 39, 40a, and 40b increased from 1985 to 2007, lost tree cover proportional to the area that burned and have not yet recovered to 2007 tree cover levels.

3.4.9 Group 4a1. Western Windward Side of East End without Recent Large Fire – Schist with Landslide Deposits

Group 4 management units on the windward side of the island are typically less steep (with the exception of unit 50a). They also include soils derived from volcanic origins (Catalina Island pluton; quartz diorite) of Miocene age and Jurassic aged Catalina Schist. This group contains WMUs 52, 53, 54, 55, 56, 57, 58, 59, 60, 61a, 61b, 61i, 63a, 63d, 64, 66a and 66b.

The general pattern for this group was an increase in tree cover from 37.3% in 1985 to 49.9% in 1998, followed by a decline to 40.8% in 2022 (Figure 26). In the period of increasing tree cover, barren cover decreased (from 18.8% in 1985 to 14.0% in 1998) while Shrub cover remained stable around 8%. As tree cover declined, shrub cover doubled, from 8.0% in 1998 to 16.8% in 2022. The exceptions to this general pattern were units 60 (Cowboy Canyon), 61a (Ben Weston), 63d (Upper Cottonwood), and 66a (Little Harbor), each of which was stable or had some increase in tree cover from 1985 to 2022.

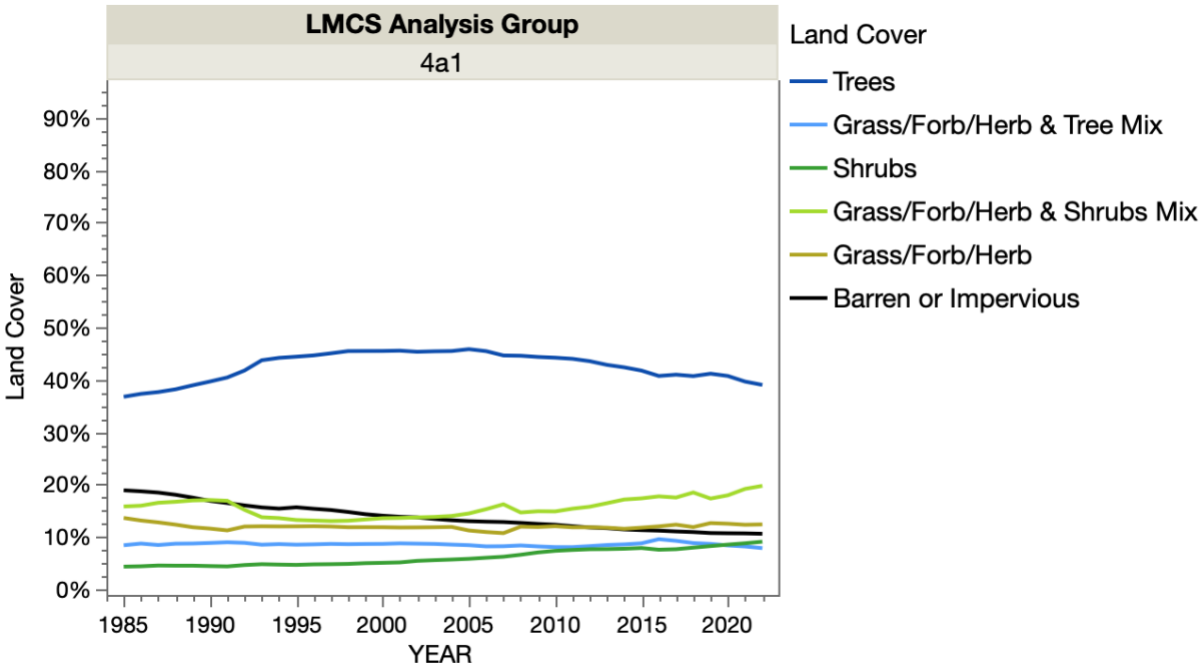

Figure 26 *Land cover trajectories in windward management units with schist parent materials unaffected by recent large fires.*

3.4.10 GROUP 4A2. WESTERN WINDWARD SIDE OF EAST END WITH 2003 AIRPORT FIRE IMPACTS–CATALINA SCHIST WITH LANDSLIDE DEPOSITS

Group 4a2 illustrates the effects of the 2003 Airport Fire on windward management units with Catalina Schist parent material. Tree cover in this unit (63c) increased from 62.7% in 1985 to a high of 72% in 1998 (Figure 27). The fire reduced tree cover from 70.4% in 2002 to 66.3% in 2003, and then drought and lack of recovery has led to a continued decline in tree cover to 56.5% in 2022, falling below even the 1985 levels. Shrubs to some degree have replaced tree cover, increasing from 10.4% in 2002 to peak at 14.6% in 2010 and continuing higher at 13.5% in 2022. Barren cover decreased from 4.6% in 1985 to 0.7% in 2003 and remains low at 0.5% in 2022. Although tree cover declined slightly before the 2003 Airport Fire, its trajectory has been negative in this management unit since that fire.

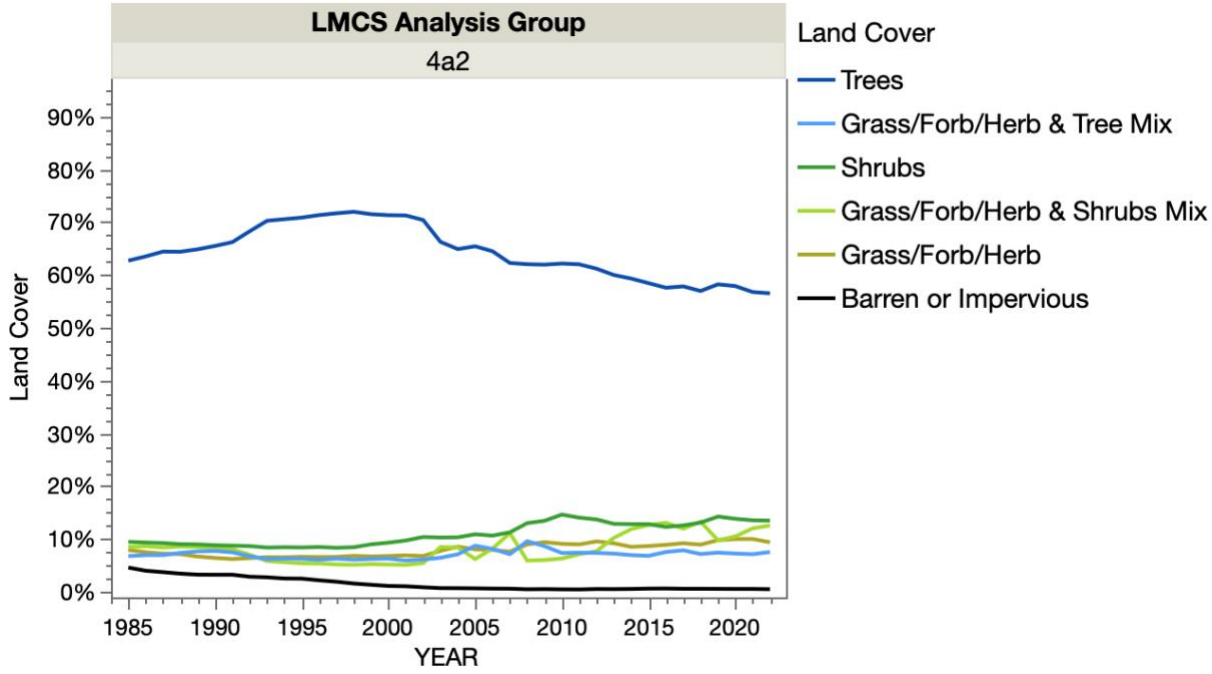

Figure 27 Land cover trajectories in windward management units with schist parent materials affected by the 2003 Airport Fire.

3.4.11 GROUP 4A3. WESTERN WINDWARD SIDE OF EAST END WITH 2006 EMPIRE FIRE IMPACTS–CATALINA SCHIST WITH LANDSLIDE DEPOSITS

Group 4a3 shares characteristics with the other 4a groups but was affected by the 2006 Empire Fire. It includes WMUs 65 and 66c. These units had some small increase in tree cover from 1985 to 1993, then remained stable at 36% through 2005 (Figure 28). After the fire, tree cover jumped down to 27.4% and declined further to 19.8% in 2022. Shrub cover increased steadily from 1985 (9.9%) to 2005 (17.1%) and continued to increase after a slight decrease associated with the fire, to 20.8% in 2011. Grass/Forb/Herb and Grass/Forb/Herb & Shrub Mix move in opposite directions over time, presumably tracking growth and dieback of shrubs within grasslands.

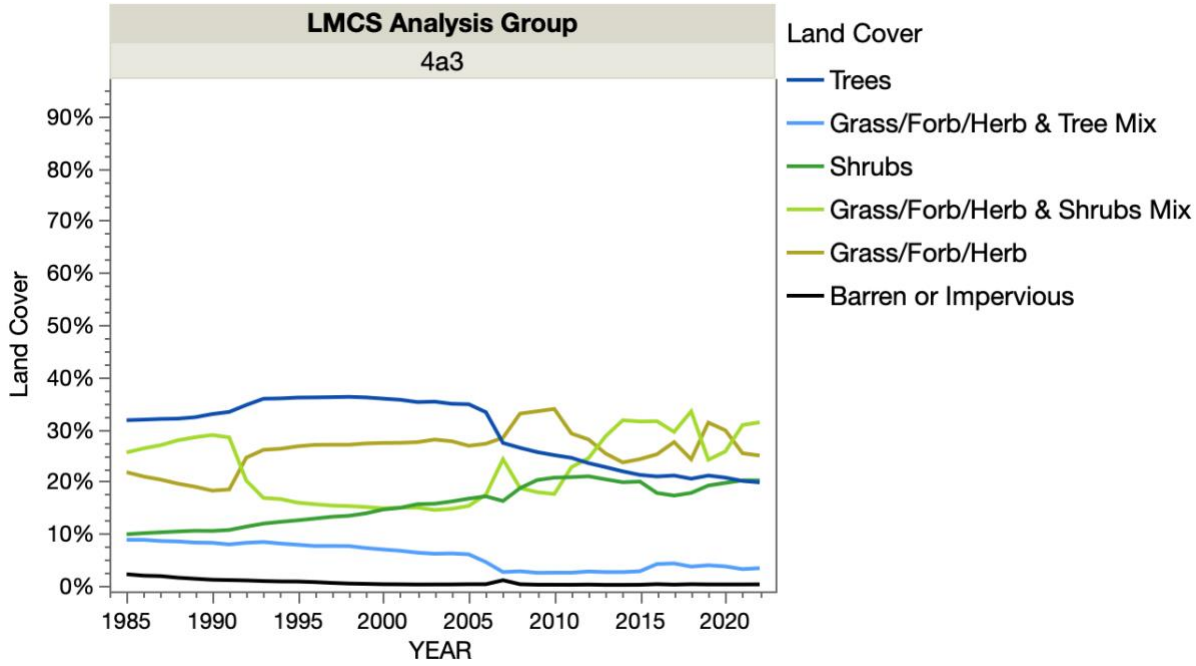

Figure 28 *Land cover trajectories in windward management units with schist parent materials affected by the 2006 Empire Fire.*

3.4.12 GROUP 4B1. WESTERN WINDWARD SIDE OF EAST END WITHOUT RECENT LARGE FIRE - VOLCANIC ROCK

Group 4b includes windward management units on the main island with volcanic derived soils. Group 4b1 includes those WMUs without a recent large fire: 43, 44, 45, 46, 47, 48, 49, 51, 61c, 61d, 61g, 61h, 61j, 61k, 61l, 61m, 61n, 62 and 63b).

Tree cover in these units increased from 37.3% in 1985 to a high of 49.9% in 1998, then slowly declined to 40.8% in 2022 (Figure 29). During the Tree decline, Shrubs increased, from 8.0% in 1998 to 16.8% in 2022. Barren ground decreased from 18.8% in 1985 to 10.7% in 2022. The Grass/Forb/Herb & Shrubs Mix increased from a low of 4.9% in 1998 to 13.3% in 2022, mirroring the increase in Shrubs.

A few management units did not follow the overall patterns. WMU 51 (Coffee Pot Canyon) saw significant increase in tree cover (perhaps from the riparian woodland drawing from a spring that feeds this area) between 1985 and 1998, which then dropped off and other vegetation classes increased relative to Barren. WMUs 61g (Upper Bullrush Canyon), 61m (Hayfield), and 61n (Middle Ranch Reservoir) all saw a steady increase in Tree cover or Tree and Shrubs cover.

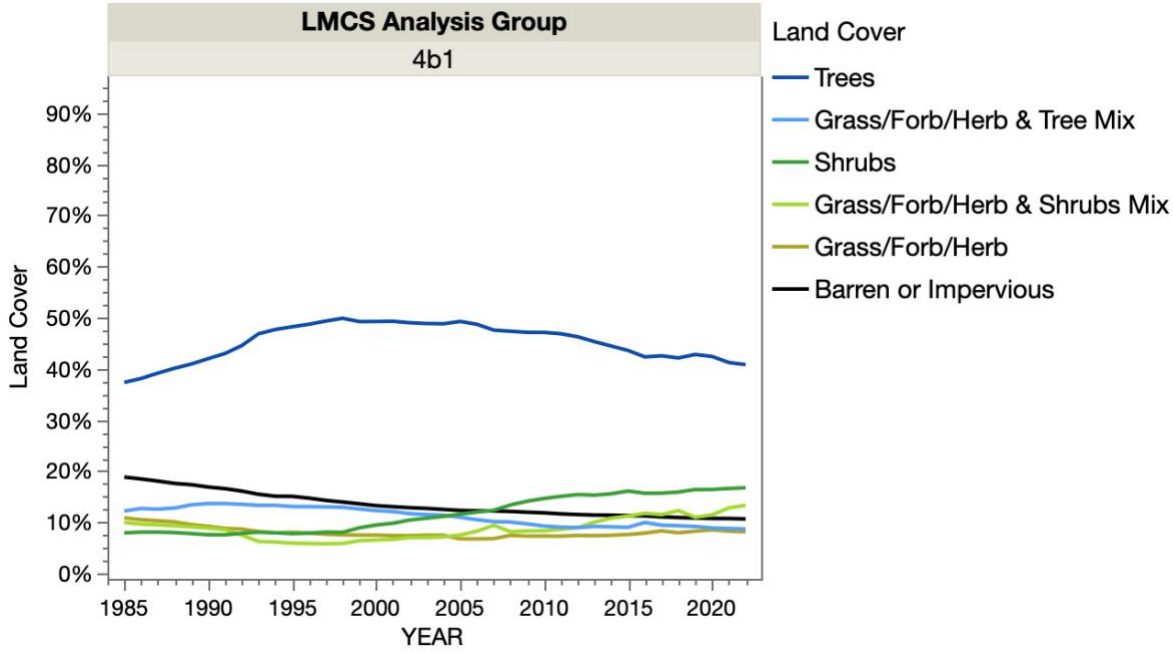

Figure 29 Land cover trajectories in windward management units with volcanic parent materials unaffected by large fires since 1985.

3.4.13 GROUP 4B2. WESTERN WINDWARD SIDE OF EAST END WITH 2007 ISLAND FIRE IMPACTS - VOLCANIC ROCK

Group 4b2 includes those management units on the windward side of the main island that were affected by the 2007 Island Fire (50a, 50b, 50c, 61e, 61f). They each have substantial increases in Tree cover from 1985 to 2006 (from 22.1% to 37.6%) and then decline in Tree cover following the fire and proportional to the amount burned in each unit (Figure 30). Like similar unburned units, Barren cover decreased consistently from 1985 (9.1%) to 2022 (0.9%) with only a slight increase in 2007. Shrubs cover increased from 1985 to 2009 (9.1% to 18.0%) and has remained stable since, even as Tree cover has increased as part of the post-fire recovery. Grass/Forb/Herb declined consistently from 1985 (25.2%) to 2006 (19.5%), increased after the fire (26.6%) and then reduced in extent again as Grass/Forb/Herb & Shrub and Tree covers increased after the fire.

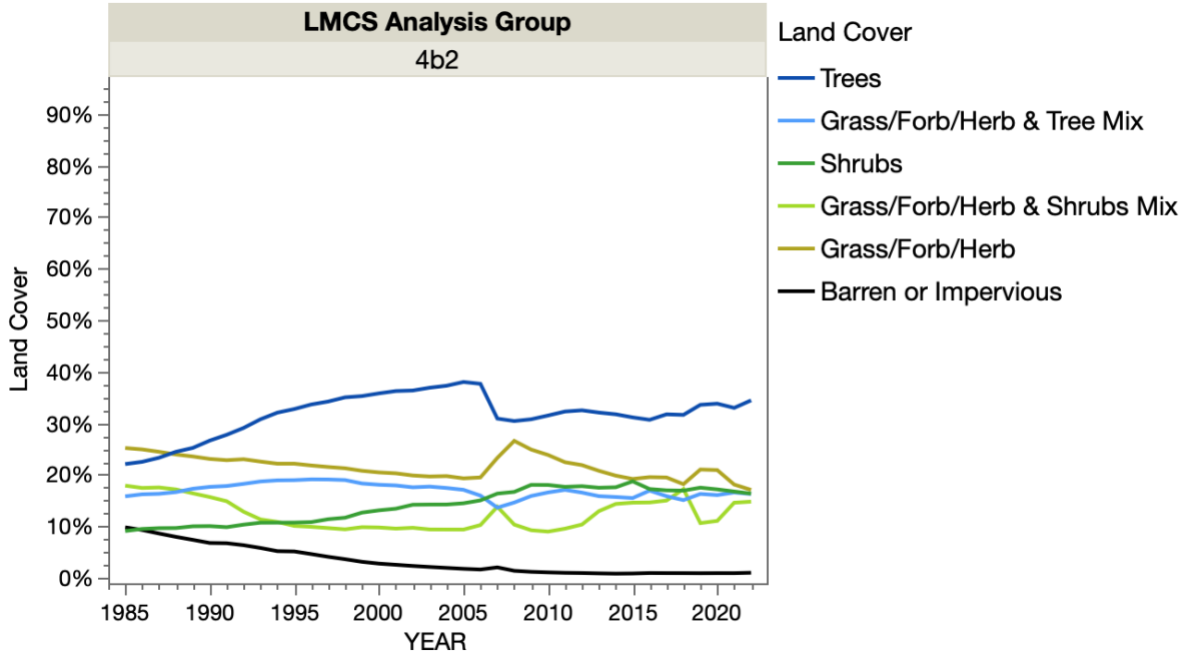

Figure 30 *Land cover trajectories in windward management units with volcanic parent materials affected by the 2007 Island Fire..*

3.4.14 GROUP 5. MANAGEMENT UNITS DOMINATED BY DEVELOPMENT

The developed area of five management units is a large proportion of its total area so we separated these out for separate consideration. They include the Wrigley Institute, Two Harbors, Two Harbors Campground, and the Quarries (11, 13, 15, 17, 42). Avalon and Middle Ranch were not lumped into this group because their developed areas are small compared with the total area of their management units.

The second largest land cover class in these units is Barren or Impervious, which stays consistently high throughout the period of analysis around 22% (Figure 31). Tree cover is the highest and ranges from 24.8% in 1985 to 32.0% in 2005 and down to 21.3% in 2022. Grass/Forb/Herb & Tree Mix declined from 10.3% in 1985 to 4.3% in 2022. Shrubs increased consistently, from 8.4% in 1985 to 19.4% in 2022.

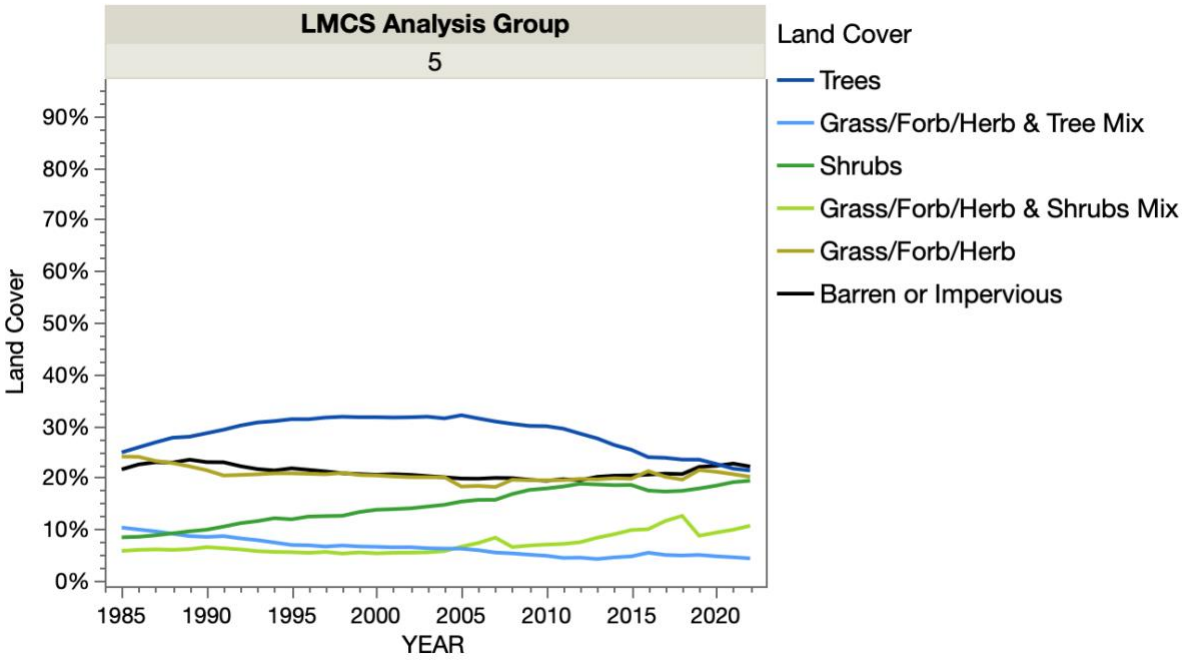

Figure 31 Land cover trajectories in management units heavily influenced by development.

3.4.15 SUMMARY

Returning to the overall trends, the watershed management unit groups are useful to compare trends in different land cover classes and their variability in different conditions on the island (Figure 32). For example, Barren and Impervious cover declines across most groups, but stays high and stable for Group 5 (developed units) and Group 2 (windward side of west end). Tree cover increases in all groups coming out of 1985, but then declines start. First is Group 2 (windward side of west end), then Group 4 (windward side of east end), then Group 3a (leeward side of east end with schist soils) and Group 1 (leeward side of west end), and finally Group 3b (leeward side of east end with volcanic soils). Declines in Tree classifications started earliest in groups with the lowest Tree cover (1998, Group 2, 26.6%) and latest in groups with highest Tree cover (2012, Group 3b1, 86.9%). It also becomes clear that the only Groups with an increasing trend in Tree cover heading into 2022 are among those that experienced fires (dotted lines in Figure 32).

The other major observation from the Group comparison is that Shrub classified pixels increased in all groups over time. Spikes in presence are found in Groups that had fires (dotted lines) and corresponding with those fires. These patterns help to corroborate that the underlying classification scheme is accurately assessing changes in vegetation form over time.

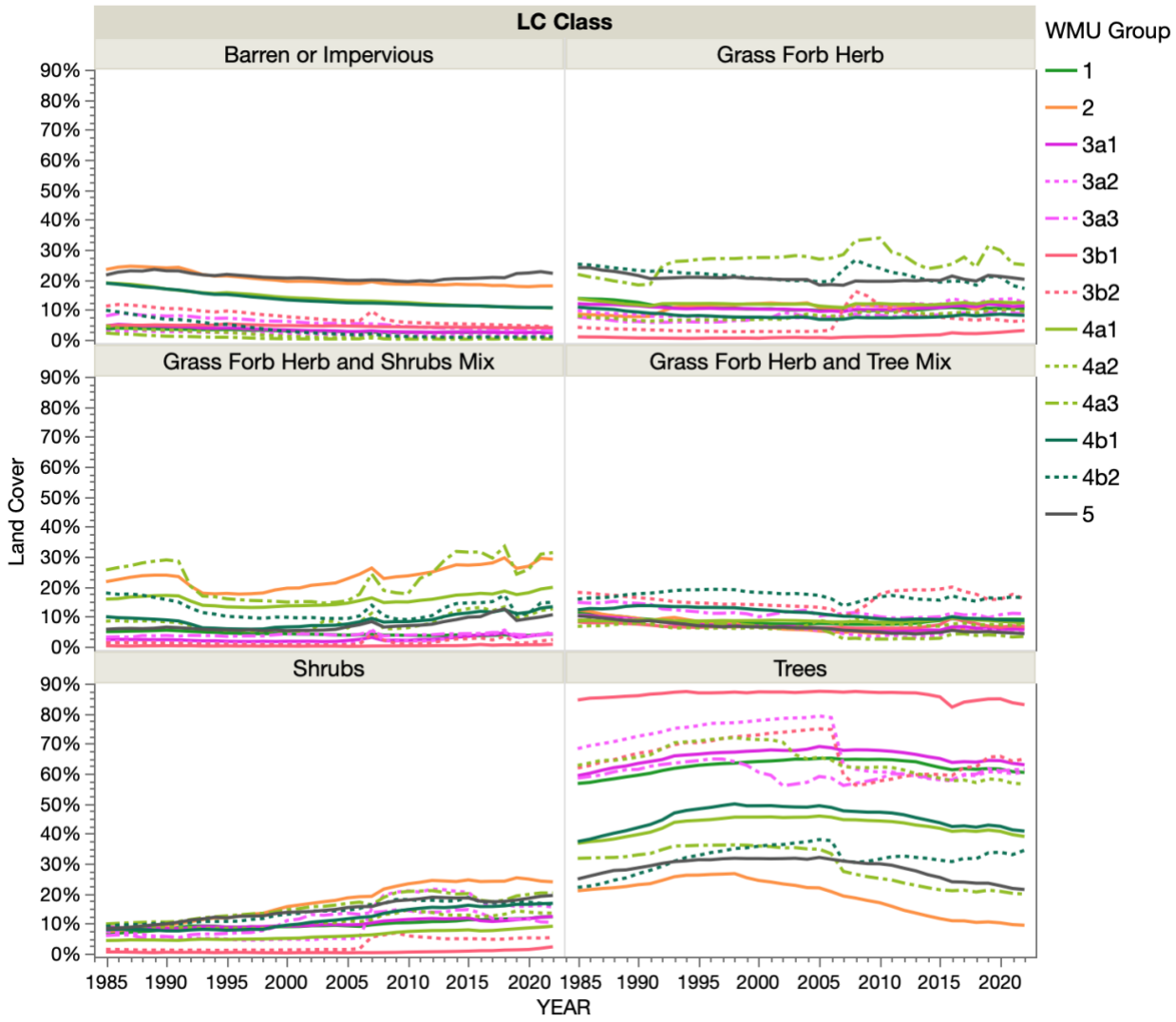

Figure 32 *Comparison of land cover class trajectories by watershed management groups, 1985 to 2022.*

4 DISCUSSION

Use of the LCMS land cover classification system for Catalina provides insights on the changes in vegetation form over time. The underlying methodology has been tested and performs well in analysis of change in forest system but can be outperformed by other land cover models (Desrochers et al. 2022). The approach applies a single, consistent methodology to the entire time series and in that way is appropriate for a time series analysis – there is no reason to suspect systematic bias in the results over time.

Once accounting for classification of healthy chaparral as Trees, as well as Trees including proper woodlands, the patterns observed in the dataset are consistent with known observations. Barren land cover at the start of the time series likely included grass and forblands that were heavily grazed, to the point of being close to bare soil. This is consistent with descriptions from this period. The analysis highlights decline in Tree cover, which has been a concern of island managers (Knapp 2010), as well as showing increases following the removal of goats and pigs. The expansion of woody vegetation, both Shrubs and Trees, following goat and pig removal is consistent with Minnich's conclusion based on historical photographs that woody vegetation was widespread before introduction of exotic herbivores (Minnich 1980).

The gradual decline of Tree (island chaparral) cover over time, and especially following fire in all but the most suitable locations, can be attributed to the effects of deer browsing (Ramirez et al. 2012). This has been investigated with exclosures following fire that isolate the effects of deer. Bison are primarily grazers and avoid woody vegetation unless food is limited (e.g., Beschta et al. 2020), so the differences inside and outside of post-fire exclosures can, at this point, be attributed to mule deer browsing. This includes significant reductions in growth and survival of dominant native shrub cover following fire, including *Heteromeles arbutifolia, Rhamnus pirifolia,* and *Rhus integrifolia* (Ramirez et al. 2012). Although remnant, but established island chaparral and woodland communities might survive and decline slowly from drought stress and resulting additional browsing pressure in the absence of large fires (see unburned tree trajectories above), large fires in conjunction with mule deer browsing pressure appear to lead to further decline in the natural chaparral and woodland vegetation. Reduction in dominant shrub cover (*Ceanothus* spp.) in long-unburned chaparral caused by deer (and woodrat) browsing in central California demonstrates this mechanism (Fox and Potts 2023). Although in that study, removal of deer was seen to simplify the community and reduce its diversity, such condition would be natural for Catalina Island as lacking large browsers throughout its evolutionary history, and would be highly beneficial to the endemic shrubs, as has already been conclusively demonstrated (Dvorak et al. 2016, Dvorak and Catalano 2016).

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Appendix D

Habitat Suitability Models for Catalina Island Plants

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EXECUTIVE SUMMARY

Restoration ecology aims to restore ecosystems to their pre-disturbance state, raising the question of what baseline conditions to target. Defining these conditions is crucial for robust restoration planning, especially in areas where seed banks are depleted, leading to incomplete regeneration post-disturbance. Various approaches exist to identify species for floristic restoration, such as historical records and reference sites.

On Catalina Island, the presence of both intact and degraded areas calls for a nuanced restoration plan that addresses type conversion and seed bank loss from unsustainable grazing and browsing. Previous research has provided initial guidance through environmental niche modeling, but species-level assessment and probabilistic mapping are needed for comprehensive restoration plans.

This report presents environmental niche models for 80 native plant species and 14 invasive species on Catalina Island, using the MaxEnt algorithm. These models help identify suitable locations for plant reintroduction, inform weed management strategies, and provide insights into species distribution patterns and environmental drivers. Comparison with previous models and potential natural vegetation maps is also discussed, along with inferred potential natural vegetation alliances based on individual species distributions. This work aims to support effective restoration efforts and understanding of the island's unique ecosystem.

1 INTRODUCTION

The perennial question in restoration ecology is "restore to what?" With the goal of restoration to return a system to its function and composition prior to disturbance, the definition of those conditions is essential to robust restoration planning (National Research Council 1992). In instances where seed banks have been eliminated or dramatically reduced, the definition of those baseline conditions and their floristic diversity is even more important, since natural passive regeneration following the removal of external stressors (e.g., invasive ungulates, agriculture) will be incomplete and biased toward persisting species.

Restoration ecologists have used different approaches to identifying the species that should be included in floristic restoration (Egan and Howell 2005). One approach is the development of species lists from historical records to ensure inclusion of the full range of species diversity. Another is to consult nearby, similar sites that can be presumed to be analogues of the restoration site and use these as "reference" sites. The relative abundance and suitability of species can also be calculated using mathematical models that relate environmental variables to probability of species presence.

The situation on Catalina is mixed in that it has intact and biodiverse natural vegetation communities still extant, but also has significantly degraded areas that have suffered type conversion and seedbank loss through the century of unsustainable grazing and browsing. The current distribution of both individual species and the vegetation associations and alliances that they form provide a partial, but incomplete, guide to the potential natural vegetation of the island. To address this, Longcore et al. (2018) used quantitative environmental niche modeling to produce probabilistic maps of the distribution of the major vegetation types on Catalina (e.g., Island Chaparral, Island Woodland). Although the summary map from this research provides a starting point, restoration plans need species-level assessment and probabilistic mapping to develop a nuanced restoration plan that maximizes probability of success by reintroducing plants to the most appropriate locations.

We therefore developed environmental niche models for 80 native plant species on Catalina to guide the development of habitat restoration plant palettes and overall restoration goals. We also developed distribution models for 14 invasive plant species to inform plans for weed management as part of the restoration program.

In this report, we document the development of these species distribution models using the MaxEnt algorithm, which has the advantage of requiring only presence data to train the model. We present the results and discuss the insights gained for understanding species distribution, such as the environmental variables most important in defining probability of presence for different plants. We also compare these results with previously developed models of oak tree distribution (Franklin and Knapp 2007) and with the composite potential natural vegetation map (Longcore et al. 2018). Finally, we

map the potential natural vegetation alliances or associations that can be inferred from the individual species distributions as they are modeled.

2 METHODS

We used the MaxEnt species distribution modeling approach because of its reliance on presence-only data and good performance with sparse training data (Phillips et al. 2006). We created probabilistic maps of presence of island plant species using the open-source MaxEnt program, Version 3.4.1 (Phillips et al. 2017) to model potential natural vegetation.

2.1 PLANT SAMPLES

There were five sources of geolocated plant records used for environmental niche modeling with MaxEnt:

1. Conservancy CHIRP invasive species survey and treatment location records (2016 to 2022)
2. Conservancy native plant observations (1995 to 2017)
3. CHH2 Herbarium Database records that have field collected geographic coordinates (2015 to 2019)
4. Conservancy native plant observations (2022 to 2023)
5. Locations collected by Land IQ during field visits in 2023

From these sources, 94 plant species were identified for modeling, which are presented in Table 6-1, including 8 Catalina island endemics, 22 island endemics, 50 other native species, and 14 invasive species.

The number of samples for each plant species depended on the number of observations in the record and the minimum distance between samples allowed. A minimum distance of 200 meters was preferred, but for rare species, while not optimal, smaller minimum distances were allowed as reported in Table 6-3.

2.2 ENVIRONMENTAL VARIABLES

To predict vegetation distributions, we generated a set of 19 environmental layers comprising 5 categorical and 14 continuous variables (Table 2-1). These layers encompass various factors known to influence vegetation patterns:

1. Climate (8 layers): Including solan insolation and cloud albedo variables to account for climatic influences on plant growth and distribution.
2. Topography (7 layers): Characterizing the physical landscape features such as elevation, slope, and aspect, which can impact local microclimate and soil properties.
3. Geology and Soil (3 layers): Representing the underlying geologic and edaphic factors that can affect nutrient availability and water-holding capacity.

Table 2-1. Environmental Data.

Environmental Variable	Description	Data Type	Source
CLIMATE			
alb_05_10m	Cloud Albedo, monthly average - May	Continuous	Clemesha unpublished data
alb_06_10m	Cloud Albedo, monthly average – June	Continuous	Clemesha unpublished data
alb_07_10m	Cloud Albedo, monthly average – July	Continuous	Clemesha unpublished data
alb_08_10m	Cloud Albedo, monthly average – August	Continuous	Clemesha unpublished data
alb_09_10m	Cloud Albedo, monthly average - September	Continuous	Clemesha unpublished data
solar_wintersol	total amount of incoming solar insolation, within Winter Solstice	Continuous	ArcGIS Solar Radiation Tool
solar_equinox	total amount of incoming solar insolation within Equinox	Continuous	ArcGIS Solar Radiation Tool
solar_summersol	total amount of incoming solar insolation, within Summer Solstice	Continuous	ArcGIS Solar Radiation Tool
TOPOGRAPHY			
DEM	Elevation	Continuous	2022/3 ifSAR 10-meter resolution DEM
asp1013	Aspect, 13 classes (including flat)	Categorical	DEM Derivative
neness10	Northeastedness	Continuous	DEM Derivative
sloper10	Slope, Radians	Continuous	DEM Derivative
tpi50	Topographic Position index, 50m window	Continuous	DEM Derivative
twi10	Terrain Wetness Index	Continuous	DEM Derivative
rugg10	Ruggedness	Continuous	DEM Derivative
GEOLOGY AND SOIL			
geol10	Geology	Categorical	Bohannon and Reiss 2004
soils08	2008 Soil Map Units (NRCS, Soil Survey 2008)	Categorical	NRCS 2008
soils55	1955 Soil Map Units (NRCS, Unpublished Soil Survey 1955)	Categorical	SCS 1955
VEGETATION PRODUCTIVITY			
ndvi	Spring NDVI	Continuous	Sentinel-2 Multispectral Data
ANALYTICAL MASK			
mask_shore	1,000-meter buffer on coastline for species limited to coastal habitat	Categorical	Buffer on Shoreline

4. Vegetation Productivity (1 layer): Assessing the overall productivity of the vegetation in different areas, which can be indicative of resource availability and ecological interactions.

An additional shoreline mask layer was used to restrict the prediction to coastal areas for species known to be limited in their distribution. This multi-layered approach enabled us to account for the complex interplay of environmental factors that shape vegetation communities, providing a robust foundation for our predictive models.

2.2.1 CLIMATE

CLOUD ALBEDO

Monthly (May to September) mean cloud albedo (proxy for cloudiness) for 1996 to 2018 for Santa Catalina Island (Figure 6-1). Unpublished data provided by R. Clemesha, following methods for development of the San Clemente Island coastal clouds and fog high-resolution record (Clemesha et al. 2021).

SOLAR RADIATION

Incoming solar radiation (watt hours per square meter, Wh/m^2) calculated for the surface of the 10-meter DEM using the ArcGIS Solar Radiation Tool for 2018 Winter Solstice (Figure 6-2), 2018 Equinox (insolation for both spring and fall equinox are the same) (Figure 6-3) and 2018 Summer Solstice (Figure 6-4), based on methods from the hemispherical viewshed algorithm developed by Rich et al. (1994) and further developed by Fu and Rich (2000, 2002).

2.2.2 TOPOGRAPHY

ELEVATION

A 10-meter resolution Digital Elevation Model (DEM) was derived from 2002/2003 Interferometric Synthetic Aperture Radar (IfSAR) (NAVD88 vertical datum) (Figure 6-5).

ASPECT

Aspect was derived from the DEM using ArcGIS Spatial Analyst and classified into thirteen categorical values (Figure 6-6).

NORTHEASTNESS

Additional spatial data were derived for aspect (i.e., geographic orientation of a slope measured in degrees), and this variable was transformed (sin (θ + 45°)) into a continuous variable that represents an index of northeastness, a proxy for climatic conditions (i.e., an orientation closer to northeast is associated with cooler and wetter conditions) (Figure 6-7).

SLOPE

Slope steepness in radians was derived from the DEM using ArcGIS Spatial Analyst (Figure 6-8).

TOPOGRAPHIC POSITION INDEX

The Topographic Position Index (TPI) is a measure of the relative position of a location within a landscape, considering its elevation and proximity to ridges and valleys. It helps classify topography into distinct landform categories, such as upper slopes, mid-slopes, and valley bottoms. TPI values were calculated by subtracting the elevation of a central cell from the average elevation of its surrounding cells within a radius of 50 meters in ArcGIS Pro (Figure 6-9).

TPI values can be positive, negative, or zero, which represent different topographic positions:

- **Positive TPI values:** Indicate that the central cell is higher than its surroundings, which generally represents ridge or hilltop locations. The higher the positive value, the more pronounced the ridge or hilltop.
- **Negative TPI values:** Represent cells that are lower than their surroundings, signifying valley or depression locations. The more negative the value, the deeper the valley or depression.
- **TPI values close to zero:** Signify cells with similar elevations to their surroundings, often found in flat areas or mid-slope locations between ridges and valleys.

TERRAIN WETNESS INDEX

A Terrain Wetness Index (TWI) is a numerical value between 0 and 1.0 that indicates the relative wetness or moisture level of a specific location in a landscape (Figure 6-10). TWI was calculated as "ln (a/tan b)" where a is the upstream contributing areas per unit width that is orthogonal to the flow direction and tan b is the local slope in radians (Beven and Kirkby 1979). The index is correlated with several soil attributes such as horizon depth, silt percentage, organic matter content, and phosphorus (Moore et al. 1993).

TWI is often used in geospatial analysis and environmental studies to understand the potential for soil saturation and surface runoff. The values are interpreted as follows:

- 0: This value represents the lowest possible wetness or moisture level. It indicates areas that are well-drained and less susceptible to standing water or waterlogging.
- 0 to 0.5: Lower values in this range signify areas with relatively drier conditions and better drainage. These areas are less likely to experience standing water or saturation.
- 0.5: This is considered an average wetness level, representing areas with moderate drainage and moderate susceptibility to waterlogging or saturation.

- 0.5 to 1.0: Higher values in this range signify areas with wetter conditions and poorer drainage. These areas are more likely to experience standing water, saturation, or waterlogging.
- 1.0: This value represents the highest possible wetness or moisture level. It indicates areas that are poorly drained and highly susceptible to standing water, waterlogging, or saturation.

Remember that TWI is a relative measure, meaning that values should be interpreted in the context of the surrounding landscape and other factors that affect soil moisture levels, such as climate, vegetation, and topography.

TERRAIN RUGGEDNESS INDEX

The Terrain Ruggedness Index (TRI) is a measure of ruggedness (or roughness), which calculates the difference in elevation from a center cell and the 8 cells surrounding it (Riley et al. 1999) (Figure 6-11). A higher value indicates more variation in elevation, while a lower value represents a more uniform and less rugged terrain. Here's how to interpret RI values:

- **Low RI values (e.g., < 5):** Indicate a relatively flat or smooth landscape with little variation in elevation. This can signify a landscape dominated by flat plains or gentle slopes.
- **Medium RI values (e.g., 5 to 10):** Represent a moderately rugged terrain with some variation in elevation, such as rolling hills or moderate slopes.
- **High RI values (e.g., > 10):** Signify a highly rugged and heterogeneous landscape with significant variation in elevation. This can include mountainous regions, steep slopes, or deeply incised valleys.

Keep in mind that the specific range of values may vary depending on the context and scale of the study area, so it's essential to consider the overall landscape characteristics and local topography when interpreting TRI values.

2.2.3 GEOLOGY AND SOIL

GEOLOGY

A preliminary unpublished U.S. Geological Survey (USGS) map by Bohannon and Reiss (2004) was provided by the Catalina Island Conservancy and was converted into a 10-meter resolution raster using the Nearest Neighbor method in ArcGIS Pro (Figure 6-12). Eighteen categorical values were assigned representing rock types from four geological time periods: Quaternary, Mioence, Late Cretaceous to Oligocne, and Jurassic

SOIL (2008)

Since 1975, the U.S. National Cooperative Soil Survey Program has used a systematic approach to classifying soils based on their properties and characteristics called Soil Taxonomy. This soil taxonomy framework was used to prepare the Soil Survey of Santa Catalina Island, published in 2008 (NRCS 2008). Twenty-three categorical soil map units

were converted into a 10-meter resolution raster using the Nearest Neighbor method in ArcGIS Pro (Figure 6-13 and Table 6-2).

SOIL (1955)

There was also an unpublished Soil Survey of the island prepared by the U.S. Soil Conservation Service (SCS) in 1955. Raster data was provided by the Conservancy and was resampled using the Nearest Neighbor method in ArcGIS Pro to create 44 soil map units at 10-meter resolution (Figure 6-14). These map units correspond to a range of different values, including soil depth (Figure 6-15), soil texture (Figure 6-16), soil permeability (Figure 6-17), and underlying geological material (Figure 6-18). The 1995 soil data was used by Franklin and Knapp (2010) for predictive modeling of *Quercus pacifica* and *Q. tomentella* potential distributions to help inform ecological relationships and potential habitat restoration sites.

2.2.4 VEGETATION PRODUCTIVITY

NORMALIZED DIFFERENCE VEGETATION INDEX

Average spring (March to June) Normalized Difference Vegetation Index (NDVI) was computed from the time-series of Sentinel-2 Multispectral data (10-meter resolution) from 2017 to 2022 using Google Earth Engine API (Figure 6-19).

The NDVI values can be interpreted as follows:

- Less than zero is water, such as reservoir
- 0 to 0.14 are areas dominated by bare ground such as cliffs, quarries, beaches, and inland areas with little to no vegetative cover. These areas include Maritime Cactus Scrub.
- 0.14 to 0.23 include Grassland and upland scrubland with an open canopy, such as Coastal Sage Scrub (CSS).
- 0.23 to 0.32 includes upland scrubland with higher perennial cover, such as from Island Chapparal, including island scrub oak (*Quercus pacifica*).
- 0.32 to 0.7 are associated with denser perennial vegetation from Island Chaparral and Island Woodland.

2.2.5 ANALYTICAL MASK

SHORE MASK

A shoreline mask was created by buffering 1,000 meters on the shoreline for species limited to coastal habitat (Figure 6-20).

2.3 MODEL DEVELOPMENT AND EVALUATION

To develop a parsimonious species distribution model, we employed an iterative approach using the MaxEnt algorithm. Parsimony refers to the principle that the most plausible explanation for an occurrence, phenomenon, or event is the simplest one, requiring the fewest entities, assumptions, or changes. By following this principle, we aimed to develop a model with the optimal balance between accuracy and simplicity, while minimizing the risk of overfitting.

This process involved the following steps:

1. Initial model: We began by constructing a model that incorporated all available environmental variables.
2. Variable influence assessment: We analyzed the model results to determine the most influential variables affecting species distribution.
3. Variable reduction: We systematically removed the variables exhibiting the lowest influence on model performance.
4. Model re-evaluation: We re-ran the model with the reduced set of variables and assessed its performance.
5. Iterative refinement: We repeated the steps of variable removal and model re-evaluation until an optimal balance between model performance and simplicity was achieved.

Throughout the process, we carefully evaluated the model's performance to ensure the retention of essential variables and the overall effectiveness of the final model in predicting species distribution. Although some environmental variables may exhibit correlations, the MaxEnt algorithm has been shown to be largely robust to covariance among environmental variables (Elith et al. 2011), thus mitigating potential issues arising from multicollinearity.

We ran suitability models with one of two resampling methods. Cross-Validation was preferred for larger datasets, while subsampling was used with smaller datasets. Cross-Validation was used with 30% of the data reserved for testing predictions, meaning 70% of the data was used to train the model. Subsampling involves drawing multiple random samples (with replacement) from the original dataset, training the model on each sample, and averaging the performance across all samples. Subsampling can provide a more robust assessment of model performance in situations where data is scarce or computationally intensive methods are prohibitive. Both methods can be used in conjunction with MaxEnt to optimize model performance and ensure reliable predictions. The number of replicates, resampling method, and the number of samples for each plant species model is presented in Table 6-3.

Model fit and performance were assessed using Maxent's test gain and Area Under Curve (AUC) statistics (Merow et al. 2013, Phillips et al. 2017). A software generated Cloglog threshold was selected, 10 percentile training presence, which was specific to

each vegetation model, and determined the threshold for minimum suitability (Phillips et al. 2017).

3 RESULTS

The Area Under the Curve (AUC) is a commonly used metric for evaluating the performance of MaxEnt models. A low AUC value indicates poor model performance, meaning the model struggles to distinguish between suitable and unsuitable conditions for the species.

A model was created for each plant species, with performance ranging from fair (AUC > 0.7) to good (AUC > 0.8) and excellent (AUC > 0.9) for most models (88 out of 94 models) (Table 6-3).

Six of the potential plant distribution models performed better than chance but relatively poorly (AUC ≤0.70) compared to the other models, possibly due to the following factors:

1. Low Sample Size: MaxEnt models can be sensitive to the quantity or distribution of presence data across the range of environmental variables in the dataset. This may apply to models for *Acmispon argophyllus,* Dissanthelium *californicum*, and *Rhamnus pirifolia*.
2. Overprediction: The model might be predicting the species' presence across a large area, leading to a high false positive rate and thus a lower AUC. This can occur when the species has a generalist habitat requirement or when the environmental variables used do not sufficiently capture the specific conditions that determine its distribution. There may not be sufficient environmental data to accurately characterize the ecological niche of *Bromus sitchensis.*
3. Habitat generalization: Widespread species often have broad habitat tolerances and can thrive in a variety of environmental conditions (e.g., *Opuntia littoralis* and *Quercus pacifica* on Catalina Island). This can make it difficult for MaxEnt to identify specific environmental variables that strongly influence their distribution, leading to a weaker model performance.

The potential ecological niche model for each of the 94 plant species are presented in Figure 6-21 to Figure 6-114. These models can be visualized in a GIS to guide the selection of suitable habitat restoration sites focused on particular native plants species or vegetation communities that are characterized by specific plant species or can be used to identify appropriate habitat restoration targets for degraded areas targeted for habitat restoration projects.

3.1 PREDICTION VARIABLES

Environmental variables played differing roles in predicting the distribution of plant species. Models were developed with between 4 to 10 environmental variables (Figure 3-1). The most common number of variables used in a model was 6.

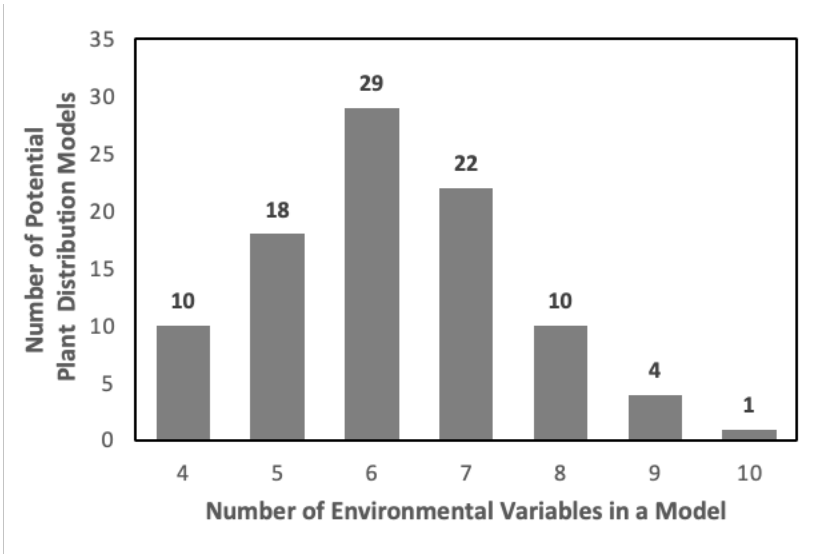


Figure 3-1 Number of Environmental Variables in Potential Vegetation Models.

The most important environmental variables as measured by permutation importance were soil types from the 2008 Soil Survey and topographic variables such as Slope, Elevation, Aspect, and Terrain Wetness Index (Figure 3-2).The permutation importance measure depends only on the final Maxent model, not the path used to obtain it. The contribution for each variable is determined by randomly permuting the values of that variable among the training points (both presence and background) and measuring the resulting decrease in training AUC.

The most important predictive values for each of the 94 models are summarized in Table 6-4.

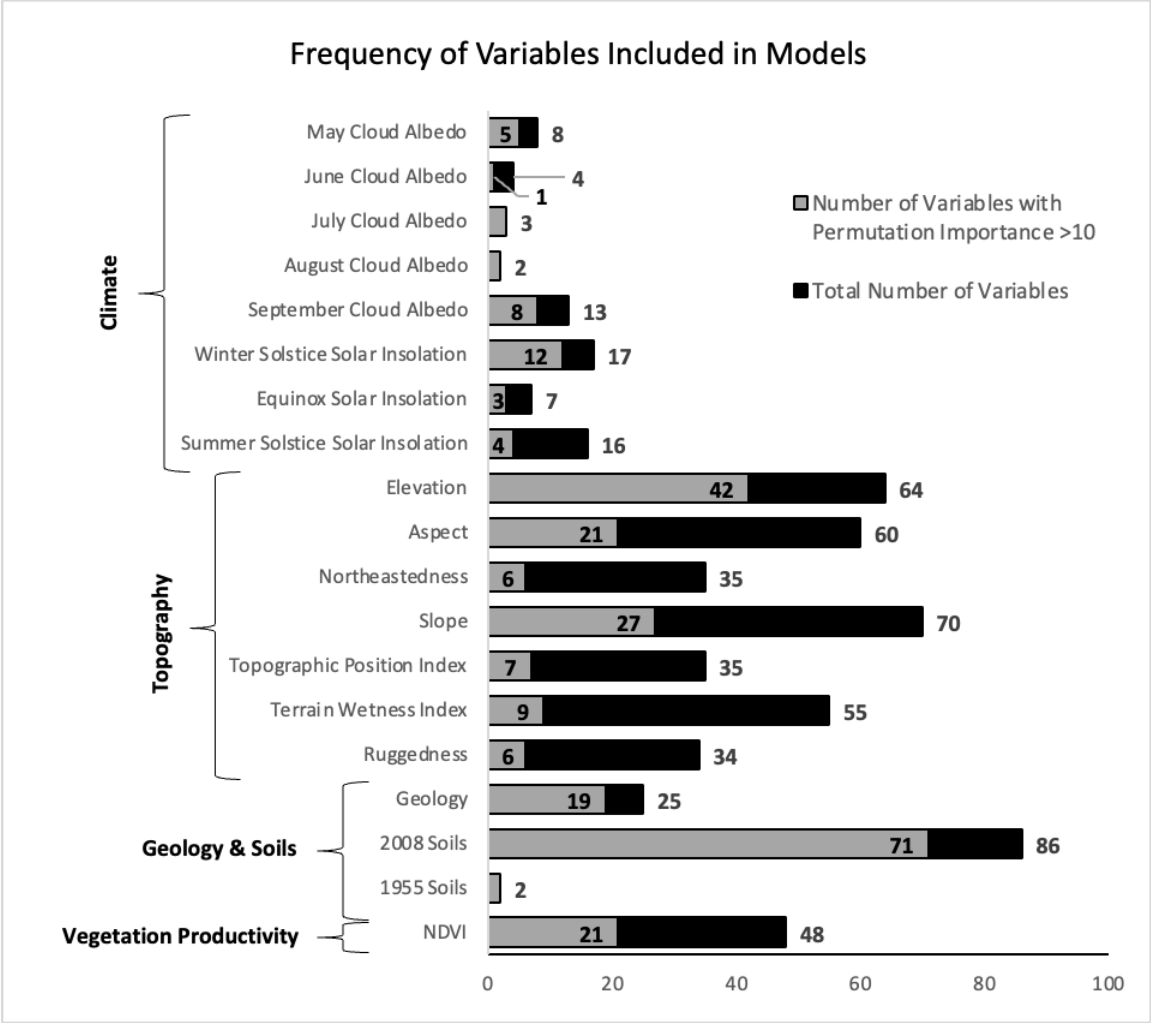


Figure 3-2 Distribution of Environmental Variables by Type.

Table 3-1. Summary of the Most Important Predictive Variables by Plant Species.

Scientific Name	Common Name	Code	Most Important Features of Predictive Env. Variables
Abronia maritima	red sand verbena	abrmar	Lowest productivity sites (NDVI peaking below 0.1), associated with high bare ground cover; near the coast; on flat to gentle slopes; Entisols soil with sand, sandy loam or very gravelly sand (Map Units 160, 190, 191, and 423).
Achillea millefolium	common yarrow	achmil	Lower productivity sites (NDVI mostly below 0.23); more common on less steep slopes but also on very steep slopes; on Xeralfs soils (Map Units 423 and 183).
Acmispon argophyllus	silver birds foot trefoil	acmarg	Alluvium (Qal), green Catalina Schist (Jcsg), and Catalina Island Pluton (Tmqd) soil parent material; with high summer solstice radiation; on ridges and hilltops.
Acmispon grandifloras	large leaved lotus	acmgra	Higher elevation sites on gentle to steep slopes; Nauti-Flyer-Marpol Complex soil; Catalina Schist (Jcsa, Jcsb), Andesite (Tma), and Alluvium (Qal) soil parent material.
Adenostoma fasciculatum	chamise	adefas	Xeralfs soils (Map Units 422 and 407); Blue and green Catalina Schist (Jcsb, Jcsg) soil parent material;
Anemopsis californica	yerba mansa	anecal	Flat to gentle slopes; valleys and drainages.
Aphanisma blitoides	aphanisma	aphbli	Low elevation sites (below 300 m); September cloud albedo peaking at 15% associated with the western, windward shoreline.
Arctostaphylos catalinae - SCIE	Catalina Island manzanita	arccat	High summer solstice radiation; Catalina Schist (Jcss, Jcsg), Intrusive rocks (Tmi), and Catalina Island pluton (Tmqd) soil parent material; east- to north- to west-facing slopes and less likely on south-facing aspects.
Artemisia californica	California sagebrush	artcal	More common on east-southeast to west-southwest facing aspects; common across on all elevations but more common below 150 meters; occurs on all soil types but more common soils with loam, sandy loam, and gravelly loamy sand; less likely on the western, windward shoreline with June cloud albedo above 24%.
*Arundo donax**	giant reed	arudon	Lower elevations below 200 m; disturbed or urbanized soils, and Ustalfs (Map Unit 184) soils associated with landslide deposits; flat to moderate slopes.
Asclepias fascicularis	narrowleaf milkweed	ascfas	Xeric soils (Map Units 191 and 421); low productivity sites (peaking at 0.2 NDVI).
Atriplex coulteri	Coulter's saltbush	atrcou	Lower productivity sites (peaking at 0.1 NDVI); high summer solstice radiation; occurs on all soil parent materials but more likely on Catalina Schist (Jcss, Jcsa, Jcsg).
Atriplex pacifica	South Coast saltscale	atrpac	Occurs on Xeralfs soils (Map Units 182, 422, 423, and 427); with low moisture levels (TWI below 0.5).
Baccharis pilularis	coyote bush	bacpil	Xerolls and Xeralfs soils (Map Units 156, 191, 411, 421, and 427); higher elevations (above 100 m); most soil parent material but more common on Alluvium (Qal).
Bergerocactus emoryi - CIE	velvet cactus	beremo	Low elevations near the coast (less than 150 m); on Alfisols soil (Map Unit 423); Catalina Schist (Jcsb, Jcsg) and Alluvium (Qal) soil parent material.

Scientific Name	Common Name	Code	Most Important Features of Predictive Env. Variables
Bothriochloa barbinodis	cane bluestem	botbar	Low elevations (below 300 m); winter solstice solar radiation peaking at 1900 Wh/m^2, which is above the mean of 1,301; on flat to moderate slopes.
*Brassica nigra**	black mustard	branig	Low elevations (below 400 m); May cloud albedo peaking at 17.5%; flat or very rugged terrain; on Beaches-Abaft complex (Map Unit 160) or Alifsols soil (Map Units 183, 184, 411, 421, and 422).
Bromus sitchensis (*carinatus*)	California brome	brocar	Occurs across all soil parent materials but more common on serpentinite Alluvium (Qal), marine wave-cut bench deposits (Qt), Catalina Schist (Jcss), intrusive volcanic metamorphic rocks (Tmi), and Catalina Island pluton (Tmqd); and soils derived from these parent materials (Map Units 156, 157, 160, 190, 411, and 412); in sites with lower solar radiation at the equinox.
*Cakile maritima**	sea rocket	cakmar	Exclusively on sand and sandy loam soils (Map Units 160 and 190); on flat to gentle slopes.
*Carduus pycnocephalus**	Italian thistle	carpyc	In depressions or valleys; flat to gentle slopes; on sand to sandy or gravelly loams (Map Units 160, 400, 410, 411, 422, 423, 424, and 425); northerly-facing slopes.
Ceanothus arboreus - CIE	felt-leaf ceanothus	ceaarb	Low to moderate solar radiation at the equinox; very gravelly sand, gravelly loam, gravelly silty loam, sandy or silty loam soils (Map Units 181, 182, 191, 400, 422, and 424); cooler and wetter sites associated with northerly aspects.
Ceanothus megacarpus var. *insularis* - CIE	island ceanothus	ceamegins	Loam and silty loam (Map Units 182 and 407) on soils from volcanic parent material; higher elevations.
Ceanothus megacarpus var. *megacarpus*	bigpod ceanothus	ceamegmeg	High solar radiation at the equinox; silty loam, gravelly loam, and gravelly silty loam soils (Map Units 182, 400, and 423); higher elevations; east-northeast to south-southwest aspect.
*Centranthus ruber**	red valerian	cenrub	Disturbed urban (Map Unit 451) and gravelly loam soils (Map Unit 400); low elevations.
Cercocarpus traskiae - SCIE	Catalina Island mountain-mahogany	certra	Flyer-Loadline-Nauti complex and Masthead-Coastwise-Dewpoint complex soils (Map Units 411 and 423); September cloud albedo peaking at 12.5%; westerly-facing slopes.
Chlorogalum pomeridianum	soap plant	chlpom	Low August cloud albedo, below 10%; flat to steep slopes; on a variety of soils (Map Units 156, 182, 191, 407, and 422).
*Cirsium vulgare**	bull thistle	cirvul	Relatively flat sites to moderate slopes; drainages or valleys; variety of soils (Map Units 156, 157, 191, 293, 407, 411, 422, 424, 456, and 993).
Comarostaphylis diversifolia subsp. *planifolia*	summer holly	comdivpla	Certain Alfisols soils (Map Units 181, 422 and 423); low August cloud albedo; flat to steep slopes.
*Cortaderia selloana**	pampas grass	corsel	Sites with wetter conditions; disturbed and developed areas (Map Units 157, 451, 454, 992) and loam soil (Map Units 400, 422, 423, 424).
Cressa truxillensis	alkali weed	cretru	Low elevations (below 100 m).

Scientific Name	Common Name	Code	Most Important Features of Predictive Env. Variables
Crocanthemum greenei - CIE	island rush-rose	crogre	Gentle to moderate slopes; high elevations (above 100 m); variety of soils (Map Units 157, 182, 400, 411, 422, 423, and 424); high solar radiation at the summer solstice.
Crossosoma californicum - CIE/PVP	Catalina Island crossosoma	crocal	Flat to moderately steep slopes; drier sites; alluvium (Qal), Catalina Schist (Jcsb, Jcsg), Catalina Island pluton (Tmqd), and andesite (Tmqd) soil parent material.
Cylindropuntia prolifera	coastal cholla	cylpro	Low productivity sites (NDVI peaking at 0.1); high September cloud albedo (peaking at 16%), associated with the coastal bluffs on the western, windward shoreline.
*Cynara cardunculus**	artichoke thistle	cyncar	Moderately high September cloud albedo (peaking a 15%, associated with the windward side of the island.
Cyperus spp.	flatsedge	cypspp	Alluvium (Qal), Catalina Schist (Jcsg, Jcsb), and Catalina Island pluton (Tmqd) soil parent material; soils associated with these parent materials (Map Units 191, 156, 181, and 411); wetter sites.
Deinandra clementina - CIE	island tarplant	deicle	Low elevations (below 100 m); Entisols (Map Units 160 and 191) and Alfisols (Map Units 157, 422, 423, and 424) soils
Deinandra fasciculata	clustered tarplant	deifas	Flat to moderate slopes; Alfisols soils (Map Units 183 and 423); more likely at lower elevations.
Delphinium parryi subsp. *maritimum*	maritime larkspur	delparmar	Lower solar radiation at the winter solstice; northerly aspects; lower elevations (below 300 m); lower May cloud albedo; more likely on Alluvium (Qal) and volcanic rock (Td, Tmv) soil parent material; sandy or loam soils (Map Units 156, 160, 191, 412, 422, and 425).
Dendromecon harfordii	Channel Island tree poppy	denhar	Coastal cliffs and higher elevations; less likely on southerly-facing slopes; Mollisols (Map Unit 157 and 412) and Alfisols soils (Map Units 182, 421, 422, 423, and 424).
Dichondra occidentalis	western dichondra	dicocc	Flat to steep slopes; Mollisols (Map Units 410 and 412) and Alfisols soils (Map Units 182, 183, 421, 422, 423, and 424).
Dissanthelium californicum - CIE	California dissanthelium	discal	Alifsols soils (Map Units 182, 183, 184, and 422); Flat to north-facing slopes.
Dudleya virens ssp. *hassei* - SCIE	Catalina Island dudleya	dudvirhas	Low elevations (below 100 m).
Dudleya virens subsp. *insularis*	island green dudleya	dudvirins	Lower solar radiation at the winter solstice; lower elevations (below 400 m); drier sites.
Elymus (Leymus) condensatus	giant wild rye	elycon	East- to north-facing slopes; all elevations but more likely at lower elevations; all soil parent materials but more likely on alluvium (Qal), green Catalina Schist (Jcsg), and marine sediments (Tms); soils associated with these parent materials (Map Units 157, 191, 183, 400, 421, and 422); high productivity sites.
Encelia californica	California sunflower bush	enccal	Low elevations (below 200 m); flat areas or mid-slope locations between ridges and valleys.

Scientific Name	Common Name	Code	Most Important Features of Predictive Env. Variables
Ericameria palmeri	Palmer's goldenbush	eripal	Lower productivity sites (NDVI below 0.3); flat to steep slopes; drier sites; Alfisols soil (Map Units 182, 411, 422, and 427).
Eriodictyon traskiae ssp. *traskiae* - SCIE	Trask's yerba santa	eritra	Alluvial soils (Map Unit 191) and loam soils (Map Units 156, 157, 182, and 407); low September cloud albedo (peaking at 10%); moderate slopes; higher elevations (above 200 m).
Eriogonum giganteum var. *giganteum* - SCIE	St. Catherine's lace	erigig	On a variety of soil parent materials except for landslide deposits (Qls) and more likely on alluvium (Qal), beach sand deposits (Qb), and basaltic igneous intrusions (Td); variety of soil types but more likely certain soil types (Map Units 156, 157, 191, 400, 407, 411, 421, and 424); low elevations (below 100 m) and higher elevations (above 400 m) on slopes; lower May cloud albedo.
Eriogonum grande var. *grande*	island buckwheat	erigra	Entisols (Map Units 160, 190, and 191) and Alfisols soils (Map Units 183, 185, 421, and 424); low productivity sites (NDVI peaking at 0.05).
Eschscholzia ramosa - CIE	Island poppy	escram	Flat to steep slopes; occurs on most soil parent materials but more likely on alluvium (Qal) and volcanic rocks (Tmi, Tmso, Tmv); occurs on most soils but more likely on certain soil types (Map Units 156, 157, 182, 183, 191, 420, 424, and 427).
Euphorbia misera - CIE	cliff spurge	eupmis	Beach sand deposits (Qb) and green Catalina Schist (Jcsg) soil parent materials; Masthead-Coastwise-Dewpoint complex soil (Map Unit 423).
*Foeniculum vulgare**	sweet fennel	foevul	Occurs on a variety of soils but more likely on certain soil types (Map Units 157, 191, 411, and 421); occurs at all elevations but more likely below 100 m and above 400 m; occurs on most parent materials but more likely on Catalina Schist (Jcsss, Jcsg), alluvium (Qal), and volcanic rocks (Tmv) soil parent material.
Frankenia salina	alkali heath	frasal	Occurs on Entisols (Map Units 160, 190, and 191) and Alfisols (Map Units 421 and 423); lower productivity sites.
Galium catalinense ssp. *catalinense* - SCIE	Catalina Island bedstraw	galcat	Lower winter solstice solar radiation; low elevations (less than 100 m); Alfisols soil (Map Units 183, 185, 421, 422, and 424).
Gambelia speciosa (Galvezia speciosa) - CIE	showy island snapdragon	gamspe	Beach sand (Map Unit 160) and Alfisols (Map Units 83, 185, and 424); lower elevations; low May cloud albedo (peaking at about 16%).
*Genista linifolia**	Mediterranean broom	genlin	Disturbed or developed soils (Map Unit 451), alluvium soils (Map Units 190 and 191), and a variety of other soil types (Map Units 181, 182, 400, 411, 422, and 423); moderate winter solstice solar radiation; wetter sites; flat to steep slopes.
Gilia nevinii - CIE	Nevin's gilia	gilnev	Occurs on all soil parent material but more likely on intrusive volcanic rocks (Tmi) and Catalina Schist with biotite and garnet schist (Jcsa); occurs on all aspects but more likely on northerly-facing slopes; occurs on all soil

Scientific Name	Common Name	Code	Most Important Features of Predictive Env. Variables
			types but more likely on certain soil types (Map Units 182 and 424).
Heteromeles arbutifolia	toyon	hetarb	Occurs at all elevations but more likely below 100 m and above 400 m; higher productivity sites; flat areas or mid-slope locations between ridges and valleys.
Hordeum intercedens	vernal barley	horint	Moderate solar radiation at the winter solstice; low productivity sites; more likely on Alfisols (Map Units 157, 181, 184, 191, 411, 412, 420, 421, 422, 423, and 424).
Isocoma menziesii var. *menziesii*	Menzie's goldenbush	isomen	Low productivity sites; more likely on certain soil types (Map Units 156, 411, 422, and 423).
Jepsonia malvifolia - CIE	island jepsonia	jepmal	Low solar radiation at the winter solstice; more likely on certain soil types (Map Units 156, 182, 183, 191, 411, 422, 423, and 424).
Lepechinia fragrans	fragrant pitcher sage	lepfra	Low July cloud albedo (peaking at 9%); wetter sites; higher elevations.
Leptosyne gigantea (Coreopsis gigantea)	giant coreopsis	lepgig	Low elevations (below 100 m); low to moderate July cloud albedo (peaking at 17%); low productivity sites; Entisols (Map Units 160 and 191), and certain other soil types (Map Units 157, 400, 424, and 427).
Lycium californicum	California boxthorn	lyccal	High July cloud albedo (peaking at 21%), associated with the western, windward shoreline; low elevations (less than 200 m); low to moderate slopes and very steep cliffs; low productivity; Entisols (Map Units 160 and 191) and Alfisols (420, 421, 422, 423, and 427).
Lyonothamnus floribundus ssp. *floribundus* - SCIE	Catalina Island ironwood	lyoflo	Low winter solstice solar radiation; more likely on certain soil types (Map Units 157, 185, 422, 424, and 427); less likely on southerly-facing slopes.
Malacothamnus fasciculatus var. *catalinensis* - SCIE	Catalina Island bushmallow	malfascat	High equinox solar radiation; low to moderate May Cloud Albedo (15 to 18%); all aspects but more likely on east- to south-facing slopes; on a variety of soil types but more likely on certain soil types (Map Units 156, 157, 160, 183, 191, 411, 422, and 423).
Malosma laurina	laurel sumac	mallau	More likely on soils with volcanic parent material (Map Units 157, 182, 400, 407, and 411); occurs on all slopes but more likely on southerly-facing slopes and steeper slopes; most likely on sites with high solar radiation on summer solstice.
Muhlenbergia microsperma	littleseed muhly	muhmic	More likely on flat to moderate, and southerly-facing slopes; low to moderate productivity sites; occurs on all soils but more likely on certain soil types (Map Units 157, 183, 190, 400, and 422).
Opuntia littoralis	coastal prickly pear	opulit	Higher winter solstice solar radiation; lower productivity sites; occurs on all aspects but more common on southerly-aspects and drier sites; occurs on all soil types but more likely on certain soil types (Map Units 183, 411, and 421).
*Pennisetum setaceum**	fountaingrass	penset	Low elevations (below 100 m); low productivity sites.

Scientific Name	Common Name	Code	Most Important Features of Predictive Env. Variables
Peritoma arborea	bladderpod	perarb	Low elevations (below 300 m); gentle to steep slopes; Alifsols soil (Map Unit 423).
*Phalaris aquatica**	Harding grass	phaaqu	Flat to moderate slopes; wetter sites; more likely on northerly-facing slopes; moderate solar radiation at the winter solstice.
Piperia spp.	orchid	pipspp	Low cloud albedo in September (peaking at 9.5%); more likely on alluvial soils (Map Unit 191) and volcanic parent material soils (Map Units 182, 410, 411, and 412) and Ustalfs soils (Map Unit 422).
Plagiobothrys collinus	popcornflower	placol	Near sea level (less than 10 m) and higher elevations (above 200 m); flat to moderate slopes; high solar radiation on the summer solstice; more likely on Alifsols (Map Units 182, 410, 411, 423, and 424).
Prunus ilicifolia ssp. *lyonii* - CIE	Catalina cherry	pruililyo	More likely on certain soil types (Map Units 157, 191, 421, and 422); wetter, more northerly-facing sites; lower elevations.
Quercus pacifica - CIE	island scrub oak	quepac	Less likely on south-facing slopes; occurs on all soil types but more likely on certain soil types (Map Units 156, 157, 412, 422, and 423); occurs at all elevations but increased likelihood above 400 m; occurs on all slopes but more likely on flat to moderately steep slopes.
Quercus tomentella - CIE	island live oak	quetom	Lower September cloud albedo (peaking at 11%); May cloud albedo below 20%; steep slopes and incised valleys; Alfisols (Map Units 181, 182, 400, 407, 411, and 424); more likely on volcanic parent material (Tma, Tmi, Tmqd).
Quercus x macdonaldii - CIE	MacDonald oak	quemac	Drainages and valleys; flat to moderate slopes; more likely on north-facing slopes; more likely on certain soil types (Map Units 156, 157, 181, 182, 191, 411, 412, and 422).
Rhamnus pirifolia - CIE	island redberry	rhapir	Gentle to very steep slopes; mid-slope to ridgelines; occurs on all soil types but more likely on certain soil types (Map Units 156, 157, 407, 410, and 411).
Rhus integrifolia	lemonade berry	rhuint	Occurs at all elevations but more likely below 100 m and above 300 m; gentle to steep slopes; occurs across a wide range of vegetative productivity but most likely at moderate productivity (NDVI peaking at 0.2); drier sites.
Ribes viburnifolium - CIE	Catalina Island currant	ribvib	Entisols (Map Units 160 and 191) and Alfisols soils (Map Units 182, 183, 184, 185, 293, 400, 411, 421, 422, and 424); lower solar radiation on the winter solstice; less likely on south- to east-facing slopes.
Salvia apiana	white sage	salapi	Higher elevations (above 300 m); drier sites; loam, sandy loam, and gravelly loamy sand soils derived from volcanic parent material (Map Units 156, 410, 411, and 412).
Salvia mellifera	black sage	salmel	Higher elevations (above 100 m); Catalina Schist (Jcsb, Jcss), Catalina Island pluton (Tmqd), and andesite volcanic rock (Tma) parent material soils; more likely on certain soil types (157, 182, 407, 412, 423, and 427) southerly-facing slopes.

Scientific Name	Common Name	Code	Most Important Features of Predictive Env. Variables
Sambucus mexicana	blue elderberry	sammex	Occurs on all soil types but more likely on certain soil types (Map Units 407, 421, and 424); occurs on all slope aspects but more likely on flat, south-southwest, and north-northwest orientations; more likely at lower elevations.
Scrophularia villosa - CIE	Catalina Island figwort	scrvil	Lower solar radiation on the winter solstice; occurs on most parent material but more likely on blue or serpentinite Catalina Schist (Jcsb, Jcss), alluvium (Qal), intrusive volcanic rocks (Tmi), and marine sediments (Tms); lower elevations; more likely on certain soil types (Map Units 183, 185, 191, 400, 422, and 424).
Sibara filifolia - CIE	island rockcress	sibfil	More likely between 100 to 300 m in elevation; two soil types (Map Unit 182 and 423); higher solar radiation on the summer solstice.
*Silybum marianum**	milk thistle	silmar	Flat to moderate slopes; drainages and valleys; higher productivity sites.
Solanum wallacei - CIE	Wallace's nightshade	solwal	Low September cloud albedo (peaking at 10%); drainages and valleys; higher productivity sites.
Stipa cernua	nodding needlegrass	sticer	Higher elevations (above 200 m); Flat to moderately steep slopes.
Stipa spp.	needlegrass	stipa	Lower productivity sites (NDVI peaking at 0.17), which are associated with grassland and open upland scrubland; more likely on gentle to moderate slopes; more likely on certain soil types (Map Units 183, 411, 412, 421, 422, and 423).
*Tamarix ramosissima**	saltcedar	tamram	Lower elevations; flat to gentle slopes; low productivity sites.
Trifolium palmeri - CIE	southern island clover	tripal	Low elevations (less than 100 m); more likely on moderate climatic conditions on east- and west-facing slopes.
Typha domingensis	southern cattail	typdom	Wetlands, drainages, and valleys; lower elevations (below 200 m); more likely on gravelly soils (Map Units 191, 412, 421, and 423).
Xylococcus bicolor	Mission manzanita	xylbic	More likely on certain soil types (Map Units 181, 182, 420, 422, and 423); flat and northerly-facing slopes; more likely on moderate slopes.

4 DISCUSSION

4.1 COMPARISON WITH EXISTING OAK MODELS

Franklin and Knapp (2010) employed statistical models to identify the key environmental factors influencing the distribution of two endemic oak species on Catalina Island: *Quercus pacifica* (island scrub oak) and *Q. tomentella* (island live oak). The goal was to pinpoint suitable habitats for restoration efforts and better understanding habitat relationships with environmental variables. The models incorporated both presence/absence and abundance data, employing three distinct modeling techniques: Classification and Regression Trees (CT, RT), Generalized Additive Models (GAM), and Generalized Linear Models (GLM). Predictive maps were generated using ArcView Geographic Information System (GIS) to visualize the results.

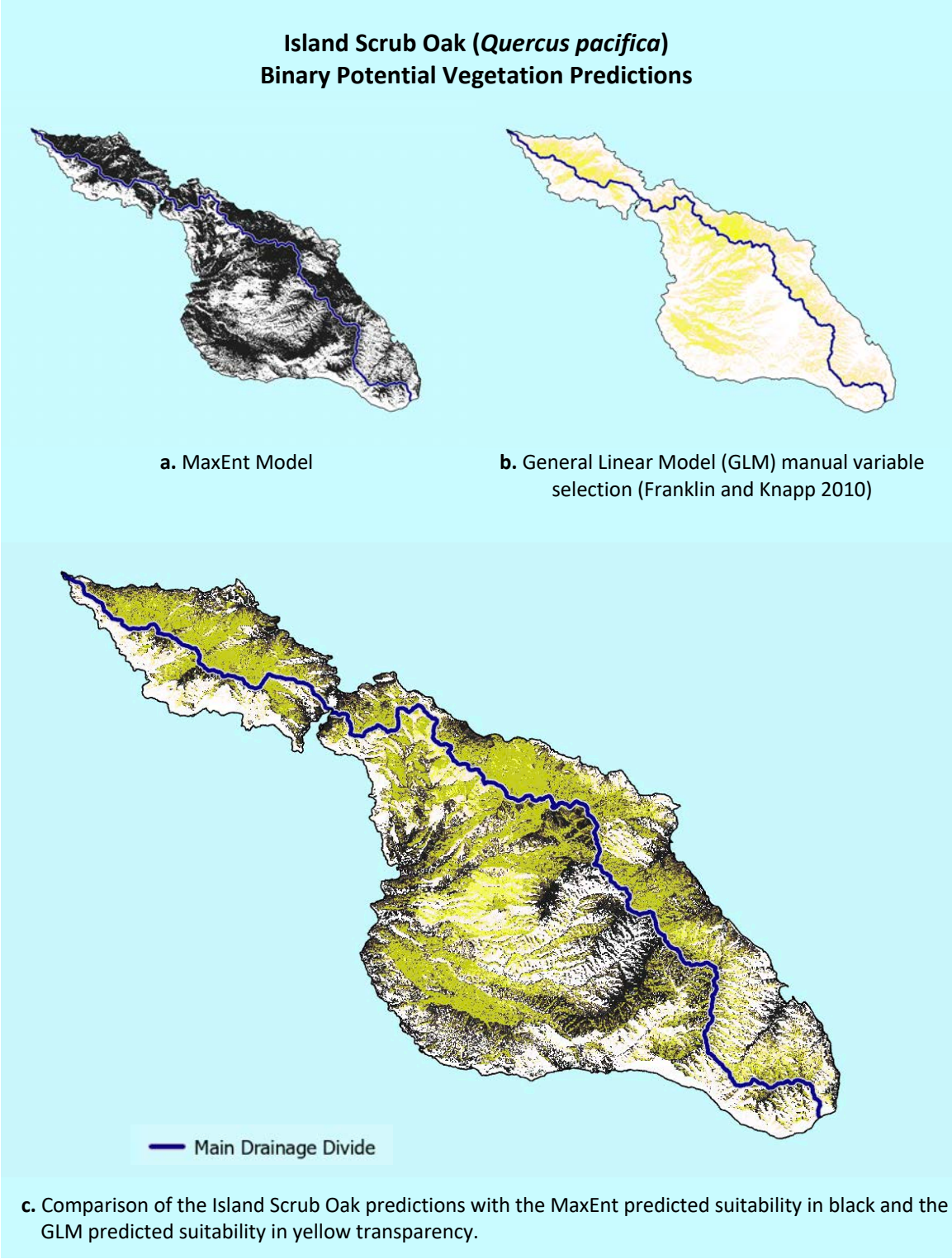
Among the models developed, the optimal predictive map for island scrub oak was found to be a GLM with manual variable selection. In contrast, the best-performing model for island live oak was determined to be a GLM with stepwise variable selection.

We compared the MaxEnt models for *Quercus pacifica* and *Q. tomentella* developed in this study and the GLMs established by Franklin and Knapp (2010) for the same species using binary (suitable or not suitable habitat) data above a suitability threshold. The suitability thresholds for the MaxEnt models are presented in Table 6-3. The threshold value for the raster datasets for the GLMs were 0.15 for *Q. pacificai* and 0.10 for *Q. tomentella* (Franklin and Knapp 2010). The raster data utilized for the GLMs was provided by the Conservancy.

4.1.1 ISLAND SCRUB OAK (*QUERCUS PACIFICA*)

The average AUC for the *Q. pacifica* MaxEnt model was 0.64 with a standard deviation of 0.18 (standard deviation). This is better than chance but relatively low compared with the other models developed in this study, and is attributed to habitat generalization, as discussed in Section 3, Results. The AUC for the GLM model was good at 0.89. However, Franklin and Knapp (2010) identify that the GLM model under predicts the distribution of *Q. pacifica*. The GLM model predicted suitability for 17% of the island, compared with the 23% mapped by Knapp (unpublished data provided by the Conservancy), which was developed as part of the 2000 Vegetation Type Map prepared by Knapp (2005).

In comparison, the MaxEnt model predicts suitable habitat for 41% of the island and generally matches the distribution of the GLM prediction (Figure 4-1). Both modeling efforts identify that *Q. pacifica* is more likely on north-facing slopes above 400 meters in elevation or on flat to moderately steep slopes in areas with higher solar radiation. Both models identify preferences for certain substrates. The GLM model used the 1955 soil dataset, and the MaxEnt model used the more recent and systematic 2008 soil dataset classification of soil map units. The MaxEnt model identifies higher likelihood on certain soil types, including Map Units 156, 157, 412, 422, and 423. See Figure 6-13 for the definition of Map Units.



a. MaxEnt Model

b. General Linear Model (GLM) manual variable selection (Franklin and Knapp 2010)

c. Comparison of the Island Scrub Oak predictions with the MaxEnt predicted suitability in black and the GLM predicted suitability in yellow transparency.

Figure 4-1 Comparison of predicted suitability for Island Scrub Oak with MaxEnt and GLM models.

4.1.2 ISLAND LIVE OAK (*QUERCUS TOMENTELLA*)

The average AUC for the *Q. tomentella* MaxEnt model was good, 0.84 ± 0.21, and the AUC for the GLM was excellent, 0.95. The GLM model predicted suitability for 28.8% of the island, which was very similar to 27.9% of the island for the MaxEnt model. Generally, the distribution of the two suitability models is similar (Figure 4-2). Both models identified that *Q. tomentella* is more likely on volcanic parent material and in locations where solar radiation is lower due to cloud albedo or landscape position, such as steep slopes and incised valleys.

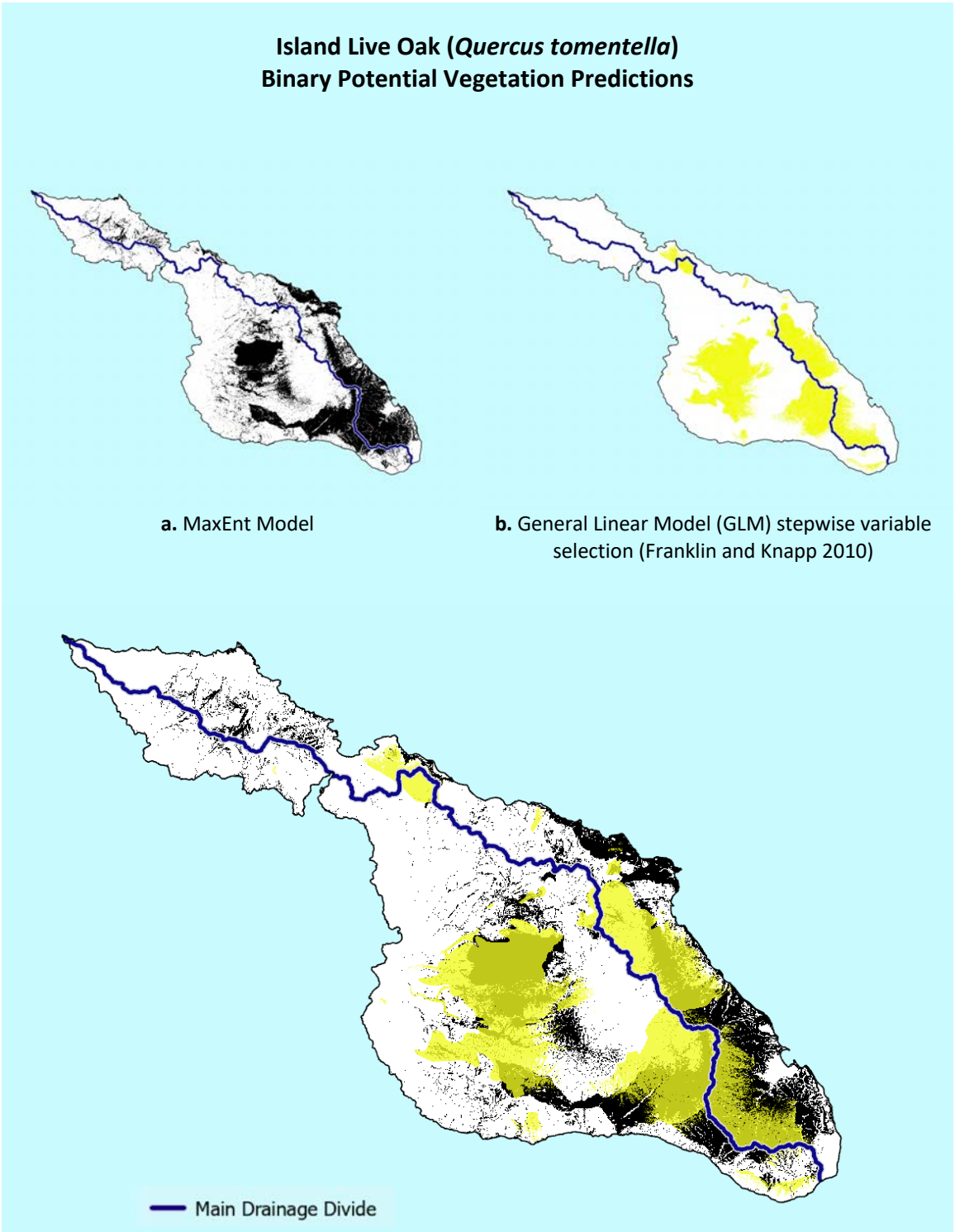
4.2 POTENTIAL VEGETATION COMMUNITIES

The primary objective is to leverage potential vegetation models of dominant and characteristic plant species outlined in the Manual of California Vegetation (MCV) to generate comprehensive maps of potential vegetation communities on Catalina Island. These maps will serve as a valuable resource for guiding whole island habitat restoration efforts.

The classification framework for potential vegetation communities adheres to the hierarchical structure outlined in the Online Edition of the MCV (CNPS 2024). This framework includes hierarchical levels such as Macro Group, Group, Alliance, and Association, and employs the established nomenclature provided in the MCV to ensure consistency and accuracy in the mapping process.

Dominant or characteristic species were selected from those available potential vegetation models in this report to define the distribution of potential vegetation communities. The selection of these potential vegetation communities are hypotheses of the restored state of the island based on our experience in southern California vegetation communities, including Catalina Island, and the existing vegetation maps for the island and relevant publications on the vegetation in the California Channel Islands. Distributions in the map are defined using binary (likely suitable or not) model outputs. The suitability threshold for each species is presented in the Table 6-3. Habitat Suitability Model Performance.

The potential MCV vegetation communities are presented in sections grouped by vegetation types identified by Knapp (2005) in the 2000 Vegetation Map and Junak et al. (2007) in a summary of typical vegetation types of the California Channel Islands: Island Woodland (IW), Island Chaparral (IC), Coastal Sage Scrub (CSS), Coastal Bluff Scrub (CBS), Maritime Cactus Scrub (MCS), Coastal Marsh (CM), Southern Beach and Dune (SBD), Vernal Ponds and Reservoirs (VPR), Grassland (GR), Nonnative Herbaceous (NNH), Nonnative Scrub (NNS).



a. MaxEnt Model

b. General Linear Model (GLM) stepwise variable selection (Franklin and Knapp 2010)

c. Comparison of the Island Scrub Oak predictions with the MaxEnt predicted suitability in black and the GLM predicted suitability in yellow transparency.

Figure 4-2 Comparison of predicted suitability for Island Live Oak with MaxEnt and GLM models.

The following three Vegetation Types are not included in this discussion because there was insufficient training data for the related dominant species: Southern Riparian Woodland (SRW), Riparian Herbaceous (RH), and Mulefat Scrub (MFS). While these three vegetation types represent only 0.3%, 0.1%, and less than 0.1% of the land area respectively, their association with riparian habitat gives them more value to the island ecology than the land area suggests. More detailed investigation focused on these island riparian systems would benefit management of associated wildlife, such as bats and the Catalina Island Shrew. Given the limited land area, these riparian systems can be censused as part of a future survey effort, as needed.

4.2.1 Island Woodland

Californian Broadleaf Forest and Woodland Group

Three potential woodland associations were identified (Figure 4-3):

a. **Island Live Oak Woodland and Forest** (*Quercus tomentella* Forest & Woodland Association) is defined by dominance by *Quercus tomentella* in the tree canopy.

b. **Catalina Ironwood Woodland and Forest** (*Lyonothamnus floribundus* subsp. *floribundus* Forest & Woodland Association) is defined by dominance by *Lyonothamnus floribundus* subsp. *floribundus* in the tree canopy.

c. **Catalina Cherry Woodland and Forest** (*Prunus ilicifolia subsp. lyonii* Forest & Woodland Association) is defined by *Prunus ilicifolia* subsp. *lyonii* in the tree canopy.

4.2.2 Island Chaparral

California Maritime Chaparral Group

Two potential maritime chaparral associations were identified (Figure 4-4):

a. **Santa Catalina Island Manzanita Chaparral** (*Arctostaphylos catalinae* Shrubland Association) is defined by dominance or co-dominance of *Arctostaphylos catalinae* in the shrub layer.

b. **Island Scrub Oak Chaparral** (*Quercus pacifica* Shrubland Association) is defined by dominance or co-dominance of *Quercus pacifica* in the shrub layer.

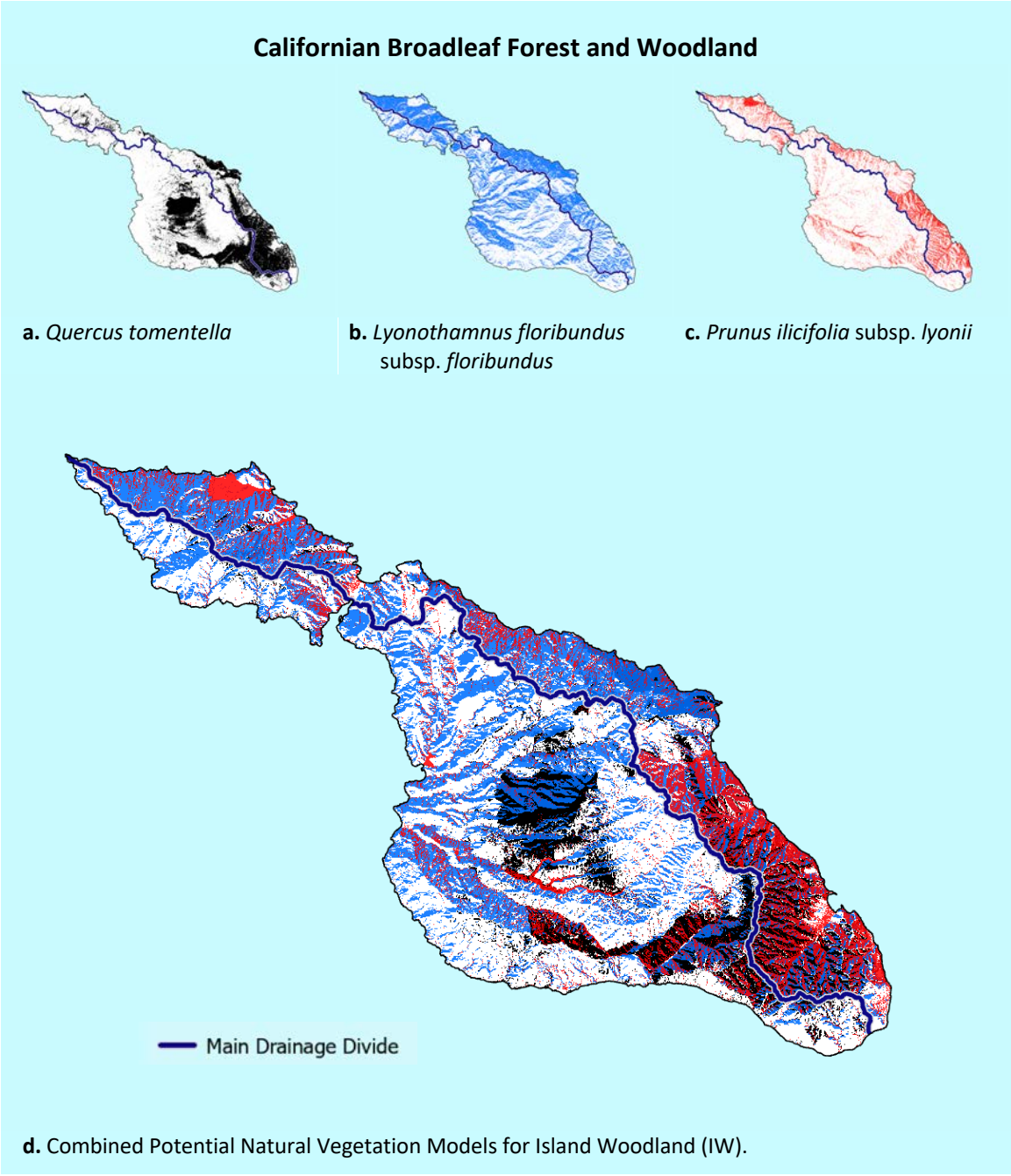


Figure 4-3 Potential Natural Vegetation Binary Predictions of Three Dominant Species in the Californian Broadleaf Forest and Woodland Group.

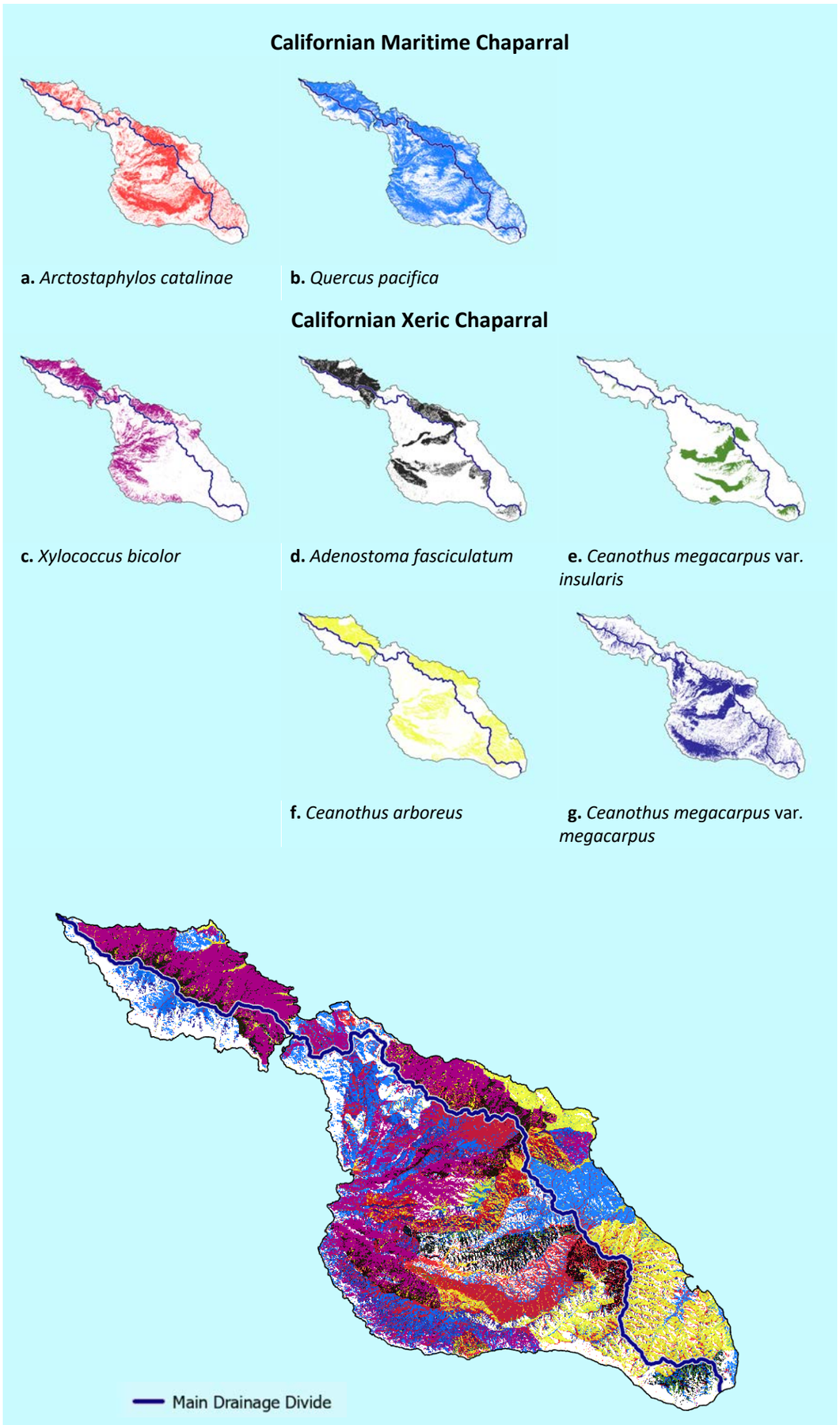


Figure 4-4 Potential Natural Vegetation Binary Predictions of Seven Dominant Species in the California Chaparral Macro Group.

CALIFORNIA XERIC CHAPARRAL GROUP

Five potential xeric chaparral alliances or associations were identified (Figure 4-4):

c. **Mission Manzanita – Lemonadeberry Chaparral** (*Xylococcus bicolor - Rhus integrifolia* Shrubland Association) is defined by co-dominance of *Xylococcus bicolor and Rhus integrifolia* in the shrub layer.

d. **Chamise – Sage Chaparral** (*Adenostoma fasciculatum - Salvia* spp. Shrubland Alliance) is defined by co-dominance of *Adenostoma fasciculatum* and *Salvia* spp. (e.g., *S. mellifera*).

e. **Island Ceanothus Chaparral** (*Ceanothus megacarpus* var. *insularis* Shrubland Association) is defined by dominance or co-dominance of *Ceanothus megacarpus* var. *insularis* in the shrub layer.

f. **Felt-Leaf Ceanothus Chaparral** (*Ceanothus arboreus* Shrubland Association) is defined by dominance or co-dominance of *Ceanothus arboreus* in the shrub layer.

g. **Big-Pod Ceanothus Chaparral** (*Ceanothus megacarpus* Shrubland Alliance) is defined by dominance or co-dominance of *Ceanothus megacarpus* var. *megacarpus* in the shrub layer.

4.2.3 COASTAL SAGE SCRUB

CENTRAL AND SOUTH COASTAL CALIFORNIAN COASTAL SAGE SCRUB (CSS) GROUP

Six potential CSS alliances or associations were identified (Figure 4-5):

a. **California Sagebrush – Coast Prickly Pear Scrub** (*Artemisia californica - Opuntia littoralis* Shrubland Association) is defined by co-dominance of *Artemisia californica* and *Opuntia littoralis* in the shrub layer.

b. **California Sagebrush Scrub** (*Artemisia californica* Shrubland Alliance) is defined by dominance or co-dominance of *Artemisia californica* in the shrub layer.

c. **Island Buckwheat Scrub** (*Eriogonum grande* var. *grande* Shrubland Association) is defined by dominance or co-dominance of *Eriogonum grande* var. *grande* in the shrub layer.

d. **California Brittle Bush Scrub** (*Encelia californica* Shrubland Association) is defined by dominance or co-dominance of *Encelia californica* in the shrub layer.

e. **White Sage Scrub** (*Salvia apiana* Shrubland Alliance) is defined by dominance or co-dominance of *Salvia apiana* in the shrub layer.

f. **Black Sage Scrub** (*Salvia mellifera* Shrubland Alliance) is defined by dominance or co-dominance of *Salvia mellifera* in the shrub layer.

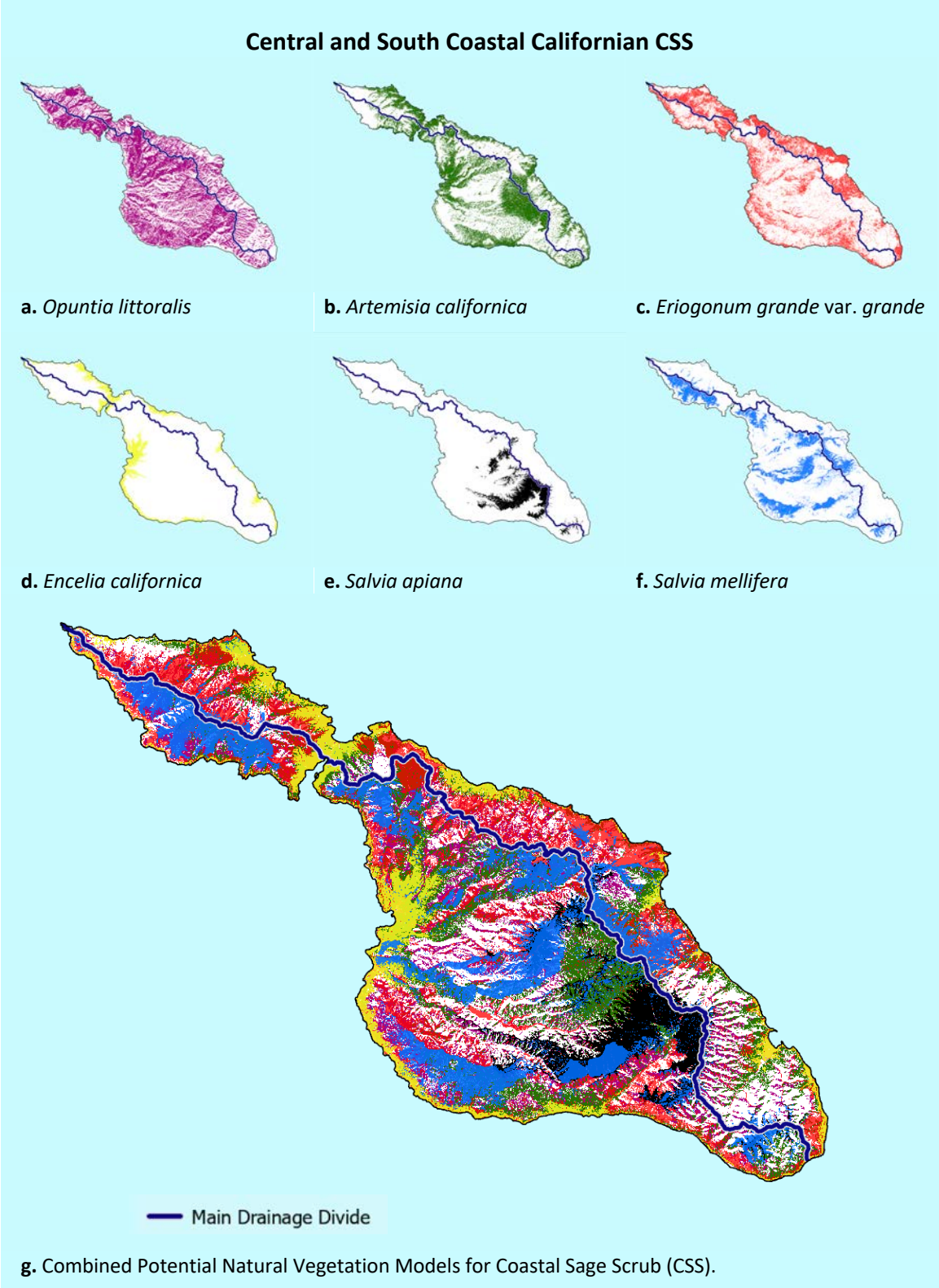


Figure 4-5 Potential Natural Vegetation Binary Predictions of Six Dominant Species in the Central and South Coastal Californian CSS Group.

4.2.4 COASTAL BLUFF SCRUB

COASTAL BAJA CALIFORNIA NORTE MARITIME SUCCULENT SCRUB GROUP

Five potential succulent scrub alliances or associations were identified (Figure 4-6):

a. **Giant Coreopsis Scrub** (*Leptosyne gigantea* Shrubland Alliance) is defined by dominance or co-dominance of *Leptosyne gigantea* in the shrub layer.

b. **Coast Prickly Pear Scrub** (*Opuntia littoralis – Opuntia oricola – Cylindropuntia prolifera* Shrubland Alliance) is defined by dominance or co-dominance of *Opuntia littoralis* in the shrub layer.

d. **Island Tarplant – Saint Catherine's Lace Scrub** (*Deinandra clementina – Eriogonum giganteum* var*. giganteum* Shrubland Alliance) is defined by dominance or co-dominance of *Deinandra clementina* and/or *Eriogonum giganteum* var. *giganteum.*

e. **Green Liveforever Succulent Scrub** (*Dudleya virens subsp. hassei* Succulent Scrub Association) is defined by dominance by *Dudleya virens subsp. hassei* in the herb layer.

f. **Saint Catherine's Lace Scrub** (*Eriogonum giganteum* var*. giganteum* Shrubland Association) is defined by dominance or co-dominance of *Eriogonum giganteum* var*. giganteum* in the shrub layer.

4.2.5 MARITIME CACTUS SCRUB

COASTAL BAJA CALIFORNIA NORTE MARITIME SUCCULENT SCRUB GROUP

One potential succulent scrub alliances or associations was identified, which is in the same MCV Group as the five vegetation communities identified above in the Coastal Bluff Scrub Vegetation Type, but has previously been described as Maritime Cactus Scrub Vegetation Type (Figure 4-6):

c. **California Boxthorn Scrub** (*Lycium californicum* Shrubland Alliance) is defined by dominance or co-dominance of *Lycium californicum* in the shrub layer.

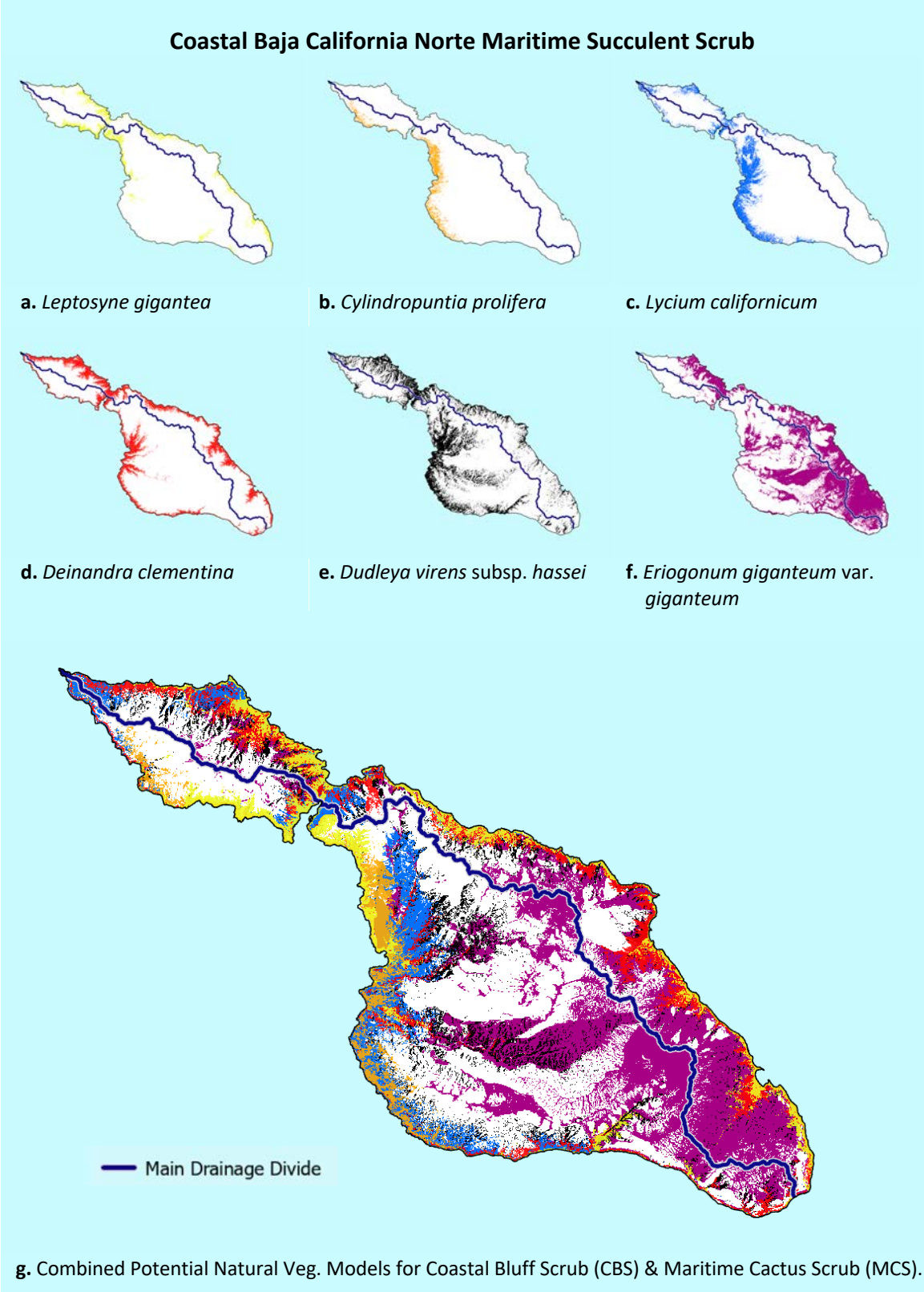


Figure 4-6 Potential Natural Vegetation Binary Predictions of Six Dominant Species in the Coastal Baja California Norte Maritime Succulent Scrub Group.

4.2.6 VERNAL PONDS AND RESERVOIRS

ARID WEST FRESHWATER EMERGENT MARSH GROUP

One potential marsh alliance was identified (Figure 4-7):

a. Cattail Marshes (*Typha* spp. Herbaceous Alliance) is defined by *Typha* (e.g., *domingensis*) dominant or co-dominant in the herbaceous layer.

CALIFORNIAN MIXED ANNUAL/PERENNIAL FRESHWATER VERNAL POOL/SWALE BOTTOMLAND GROUP

One potential vernal pool/swale bottom alliance was identified (Figure 4-7):

b. Clustered Tarplant Fields (*Deinandra fasciculata* Herbaceous Alliance) is defined by *Deinandra fasciculata* dominant or co-dominant with other herbs (e.g., *Hordeum intercedens*).

4.2.7 COASTAL MARSH

TEMPERATE PACIFIC TIDAL SALT AND BRACKISH MEADOW GROUP

One potential brackish meadow alliance was identified (Figure 4-7):

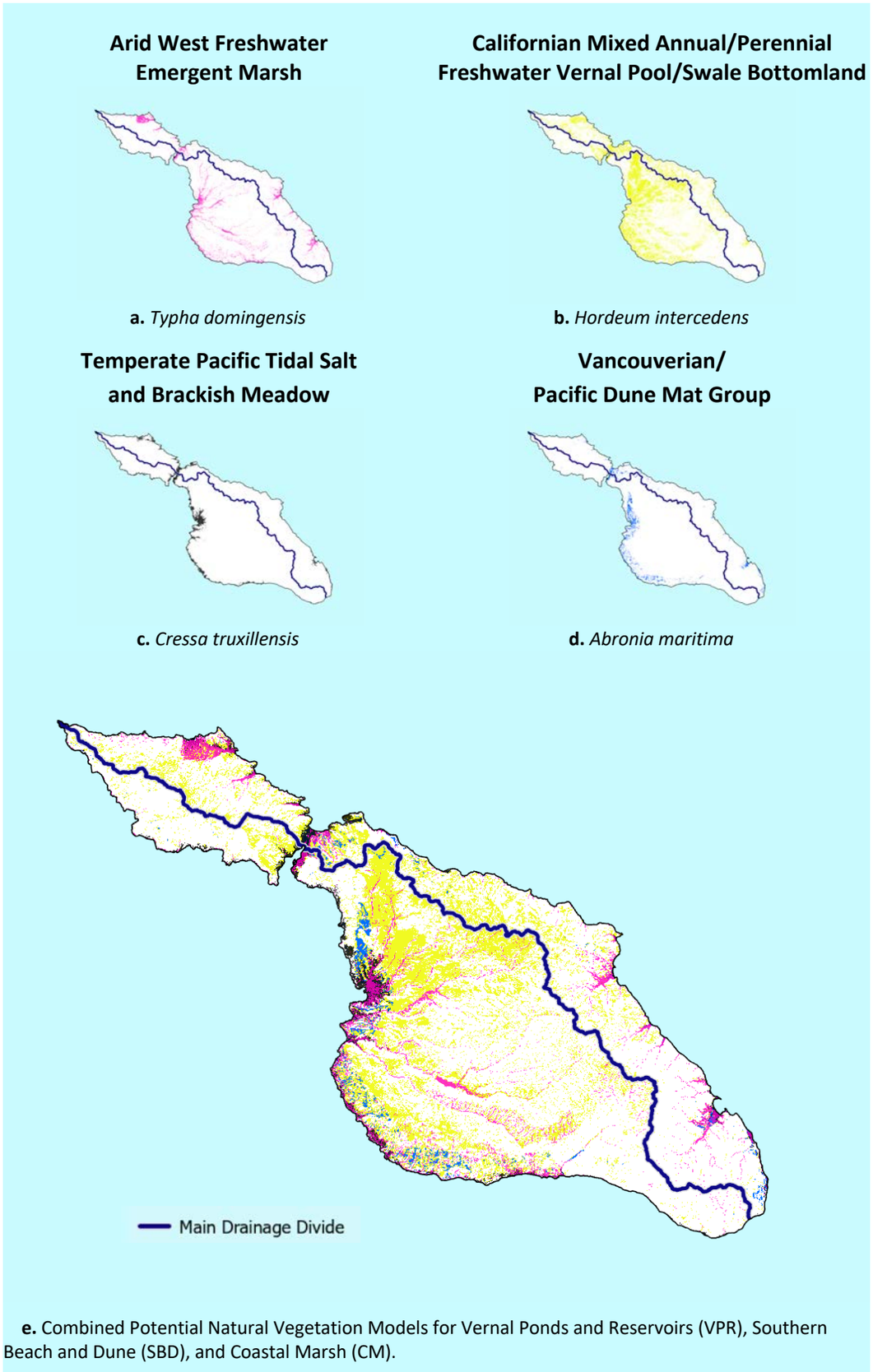
c. Salt Grass Flats (*Distichlis spicata* Herbaceous Alliance) is defined by *Distichlis spicata* dominant or co-dominant with other herbs (e.g., *Cressa truxillensis*).

4.2.8 SOUTHERN BEACH AND DUNE

VANCOUVERIAN/PACIFIC DUNE MAT GROUP

One potential dune mat association was identified (Figure 4-7):

d. Dune Mat (*Ambrosia chamissonis - Abronia maritima - Cakile maritima Herbaceous Association*) is defined by *Abronia maritima* other perennial herbs, grasses, and low shrubs, often including the invasive plant, *Cakile maritima.*



e. Combined Potential Natural Vegetation Models for Vernal Ponds and Reservoirs (VPR), Southern Beach and Dune (SBD), and Coastal Marsh (CM).

Figure 4-7 Potential Natural Vegetation Binary Predictions of Four Dominant Species in the Four Different Vegetation Community Groups, Including Fresh Water Marsh, Brackish Meadow, Vernal Pool/Swale, and Dune Mat.

4.2.9 GRASSLAND

SOUTHWESTERN NORTH AMERICAN ALKALI MARSH/SEEP VEGETATION GROUP

One potential alkali marsh/seep association was identified (Figure 4-8):

a. **Creeping Wildrye Turfs** (*Elymus triticoides* - *Bromus* spp. - *Avena* spp. Herbaceous Association) is defined by *Elymus triticoides* dominant or co-dominant with other herbs (e.g., *Deinandra fasciculata*) or grasses (e.g., *Stipa* spp.), including invasive annual grasses.

CALIFORNIA PERENNIAL GRASSLAND GROUP

One potential perennial grassland alliance was identified (Figure 4-8):

b. **Giant Wild Rye Grassland** (*Elymus condensatus* Herbaceous Alliance) is defined by *Elymus condensatus* dominant or co-dominant in the herbaceous layer.

WESTERN DRY UPLAND PERENNIAL GRASSLAND GROUP

One potential dry upland perennial grassland alliance was identified (Figure 4-8):

c. **California Brome Prairie** (*Bromus sitchensis* - *Elymus glaucus* Herbaceous Alliance) is defined by *Bromus sitchensis* and/or *Elymus glaucus* dominant or co-dominant with other herbs (e.g., *Achillea millefolium*).

CALIFORNIA ANNUAL HERB/GRASS GROUP

One potential annual forbland or grassland alliance was identified (Figure 4-8):

d. **Fiddleneck – Phacelia FIelds** (*Amsinckia* spp. - *Phacelia* spp. Herbaceous Alliance) is defined by *Amsinckia* spp. and/or *Phacelia* spp. dominant or co-dominant with other herbs (e.g., *Deinandra fasciculata*, *Lupinus bicolor*). Emergent shrubs may be present at low cover, such as *Ericameria palmeri.*

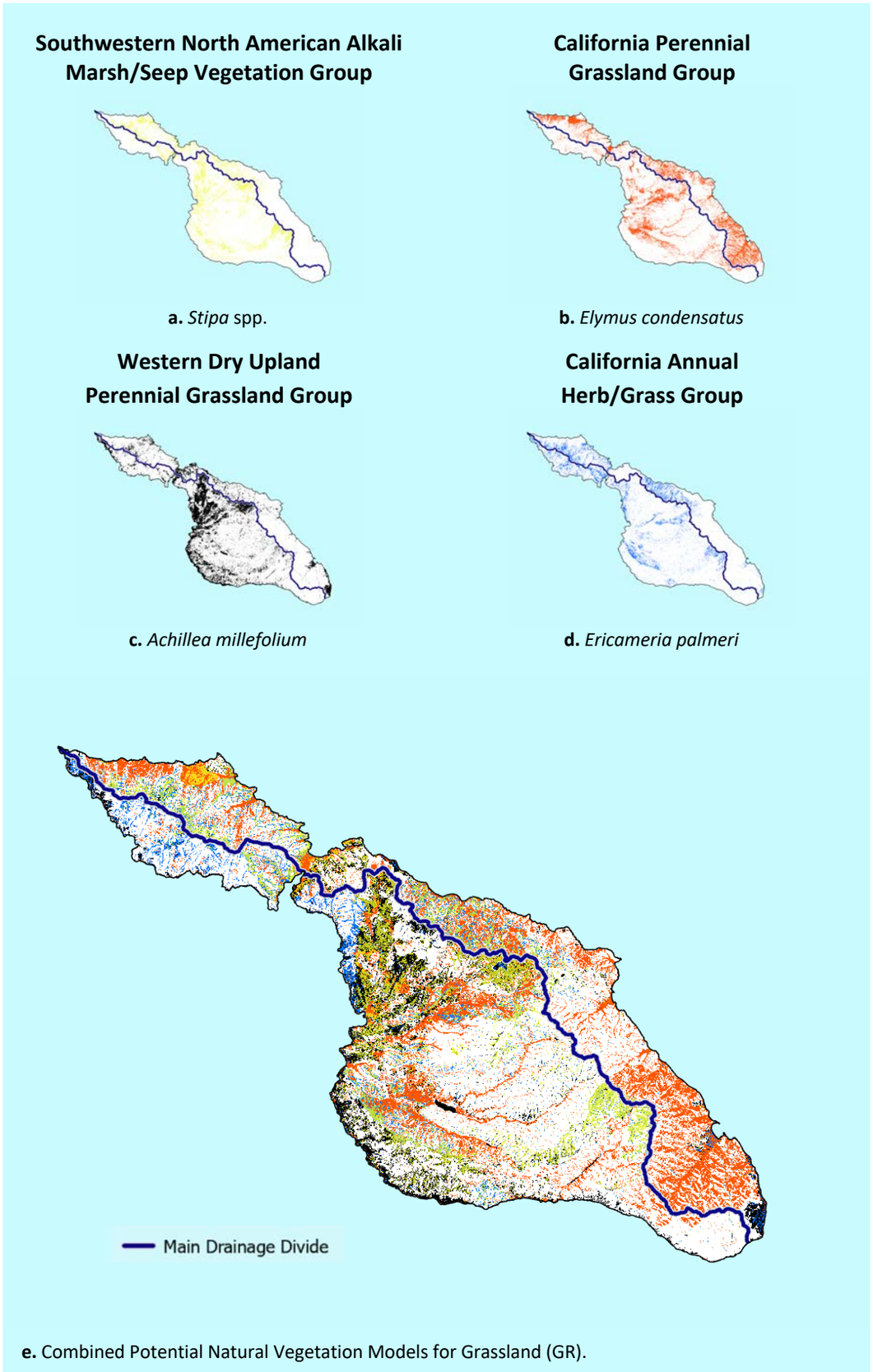


Figure 4-8 Potential Natural Vegetation Binary Predictions of Four Dominant Species in the Four Different Grassland Groups.

4.2.10 NONNATIVE HERBACEOUS

The Nonnative Herbaceous (NNH) Vegetation Type, includes the following invasive species that are managed as part of the Conservancy's invasive plant management program (see CHIRP, Appendix A)

Seven invasive herbaceous flowering plant species were modeled (Figure 4-9), not including grasses which are listed separately below:

- **a.** Black mustard (*Brassica nigra*)
- **b.** Sea rocket (*Cakile maritima*)
- **c.** Italian thistle (*Carduus pycnocephalus*)
- **d.** Bull thistle (*Cirsium vulgare*)
- **e.** Artichoke thistle (*Cynara cardunculus*)
- **f.** Sweet fennel (*Foeniculum vulgare*)
- **g.** Milk thistle (*Silybum marianum*)

There are four invasive species that were modeled in the Grasses Family (Poaceae) (Figure 4-10):

- **a.** Giant reed (*Arundo donax*)
- **b.** Pampas grass (*Cortaderia selloana*)
- **c.** Fountaingrass (*Pennisetum setaceum*)
- **d.** Harding grass (*Phalaris aquatica*)

4.2.11 NONNATIVE SCRUB

The Nonnative Scrub (NNS) includes the the following three invasive species, which were modeled, including a significant potential invasive threat from Mediterranean broom (*Genista linifolia*) (Figure 4-11):

- **a.** Red valerian (*Centranthus ruber*)
- **b.** Mediterranean broom (*Genista linifolia*)
- **c.** Saltcedar (*Tamarix ramosissima*)

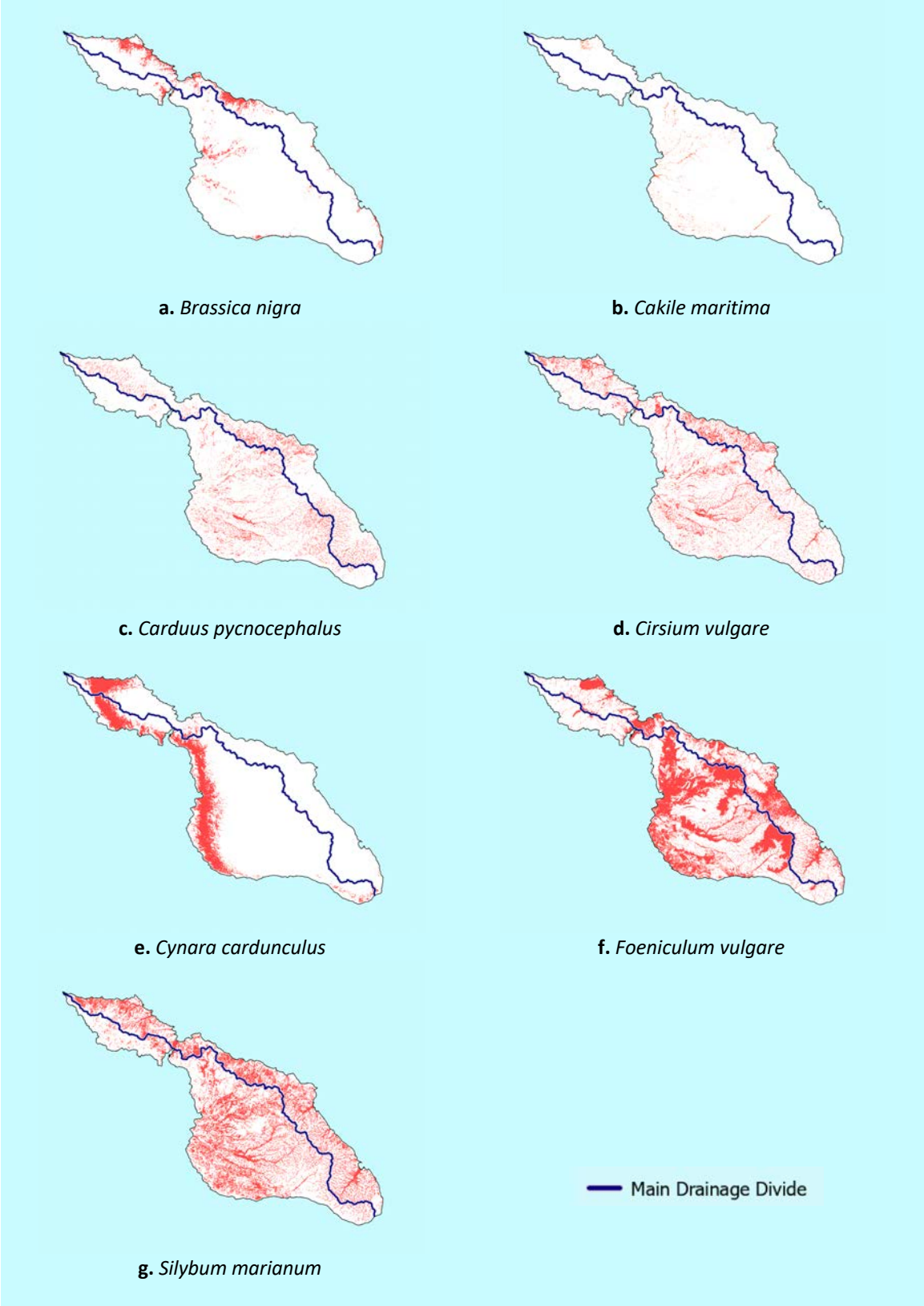


Figure 4-9 Potential Distribution of Seven Invasive Herbaceous Flowering Plants (excluding Grasses).

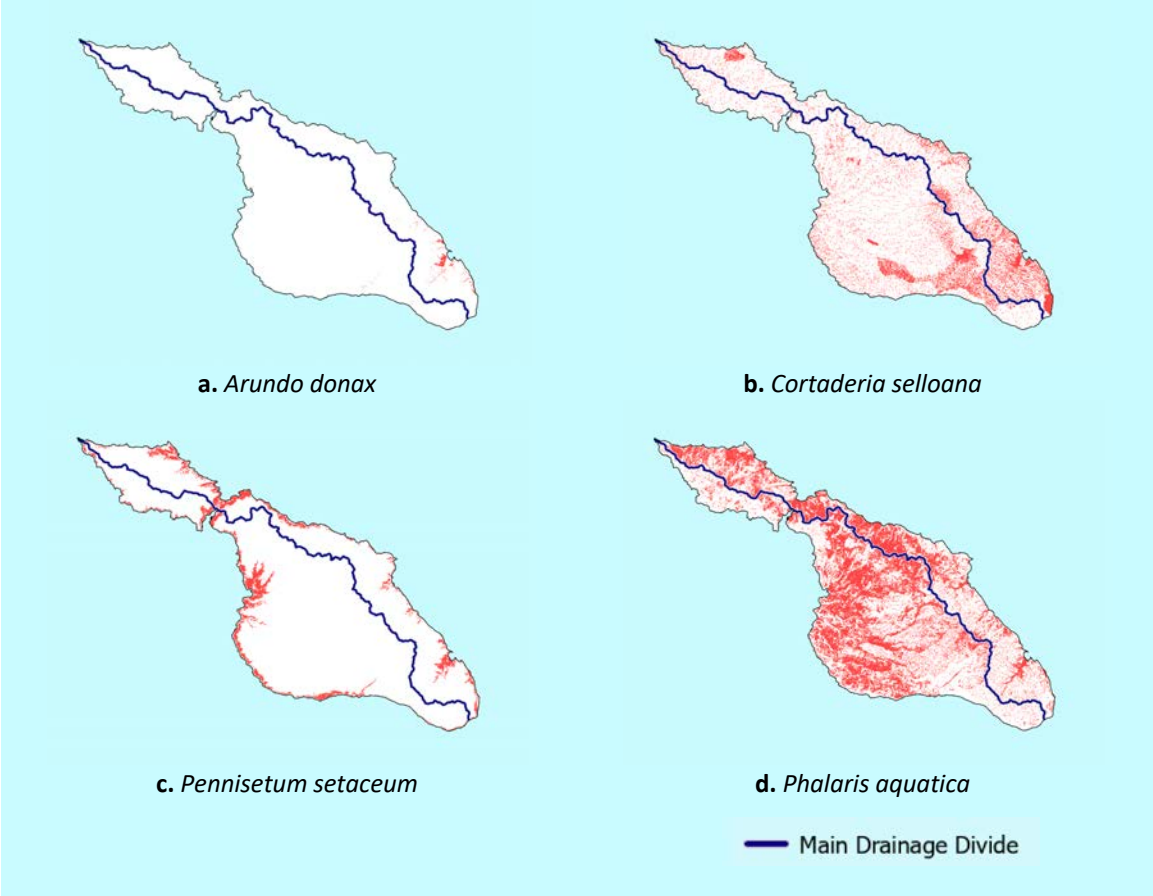


Figure 4-10 Potential Distribution of Four Invasive Grasses.

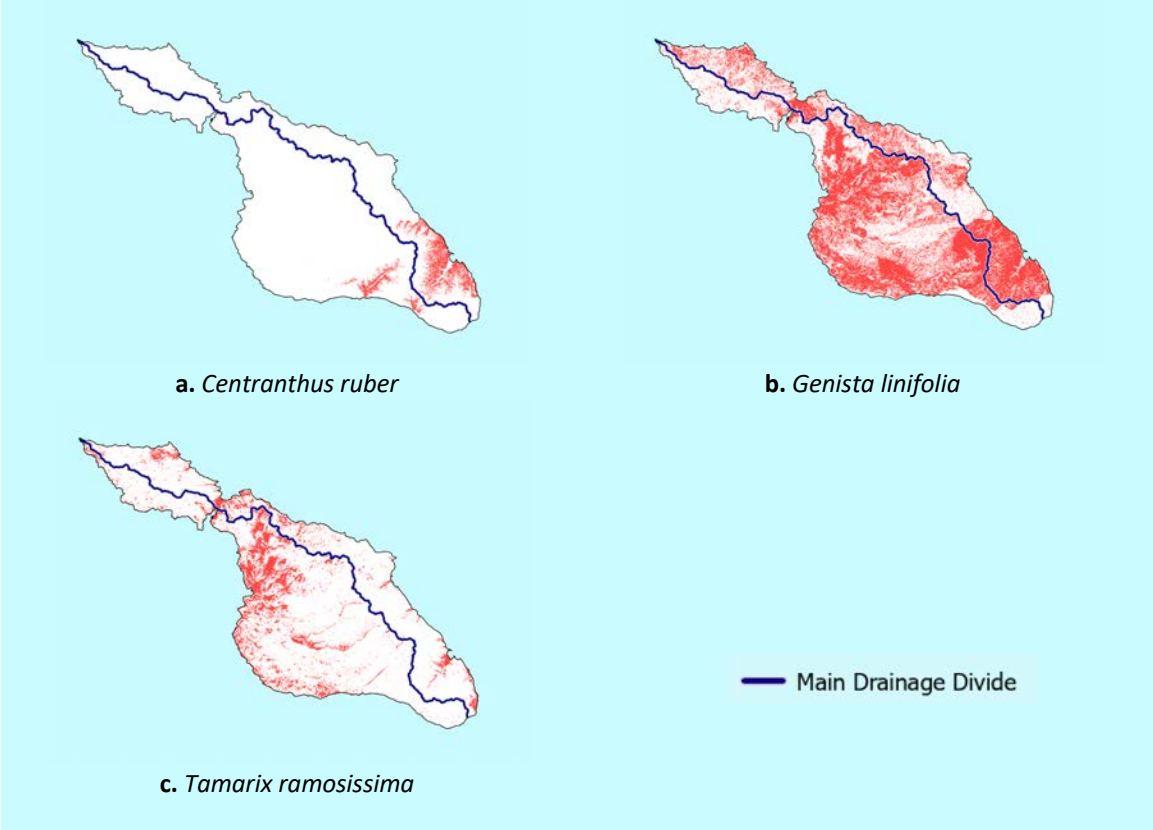


Figure 4-11 Potential Distribution of Three Invasive Shrubs.

4.3 Comparison with Existing Composite Potential Natural Vegetation Map

The potential vegetation alliances identified in Section 4.2 offer a more detailed understanding of the predicted composition of restored island vegetation communities, expanding upon the approach employed by Longcore et al. (2018). In their study, MaxEnt models were trained for vegetation types using samples from the 2000 Vegetation Map by Knapp (2005), ultimately generating a potential natural vegetation map (Figure 4-12).

The Longcore et al. (2018) approach possesses certain advantages, including more robust predictions for Southern Riparian Woodland, Riparian Herbaceous, and Mulefat Scrub, as our study was constrained by limited training data for characteristic plant species within these vegetation types.

The vegetation alliances discussed in Section 4.2 present hypothetical distributions of key or dominant species, providing valuable insights for the development of nuanced restoration plans. These detailed predictions aid in optimizing the likelihood of successful restoration by guiding the reintroduction of plants to the most suitable locations based on species-specific environmental preferences. This enhanced understanding of potential vegetation alliances will ultimately contribute to more effective restoration strategies for Catalina Island's unique ecosystems.

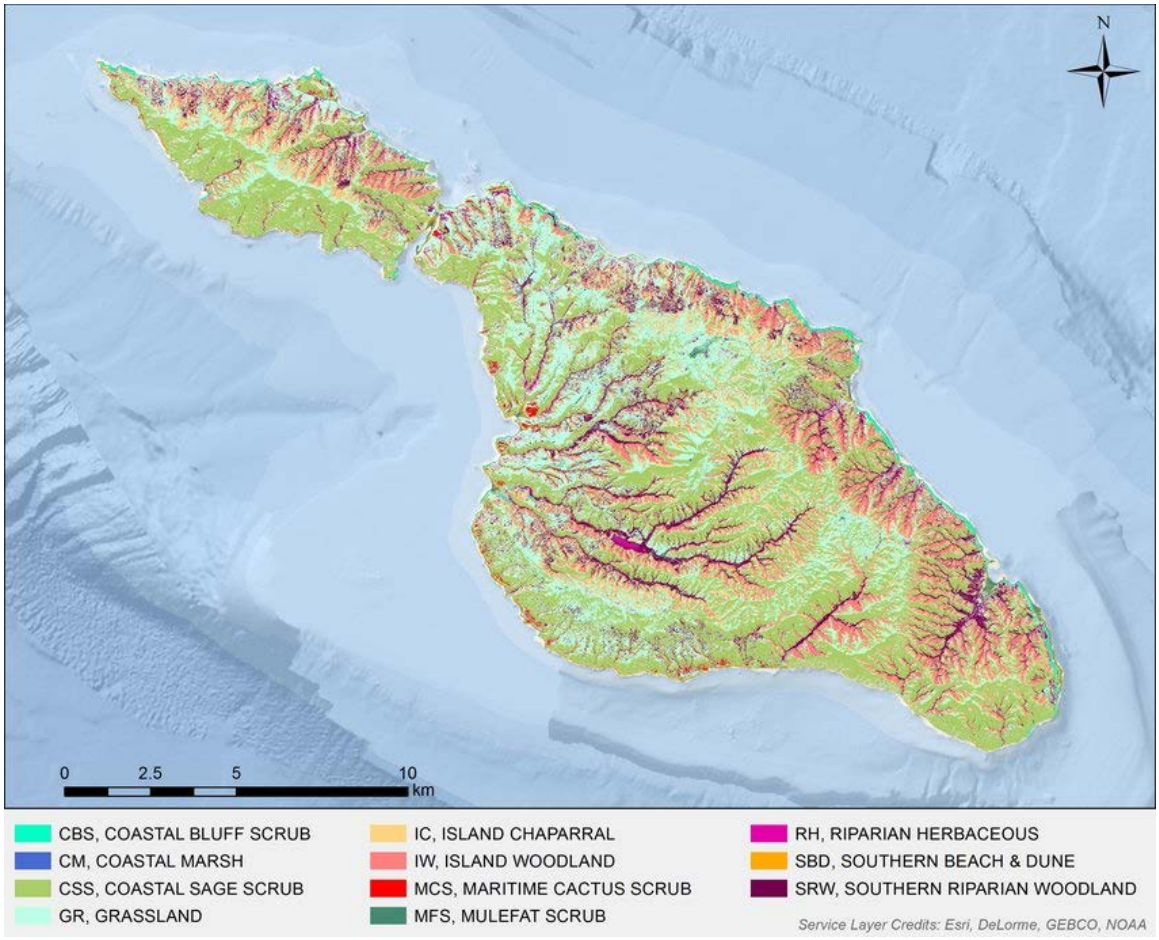


Figure 4-12 Potential Natural Vegetation Type Map (Longcore et al. 2018).

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6 SUPPORTING MATERIALS ATTACHMENT

This section includes additional figures and tables that support the conclusions of the report and can be used as a reference for the development of site-specific habitat restoration projects.

Table 6-1. Plants Selected for Species Environmental Niche Modeling.

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
Abronia maritima	red sand verbena	abrmar	---	S3	4.2	P	Scarce	**SBD**, In sand of beaches and dunes. *Pacific shore between Ben Weston Beach and Little Harbor: Ben Weston, Cottonwood Canyon, Shark Harbor, and Little Harbor Beaches; Catalina Harbor.*
Achillea millefolium	common yarrow	achmil	---	---	---	P	Common	**GR/MCS**, Rocky sea bluffs, sunny grassy slopes, and coastal ridges. *Widely distributed, including Pebbly Beach; Avalon; White's (Swain's) Landing; Little Harbor; Isthmus.*
Acmispon argophyllus	silver birds foot trefoil	acmarg	---	---	---	P	Common	**CSS/IC**, Dry, open, sunny, rocky slopes. *Widely scattered, including Pebbly Beach, Avalon, Swain's, Cape, Middle Ranch, and Cottonwood Canyons; above Empire Landing; Isthmus; Cherry Valley.*
Acmispon grandifloras	large leaved lotus	acmgra	---	---	---	P	Scarce	**CSS/IC/B**, Shaly banks. *Emerald Bay (Johnson's Landing) on shrubby stream bottom, shaly bank; North slope of Black Jack Mountain along Summit Road on shaly bank; Airport Fire Burn Area; Boushey, Cottonwood, Goat Harbor, and Parsons Landing, Canyons; Upper Buffalo oral Reservoir; Wild Boar Gully.*
Adenostoma fasciculatum	chamise	adefas	---	---	---	P	Common	**IC**, Dry, rocky clay slopes, and ridges, primarily on leeward channel-facing side. *Avalon, Hamilton, Gallagher's, Swain's, Middle Ranch, and Bulrush Canyons; East Mountain; Fox Landing (Buttonshell Beach); slopes of Black Jack Mountain; Ironwood Gully at Isthmus; Fourth of July Cove.*
Anemopsis californica	yerba mansa	anecal	---	---	---	P	Scarce	**VPR/RH**, Freshwater aquatic and alkali marsh *Stream in Little Springs Canyon; Big Springs Canyon; below dam in Cottonwood Canyon; along Empire Landing Road; lower Buffalo Springs Reservoir.*

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
Aphanisma blitoides	aphanisma	aphbli	---	S2	1B.2	A	Rare	**MCS/CBS**, Rocky bluffs. *Rocky bluffs on leeward channel-facing side of island; Catalina Harbor; China Point.*
Arctostaphylos catalinae - SCIE	Catalina Island manzanita	arccat	---	S2	1B.2	S-T	Abundant	**IC**, Uplands of central part of island. *Haypress; Boushey Canyon; north of Silver Peak; upper end of Gallaher's Canyon; ridge south of Bulrush Canyon; east slope of Black Jack Mountain; Swain's Canyon.*
Artemisia californica	California sagebrush	artcal	---	---	---	S	Abundant	**CSS**, Dry slopes and hilltops, sea bluffs, openings in chaparral canopy, and rocky or grassy canyon slopes. *Lookout Point; Avalon Valley; White's Landing; east slope of Black Jack Mountain; Shark Harbor; Isthmus; Howland's Landing.*
*Arundo donax**	giant reed	arudon	---	---	---	P	Scarce	**NNH**, Disturbed freshwater riparian. *Avalon Canyon; lower Cottonwood Canyon; Isthmus area.*
Asclepias fascicularis	narrowleaf milkweed	ascfas	---	---	---	P	Scarce	**VPR/IC/GR**, Temporary ponds, freshwater riparian, and grassy slopes on leeward channel-facing side. *Locally abundant in temporary ponds formed in Steatite (Soapstone) Quarries near Arrow Point above Parsons Landing; Cherry Valley; Sliver Canyon; Grand Canyon.*
Atriplex coulteri	Coulter's saltbush	atrcou	---	S1S2	1B.2	P-A	Occasional	**MCS**, Bare, dry, clayey or rock ridges and reservoir margins throughout the island. *Bulrush Ridge; Haypress Reservoir; Eagle's Nest; Cottonwood Canyon; Isthmus.*
Atriplex pacifica	South Coast saltscale	atrpac	---	S2	1B.2	A	Occasional	**SBD/B/CSS**, Dry, open slopes. *Middle Ranch, Bulrush, and Cottonwood Canyons; East End Road; Echo Lake.*
Baccharis pilularis	coyote bush	bacpil	---	---	---	S	Common	**CSS/IC**, Rocky, clay or sandy soils on slopes and ridges, or margin of reservoirs and dry stream beds.

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
								Widely distributed including Wrigley Reservoir, Haypress, Little Springs, Swain's, Middle Ranch, and Fern Canyons, above Empire Landing, and Parsons Slump.
Bergerocactus emoryi - CIE	velvet cactus	beremo	---	S2	2B.2	S	Scarce	**MCS**, Pacific sea-bluffs. *Salta Verde to Catalina Harbor and Isthmus.*
Bothriochloa barbinodis	cane bluestem	botbar	---	---	---	P	Occasional	**IC/CBS/MCS**, Dry, rocky hillsides. *Scattered on West End; Avalon Canyon; between Cherry Valley and Howland's Landing; south of Salta Verde Road.*
*Brassica nigra**	black mustard	branig	---	---	---	A	Occasional	**NNH**, Disturbed clayey soils and roadsides. *Avalon; White's Landing; roadsides between Middle Ranch and Cottonwood Canyons, Little Harbor to Catalina Harbor; Parsons Slump.*
Bromus sitchensis (carinatus)	California brome	brocar	---	---	---	P	Common	**IC/CBS/RH**, North-facing slopes, coastal bluffs, and creek beds. *North-facing slope of Bulrush Canyon; Upper Cape Canyon below reservoir; creek bed in Middle Canyon; below Eagle's Nest; coastal bluffs of Toyon Bay; cliffs near Jewfish Point.*
*Cakile maritima**	sea rocket	cakmar	---	---	---	P	Scarce, Locally Common	**SBD**, Sandy beaches. *White's Landing; Howland's Landing; Rippers Cove; Toyon Bay; Parsons Landing; Ben Weston and Cottonwood Canyon Beaches; Shark and Little Harbors.*
*Carduus pycnocephalus**	Italian thistle	carpyc	---	---	---	A	Occasional	**SRW/IC/VPR**, Roadside, riparian areas and reservoir edges. *Widely distributed including Empire Landing; Buffalo Springs Reservoir; Cottonwood, Grand, and Bulrush Canyons; West End along roads and leeward coast.*
Ceanothus arboreus - CIE	felt-leaf ceanothus	ceaarb	---	---	---	S-T	Common, Locally Abundant	**IC**, Leeward, channel-facing slopes and protected canyons of windward side where protected from invasive browsers.

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
								Pebbly Beach, Big Wash, Hamilton, Swain's, and Grand Canyons; Farnsworth Loop; slopes of Black Jack and Orizaba Mountains; Fourth of July Cove; Cherry Valley; ridge between Howland's and Johnson's Canyons.
Ceanothus megacarpus var. *insularis* - CIE	island ceanothus	ceamegins	---	S4	4.3	S	Occasional	**IC**, High elevation dry, rocky slopes and ridges in rocky clay soil on eastern half of island. *Salta Verde; upper Cape Canyon; upper Coffee Pot Canyon; East End; slopes of Black Jack Mountain; upper Swain's Canyon; east of the airport.*
Ceanothus megacarpus var. *megacarpus*	bigpod ceanothus	ceamegmeg	---	---	---	S	Occasional	**IC**, Dry, shrubby slopes, ridges, and canyons. *Avalon Canyon; slopes of Black Jack Mountain; Cape Canyon; East End; Renton Pass Canyon; Silver Peak Area; Swain's Canyon; Wild Board Gully.*
*Centranthus ruber**	red valerian	cenrub	---	---	---	S	Scarce, Locally Common	**NNS**, Disturbed slopes, roadsides, and drainages. *Widely scattered but locally common in Avalon Canyon; Silver Canyon; Stage Road; upper Toyon Road.*
Cercocarpus traskiae - SCIE	Catalina Island mountain-mahogany	certra	E	E	1B.1	T	Rare	**IC**, Occurs where protected from invasive browsers. *Wild Boar Gully; planted at airport; Buffalo Springs Canyon; Pebbly Beach Canyon; Black Jack Mountain.*
Chlorogalum pomeridianum	soap plant	chlpom	---	---	---	P	Occasional	**GR/B**, Thin soils on very rocky ridges and slopes, or heavily eroded clayey slopes. Possibly natural forblands dominated by bulb plants, or remnant shrubland or perennial grassland soils that have been degraded. *Cape Canyon Reservoir; Black Jack Mountain; mouth of Cholla Canyon (in Middle Ranch Canyon); Cottonwood Canyon; White's Landing Canyon.*

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
*Cirsium vulgare**	bull thistle	cirvul	---	---	---	P	Common, Locally Abundant	**GR/NNH**, Disturbed areas, near reservoirs. Widely distributed, including Middle Ranch Canyon, reservoirs, and roadside drainages.
Comarostaphylis diversifolia subsp. *planifolia*	summer holly	comdivpla	---	---	---	S-T	Occasional	**IW/IC**, Central interior canyons and high elevation woodlands. *Upper slopes of Mt. Orizaba and Black Jack Mountain; steep north-facing slope of Orizaba Canyon; west-facing slope of Mt. Orizaba near upper end of Escondido Ranch Canyon; Swain's Canyon; upper Sweetwater Canyon; south side of south fork of Fern Canyon; Boushey Canyon to Isthmus; Cottonwood Canyon; south of Salta Verde Ridge Road; central interior canyons.*
*Cortaderia selloana**	pampas grass	corsel	---	---	---	P	Occasional	**NNH**, Widely distributed in drainages, rocky areas, and disturbed areas. *Widely scattered throughout island, including in Avalon Canyon and Hamilton Cove.*
Cressa truxillensis	alkali weed	cretru	---	---	---	P	Occasional	**SBD/CM**, Sandy or gravelly beaches, or other saline locations along the coast. *Avalon, Shark, Little and Catalina Harbors; Howland's and Parsons Landings.*
Crocanthemum greenei - CIE	island rush-rose	crogre	T	S3	1B.2	S	Scarce	**IC/B**, High elevation, central portion of island or open, dry, rocky or eroded, clayey slopes. *Avalon Canyon; Haypress; east slope of Black Jack Mountain; Big Springs, Gallagher's, Cottonwood, Goat Harbor, Swain's, White's Landing, upper Silver, and Wild Boar Canyons; north of Silver Peak; Boushey Canyon Road.*
Crossosoma californicum - CIE/PVP	Catalina Island crossosoma	crocal	---	S3	1B.2	P	Common	**IC/CSS**, Widely scattered throughout island. *Widely scattered throughout the island, including East Peak; Renton Mine; Lookout Point; Avalon Valley; White's Landing; east slope of Black Jack Mountain; Middle Ranch Canyon; Indian Head Point; Isthmus; Fourth of July Cove.*
Cylindropuntia prolifera	coastal cholla	cylpro	---	---	---	S	Scarce	**MCS/CBS**, Windward Pacific slopes and ridges.

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
								Catalina Harbor to Ben Weston Beach; Ribbon Rock.
*Cynara cardunculus**	artichoke thistle	cyncar	---	---	---	P	Rare	**IC/GR**, Disturbed areas. *Cherry Cove; Fourth of July Cove; north of Silver Peak; White's Landing; Lone Tree Road.*
Cyperus (eragrostis, odoratus)	flatsedge	cypspp	---	---	---	A	Scarce	**VPR/RH**, Reservoirs, drainages. *Cape Canyon Reservoir; upper Coffee Pot Canyon; Fern Canyon; Haypress Reservoir; Middle Ranch Canyon; lower Bulrush Canyon; Thompson Reservoir.*
Deinandra clementina - CIE	island tarplant	deicle	---	S4	CNPS 4.3	S	Occasional	**CBS/IC/CSS/B**, Dry, rocky sea cliffs, and rare rocky inland bluffs. *Lookout Point; Avalon Bay; Gallagher's and White's Landing; Cottonwood Canyon; Thompson Reservoir; Little Harbor; Isthmus.*
Deinandra fasciculata	clustered tarplant	deifas	---	---	---	A	Common	**CSS/GR/B**, Common everywhere, often abundant on dry, open, sunny, rocky, grassy, and eroded clayey slopes. *Widely distributed including Avalon, Swain's, Middle Ranch, and Cottonwood Canyons; Little Harbor; Isthmus; Parsons Landing.*
Delphinium parryi subsp. *maritimum*	maritime larkspur	delparmar	---	---	---	P	Occasional	**IC/CSS/GR**, Grassy, clayey, or rocky slopes of leeward, channel-facing slopes. *Widely scattered throughout the island including Pebbly Beach, Avalon, and Gallagher's Canyons; Haypress; north slope of Black Jack Mountain; above Emerald Bay.*
Dendromecon harfordii	Channel Island tree poppy	denhar	---	---	---	S	Abundant	**IC/CSS**, Dry, eroded slopes and ridges of channel slopes, canyon bottoms, road cuts and mine talus where protected from invasive browsers. *Scattered throughout the island, including Renton Mine; Black Jack Mountain; Airport region; West End from Cherry Valley to Johnson's Landing.*
Dichondra occidentalis	western dichondra	dicocc	---	S3S4	4.2	P	Common	**IC/CSS/GR**, Dry open or grassy, semi-shaded slopes.

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
								Widely distributed, including Avalon; Moonstone Cove; east slope of Black Jack Mountain; near head of Swain's Canyon; Cottonwood Canyon; Salta Verde.
Dissanthelium californicum - CIE	Catalina grass	discal	---	S1	1B.2	A	Scarce	**IC/CSS**, Described in 1848 from a Gambel collection from Santa Catalina Island. Impacted by goats and other invasive browsers. Last seen in 1903 until 2005 rediscovered by Jenny McCune in the Airport Burn, White's Landing, and Camp Cactus areas. *Lower Bulrush; upper Cottonwood and White's Landing Canyons; north of East Summit; Deer Valley.*
Dudleya virens ssp. *hassei* - SCIE	Catalina Island dudleya	dudvirhas	---	S2	CNPS 1B.2	P	Occasional	**CBS/IC**, Sea bluffs and dry, rocky slopes mostly near the channel shore. *Lookout Point; Hamilton Beach; mouth of Gallagher's Canyon; White's Landing; Indian Head Point; Salta Verde Point.*
Dudleya virens subsp. *insularis*	island green dudleya	dudvirins	---	S2	1B.2	P	Common	**CBS/MCS/IC**, Sea bluffs and rocky headlands, mostly on windward, Pacific side; and less frequently on dry, rocky inland slopes. *Isthmus to Silver Canyon, including Indian Head Point, Shark Harbor, and Little Harbor; Airport Road; Avalon; White's Landing; Middle Ranch Canyon.*
Elymus (Leymus) condensatus	giant wild rye	elycon	---	---	---	P	Common	**IC/CSS**, Dry, sunny slopes or edge of woodlands and canyon bottoms. *Widely scattered including Pebbly Beach, Hamilton, Toyon, Middle Ranch, and Cottonwood Canyons; Isthmus; Howland's Landing.*
Encelia californica	California sunflower bush	enccal	---	---	---	S	Abundant	**CSS/MCS**, Sea-bluffs and dry, rocky canyon slopes and ridges. *Widely distributed including East Mountain; Lookout Point; Avalon Valley; Bulrush Canyon; Indian Head Point; Little Harbor; White's and*

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
								Empire Landings; Isthmus, Cherry Valley; Parsons Landing.
Ericameria palmeri	Palmer's goldenbush	eripal	---	---	---	S	Occasional	**B/GR**, Sparsely scattered throughout island. *Sparsely scattered, including Airport Road; lower Cottonwood Canyon; Empire Landing; Silver Peak Road on West End.*
Eriodictyon traskiae ssp. *traskiae* - SCIE	Trask's yerba santa	eritra	---	---	---	S	Occasional	**IC/CSS**, On rocky clay or eroded, clay soils. *Vicinity of Black Jack Mountain and Mt. Orizaba on rocky clay or eroded, clay soil; White's Landing, Swain's, Sweetwater, Buffalo Springs, and Cape Canyons; East End; Toyon Junction area.*
Eriogonum giganteum var. *giganteum* - SCIE	St. Catherine's lace	erigig	---	S2	4.3	S	Common	**CSS/IC**, Channel-facing slopes on dry, rocky slopes, ridges and promontories; less common on leeward side of main drainage divide. *Widely distributed including Renton Mine; Lookout Point; Avalon, Hamilton, Gallaher's, Swain's, and Middle Ranch Canyons; White's Landing; east slope of Black Jack Mountain; Isthmus.*
Eriogonum grande var. *grande*	island buckwheat	erigra	---	S4	4.2	S	Abundant	**CBS/SBD/CSS**, Sea-cliffs, beaches, or component of CSS. *Widely distributed around perimeter of island, including Pebbly Beach; Avalon Bay; mouths of Hamilton and Gallagher's Canyons; White's Landing; Ben Weston Beach; Little Harbor; Isthmus; Parsons Landing.*
Eschscholzia ramosa - CIE	Island poppy	escram	---	S4	4.3	A	Common, Locally Abundant	**SBD/CBS/IC/CSS/GR**, Grassy slopes, dry, rocky sea-bluffs and canyon slopes, and along dry streams. *Widely distributed including Pebbly Beach, Gallagher's, Cape, and Cottonwood Canyons; White's Landing; Little Harbor; Isthmus; Goat Harbor Burn Area.*
Euphorbia misera - CIE	cliff spurge	eupmis	---	S2	2B.2	S	Rare	**MCS/CBS**, Rocky shore, sea cliffs. *Lookout Point to Seal Rocks in quarry area; Little Harbor.*

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
*Foeniculum vulgare**	sweet fennel	foevul	---	---	---	P	Common, Locally Abundant	**GR/NNH**, Disturbed places, roadsides, abandoned agriculture fields, rocky sea bluffs. *Widely distributed including Lookout Point;* Avalon, Gallagher's, Swain's, Parson's Landing, and Middle Ranch Canyons.
Frankenia salina	alkali heath	frasal	---	---	---	P-S	Occasional	**CM/SBD**, Salt marsh, beaches, and bases of shore bluffs along coast; inland alkaline soils. *Pebbly, Ben Weston, and Cottonwood Canyon Beaches; Shark, Little, and Catalina Harbors; Indian Head Point; old quarry above Empire Landing; Parsons Landing.*
Galium catalinense ssp. *catalinense* - SCIE	Catalina Island bedstraw	galcat	---	S2	1B.3	P	Common	**CBS/IC/IW**, Coastal bluffs and less common inland on rocky canyon slopes. *Jewfish Point; Avalon Bay; mouth of Gallaher's Canyon; east slope of Black Jack Mountain; below Eagle's Nest in Middle Ranch Canyon; Cottonwood Canyon; Wild Boar Gully; Shark Harbor; Isthmus; Fourth of July Cove; Parsons Landing.*
Gambelia speciosa (Galvezia speciosa) - CIE	showy island snapdragon	gamspe	---	S3	1B.2	S	Occasional	**CBS/CSS**, Rocky sea bluffs of channel-facing side and less frequently inland canyon walls where protected from invasive browsers. *Scattered along coast, including Moonstone Cove; White's Landing; Isthmus; Empire Landing; Fisherman's Cove; Little Harbor; Swain's Canyon; Iron Bound Bay; Johnson's Landing.*
*Genista linifolia**	Mediterranean broom	genlin	---	---	---	S	Common	**NNS**, Highly invasive upland shrub well established on slopes in the Avalon watershed and is actively controlled by the Conservancy throughout the island where occurs on Conservancy land. *Dominant in Avalon area; widely distributed southeast of the Isthmus, especially Buffalo Springs and Cottonwood Canyons; Empire Landing; Toyon Junction area; Boushey Canyon; near Silver Peak.*

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
Gilia nevinii - CIE	Nevin's gilia	gilnev	---	S4	4.3	A	Scarce	**CBS/MCS/CSS**, Rocky headlands and sea cliffs along the coast; rare inland on canyon slopes. *Avalon Canyon; upper Big Springs Canyon; Black Jack Mountain area; Buffalo Springs Canyon; upper Cape Canyon; Goat Harbor Canyon; Hamilton Canyon; Little Harbor; West End; ridge between Moonstone and White's Coves.*
Heteromeles arbutifolia	toyon	hetarb	---	---	---	S-T	Abundant	**IC/IW/CSS**, Canyons, mountain sides and bluffs. *Widely distributed including East Mountain; Salta Verde; Pebbly Beach; Isthmus; Cherry Valley, Parsons Landing; Avalon, Gallagher's, Swain's, Middle Ranch, Bulrush, and Cottonwood Canyons; Moonstone Cove; slopes of Black Jack Mountain and Mr. Orizaba; above Empire Landing.*
Hordeum intercedens	vernal barley	horint	---	S3S4	3.2	A	Common	**GR/VPR/B**, Dry, open slopes. *Widely distributed including Middle Ranch Canyon below Eagle's Nest; dried pool of Steatite (Soapstone) Quarries above Parsons Landing.*
Isocoma menziesii var. *menziesii*	Menzie's goldenbush	isomen	---	S2	1B.2	S	Abundant	**SBD/GR/CSS**, Common on sandy or pebbly beaches, rock cliffs and talus of sea bluffs; less frequent inland on rocky clay or rocky sandy soils. *Widely distributed including Ben Weston Beach; Cottonwood Canyon Beach; Little Harbor; Wrigley Reservoir; Catalina Harbor; Palisades near Jewfish Point.*
Jepsonia malvifolia - CIE	island jepsonia	jepmal	---	S4	4.2	P	Common	**IC/CSS/GR**, Dry, open slopes and ridges; rhizomatous. *Widely distributed including on ridge on the south side of Avalon Valley above Avalon Terrace in oak woodland; Empire Landing; Lookout Point ridge; bluffs between Pebbly Beach and Avalon Bay; Fisherman's Cove; Cherry Valley; Fourth of July Cove Valley; Blue Cavern Point.*
Lepechinia fragrans	fragrant pitcher sage	lepfra	---	S3	4.2	S	Occasional	**IC**, Dry slopes.

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
								Slopes of Black Jack Mountain; near mouth of Cape Canyon; upper end of Cape Canyon; Boushey, Cape, Cottonwood, Middle Ranch, Swain's, and White's Landing Canyons; Twin Rocks area.
Leptosyne gigantea (Coreopsis gigantea)	giant coreopsis	lepgig	---	---	---	S	Occasional, Locally Common	**CBS/IC/CSS**, Sea bluffs and rocky ridges near coast where protected from invasive herbivores. *Pebbly Beach; mouth of Hamilton Canyon, Moonstone Cove; lower Middle Ranch Canyon; Isthmus area; old quarry above Empire Landing, Bird Rock; Parsons Landing; Airport Road.*
Lycium californicum	California boxthorn	lyccal	---	S4	4.2	S	Abundant	**MCS/CBS**, Sea bluffs and headlands and dry, rocky slopes, banks, and ridges. *Salta Verde; Ben Weston beach; below Eagle's Nest; Cottonwood Canyon and Beach; Indian Head Point; Little Harbor; Catalina Harbor; Isthmus Cove.*
Lyonothamnus floribundus ssp. *floribundus* - SCIE	Catalina Island ironwood	lyoflo	---	S2	1B.2	T	Occasional	**IW**, About 110 groves with 50 to 100 clonal tree stems each in canyons and on mountain slopes. *Scattered throughout West End, including north side of West Peak, west of Lion's Head, and Johnson's Canyon; Gallagher's, Toyon (Banning's), Swain's, and lower Bulrush Canyons; east slope of Black Jack Mountain; Ironwood Gully at the Isthmus.*
Malacothamnus fasciculatus var. *catalinensis* - SCIE	Catalina Island bushmallow	malfascat	---	S2	4.2	S	Common	**CSS/IC**, Dry, rocky slopes, road cuts, and dry creek beds. *Widely distributed including Avalon, Gallagher's, Swain's, Middle Ranch, and Bulrush Canyons; White's Landing; Little Harbor; Empire Landing; Isthmus; Parsons Landing.*
Malosma laurina	laurel sumac	mallau	---	---	---	S-T	Abundant	**CSS/IC**, Canyons and rocky or clayey, slopes. *Widely distributed including Pebbly Beach, Avalon, and Middle Ranch Canyons; Black Jack Mountain; Parsons Landing.*

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
Muhlenbergia microsperma	littleseed muhly	muhmic	---	---	---	A	Common	**MCS/CSS/IC**, Dry, rocky slopes and sandy, dry stream beds. *Widely distributed including Hamilton, Middle Ranch, and Cottonwood Canyons; Salta Verde; bluff at White's Landing; Cherry Valley.*
Opuntia littoralis	coastal prickly pear	opulit	---	---	---	S	Abundant	**CSS/CBS/MCS**, Dry, rocky slopes and ridges. *Widely distributed across the island and presumably more frequent than would have occurred historically due to resistance to invasive herbivores introduced in the 1800s.*
*Pennisetum setaceum**	fountaingrass	penset	---	---	---	P	Occasional	**GR/B**, Roadside and disturbed slopes *Avalon Canyon, Hamilton Cove, and Pebbly Beach.*
Peritoma arborea	bladderpod	perarb	---	---	---	S	Common	**CBS/MCS/CSS**, Dry, rocky sea bluffs; less common inland on dry, sunny, clayey, or rocky canyon slopes. *Widely scattered including Palisades near Jewfish Point; Lookout Point; Avalon Bay; White's Landing; below Eagle's Nest; Ben Weston Beach; Cottonwood Canyon above dam; above Empire Landing; Isthmus; above Emerald Bay; Parsons Landing.*
*Phalaris aquatica**	Harding grass	phaaqu	---	---	---	P	Common, Locally Abundant	**GR**, Introduced to island for forage in Middle Ranch hayfields and cleared portions of Bulrush Canyon (Knapp 2005); rhizomatous. *Widely distributed including Bulrush, Middle Ranch, and Cottonwood Canyons; Haypress; upper end Gallagher's Canyon; Salta Verde; upper end of Cape Canyon; Hen Cove north of White's Landing.*
Piperia cooperi	orchid	pipspp	---	---	---	P	Occasional	**IC/CSS**, Dry, rocky clay slopes, talus, or disturbed soils. *Avalon, Hamilton, Cottonwood, White's Landing, and Middle Ranch Canyons; sea bluff at Hamilton Beach; Road to Airport from Rancho Escondido; above Fourth of July Cove; east slope of Black Jack*

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
								Mountain; West End Road; Isthmus area; Empire Landing area.
Plagiobothrys collinus	San Diego popcornflower	placol	---	---	---	A	Rare	**GR/Bare**, Hard packed clay soils on island's summit. *Viewpoint near Wrigley Reservoir; Toyon picnic area; slopes of Black Jack Mountain; right fork of Cottonwood Canyon; Rancho Escondido; Goat Harbor Burn area.*
Prunus ilicifolia ssp. *lyonii* - CIE	Catalina cherry	pruililyo	---	---	---	T	Abundant	**IW/IC**, Groves in canyons on channel-facing slope. *Widely distributed including Renton Mine, Avalon, Gallagher's, Swain's, Cape, and Bulrush Canyons; Moonstone Cove; slopes of Black Jack Mountain and Mt. Orizaba; Cherry Valley; Parsons Landing.*
Quercus pacifica - CIE	island scrub oak	quepac	---	S4	4.2	T	Abundant	**ISOC/IC/IW**, Most abundant small tree or large shrub on wooded slopes and ridges across the island; thrives in heavy clay, rocky clay, and coarse loam island soils. *Widely distributed including Pebbly Beach, Avalon, Gallagher's, Swain's, Middle Ranch, Bulrush, Silver, and Cottonwood Canyons; slopes of Black Jack Mountain and Mt. Orizaba peaks; Salta Verde; Isthmus; Cherry Valley; Parsons Landing.*
Quercus tomentella - CIE	island live oak	quetom	---	S3S4	4.2	T	Scarce	**IW**, Groves in several deep and moist canyons on Southeast half of island. *Pebbly Beach, Cherry, Gallagher's, Cape, Howland's Landing, Swain's, Silver, Sweetwater, and Fern Canyons; north slopes of Mt. Orizaba.*
Quercus x macdonaldii - CIE	MacDonald oak	quemac	---	---	---	T	Occasional	**IW/IC**, Hybrid of Valley Oak (*Quercus lobata*) and island scrub oak (*Q. pacifica*) (Nixon 2002). *Widely scattered including Pebbly Beach, Haypress, Middle Ranch, Bulrush, and Cottonwood Canyons; slopes of Black Jack Mountain; southwest of Empire Landing; Isthmus.*
Rhamnus pirifolia - CIE	island redberry	rhapir	---	S4	4.2	S-T	Abundant	**IC/IW**, Rocky canyon slopes and ridges, mostly on channel-facing slope.

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
								Widely distributed including Pebbly Beach, Avalon, Gallagher's, Swain's, Cape, Middle Ranch, Bulrush, and Grand Canyons; Haypress; above Empire Landing; Fourth of July Cove; Cherry Valley; Howland's Landing.
Rhus integrifolia	lemonade berry	rhuint	---	---	---	S	Abundant	**IC/CSS/MCS**, Dry, open to densely wooded slopes, varying from a small shrub on sea bluffs to small trees. *Widely distributed including Seal Rocks, Pebbly Beach, Avalon, Gallagher's, Swain's, and Cottonwood Canyons; Black Jack Mountain and Mt. Orizaba; Ben Weston Beach; Empire Landing; Isthmus; Silver Peak.*
Ribes viburnifolium - CIE	Catalina Island currant	ribvib	---	S2	1B.2	S	Common	**IC/IW**, Shaded slopes and banks, mostly on channel-facing side. *Widely distributed including near East Mountain, Pebbly Beach, Avalon, Gallagher's, Banning's, and Bulrush Canyons; Haypress; east slope of Black Jack Mountain; Fourth of July Cove to Cherry Valley; Johnson's Valley; north of West Peak.*
Salvia apiana	white sage	salapi	---	---	---	S	Common	**CSS/GR**, Dry rock slopes and ridges on southeast half of the island. *Widely distributed on southeast half of the island, including Pebbly Beach, Avalon, Cape, Middle Ranch, and Bulrush Canyons; Stagecoach Road near Wrigley Reservoir; Renton Mine ridge.*
Salvia mellifera	black sage	salmel	---	---	---	S	Abundant	**CSS/IC**, Dry, exposed slopes in clay or rocky clay soils; common component of CSS and understory of IC. *Widely distributed including East Mountain, Pebbly Beach, Avalon, Swain's, Cape, Middle Ranch, and Bulrush Canyons; slopes of Black Jack Mountain; above Empire Landing; Isthmus.*
Sambucus mexicana	blue elderberry	sammex	---	---	---	S-T	Common	**IW/SRW/IC**, Central interior canyons and scattered on channel side.

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
								Pebbly Beach, Avalon, Gallagher's, Swain's, Cape, Middle Ranch, and Bulrush Canyons; old quarry above Empire Landing; Howland's Landing.
Scrophularia villosa - CIE	Catalina Island figwort	scrvil	---	S3	1B.2	P	Common	**IC**. On wooded, brushy, or open canyon slopes and bottoms, mostly on channel-facing slopes. *Widely scattered on channel side from Parsons Landing to Goat Harbor; Avalon area; Haypress; lower Bulrush Canyon; Cape and Cottonwood Canyons; Isthmus area.*
Sibara filifolia - CIE	island rockcress	sibfil	E	S2	1B.1	A	Rare	**CSS**, Sea bluffs. *Cape Canyon; China Point area; Wild Boar Gully.*
*Silybum marianum**	milk thistle	silmar	---	---	---	A	Scarce	**IC/GR**, Scattered on southeast half of the island. *Gallagher's Canyon; above reservoir in lower Cottonwood Canyon; north slopes of Silver Peak; roadside between Cherry Valley and Howland's Landing.*
Solanum wallacei - CIE	Wallace's nightshade	solwal	---	S2	1B.1	S	Occasional	**IC/CSS**, Southeast half of Island on rocky banks and slopes, in washes, and along dry stream beds. *Goat Harbor Canyon to Renton Mine Canyon; central interior canyons, including Coffee Pot, Cottonwood, and Boushey Canyons.*
Stipa cernua	nodding needlegrass	sticer	---	---	---	P	Rare	**IC/CSS/GR**, Dry, eroded, clayey, or grassy slopes *Haypress; hillside along Airport Road before turn-off to Middle Ranch; near viewpoint east of Wrigley Reservoir.*
Stipa (lepida, pulchra)	needlegrass	stipa	---	---	---	P	Common	**IC/CSS/GR/B**, Dry, rocky slopes and ridges. *Widely distributed throughout the island.*
*Tamarix ramosissima**	saltcedar	tamram	---	---	---	P	Occasional	**NNW/BSB/VPR**, Invasive in wetland and riparian areas. *Sparsely scattered throughout island, especially the West End.*
Trifolium palmeri - CIE	southern island clover	tripal	---	S4	4.2	A	Scarce	**CBS/CSS/GR**, Sunny hillsides in a thin layer of red soil over rock. Dry, open, clayey slopes, grassy slopes.

Scientific Name	Common Name	Code	Fed.	State	CNPS	Life-form	Abundance	Typical Habitat *Typical Locations on Island*
								Avalon; upper end of Bulrush Canyon; Little Harbor; Middle Ranch Canyon; slopes above Gallagher's Canyon; west of Isthmus Harbor; slope above Cabrillo Harbor.
Typha domingensis	southern cattail	typdom	---	---	---	P	Occasional, Locally Common	**CM/RH/VPR**, Shallow water or wet mud of streams and ponds. *Scattered throughout including Lower Middle Ranch and Cottonwood Canyons; lower Buffalo Springs Reservoir; Steatite (Soapstone)* Quarries above Parsons Landing.
Xylococcus bicolor	Mission manzanita	xylbic	---	---	---	S	Occasional	**IC/IW**, Slopes on Catalina Schist. *Channel side of West End, including Fourth of July Cove, Cherry Valley, Howland's Landing, and ridge above Johnson's Landing; lower Middle Ranch Canyon; Cottonwood Canyon; lower Bulrush Canyon; Big Springs Canyon; East of Isthmus, north-facing slope of Wild Boar Gully north of Black Ridge.*

**Invasive Plant; SCIE = Santa Catalina Island Endemic; CIE = Channel Island Endemic; PVP = Palos Verdes Peninsula Endemic*
Lifeform abbreviations: A = Annual; P = Perennial Herbaceous; S = Woody Perennial Shrub; T = Tree
The general abundance of the plant species on Catalina Island are described as follows:

- *Rare: Species have only been found in a few locations*
- *Scarce: Species only found in several locations*
- *Occasional: Species found infrequently but more often than uncommon*
- *Common: Species found throughout but not abundant*
- *Abundant: Species found throughout, and abundant within the growth habitat of the species*

The Typical Habitat and Typical Locations on Island data is from compiled from A Flora of Santa Catalina Island (Thorne 1967), CHH2 Herbarium Records, and the draft Catalina Flora provided by the Conservancy. Typical Habitat Type is Classified by Vegetation Communities Identified by Knapp (2005) in the 2000 Vegetation Map and presented below in order of decreasing prevalence on Catalina Island:

- *Coastal Sage Scrub (CSS)*
- *Island Chaparral (IC)*
- *Island Scrub Oak Chaparral (ISOC)*
- *Grassland (GR)*
- *Bare (B)*
- *Developed (D)*

- *Nonnative Herbaceous (NNH)*
- *Island Woodland (IW)*
- *Southern Riparian Woodland (SRW)*
- *Nonnative Scrub (NNS)*
- *Southern Beach and Dune (SBD)*
- *Nonnative Woodland (NNW)*
- *Coastal Bluff Scrub (CBS)*
- *Bare Streambed (BSB)*
- *Vernal Ponds and Reservoirs (VPR)*
- *Riparian Herbaceous (RH)*
- *Coastal Marsh (CM)*
- *Maritime Cactus Scrub (MCS)*
- *Mulefat Scrub (MFS)*

The table uses the following abbreviations for special status designations:

C ***Candidate** for Listing (State or Federal governments).*

E ***Endangered** (listed by State or Federal governments). "Take" of the species or disturbance of occupied habitat are prohibited unless specifically authorized.*

FP ***Fully Protected** by the State of California. These species may not be taken or possessed at any time, although take may be authorized for necessary scientific research.*

T ***Threatened** (listed by State or Federal governments). "Take" of the species or disturbance of occupied habitat are prohibited unless specifically authorized.*

PT ***Proposed Threatened**. Species recently proposed to be listed as threatened by State or Federal governments.*

SSC ***Species of Special Concern**. The California Dept. of Fish and Wildlife has designated certain vertebrate species as Species of Special Concern because declining population levels, limited ranges, and/or continuing threats have made them vulnerable to extinction. The goal of designating species as Species of Special Concern is to halt or reverse their decline by calling attention to their plight and addressing the issues of concern early enough to secure their long-term viability.*

California Native Plant Society (CNPS). *The table includes plant taxa assigned the following ranks by CNPS:*

- ***1A**, referring to taxa CNPS presumes to be extirpated in California and either rare or extinct elsewhere.*
- ***1B.1**, referring to taxa CNPS considers to be rare, threatened, or endangered in California and elsewhere; seriously threatened in California (over 80% of occurrences threatened / high degree and immediacy of threat).*
- ***1B.2**, referring to taxa CNPS considers to be rare, threatened, or endangered in California and elsewhere; moderately threatened in California (20-80% of occurrences threatened / moderate degree and immediacy of threat).*
- ***1B.3**, referring to taxa CNPS considers to be rare, threatened, or endangered in California and elsewhere; not very threatened in California (less than 20% of occurrences threatened / moderate degree and immediacy of threat).*
- ***2B.2**, referring to taxa CNPS considers to be rare, threatened, or endangered in California, but more common elsewhere; moderately threatened in California (20-80% occurrences threatened / moderate degree and immediacy of threat).*

- ***3**, referring to taxa for which CNPS lacks the necessary information to assign them to one of the other ranks or to reject them; taxonomy is typically uncertain.*

- ***4.1**, referring to taxa of limited distribution or infrequent throughout a broader area in California, whose status should be monitored regularly; moderately threatened in California (>80% occurrences threatened / moderate degree and immediacy of threat).*

- ***4.2**, referring to taxa of limited distribution or infrequent throughout a broader area in California, whose status should be monitored regularly; moderately threatened in California (20-80% occurrences threatened / moderate degree and immediacy of threat).*

- ***4.3**, referring to taxa of limited distribution or infrequent throughout a broader area in California, whose status should be monitored regularly; not very threatened in California (less than 20% of occurrences threatened / low degree and immediacy of threat or no current threats known).*

***NatureServe Element Rankings.** In some cases, species are recognized as ecologically sensitive by the California Natural Diversity Database (CNDDB), which uses a ranking methodology maintained by NatureServe. Species are given a State rank (S-rank) that applies to the taxon's conservation status in California. "Q" denotes questionable taxonomy. Taxa with rankings of S1, S2, or S3 may be considered "sensitive" at the state level, and potentially worthy of special consideration in resource planning. Taxa with higher rankings (S4, S5) are considered "apparently secure" or "secure" at the state level and therefore are not treated as "sensitive" for purposes of this report. NatureServe Element Rankings are identified only for taxa that have no other federal or state special status. NatureServe Ranks:*

- ***S1, Critically Imperiled,** referring to taxa critically imperiled in the state because of extreme rarity (often 5 or fewer populations) or because of factor(s) such as very steep declines making it especially vulnerable to extirpation from the state.*

- ***S2, Imperiled,** referring to taxa imperiled in the state because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the state.*

- ***S3, Vulnerable,** referring to taxa vulnerable in the state due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation from the state.*

- ***SX,** referring to taxa presumed to be extirpated from the state.*

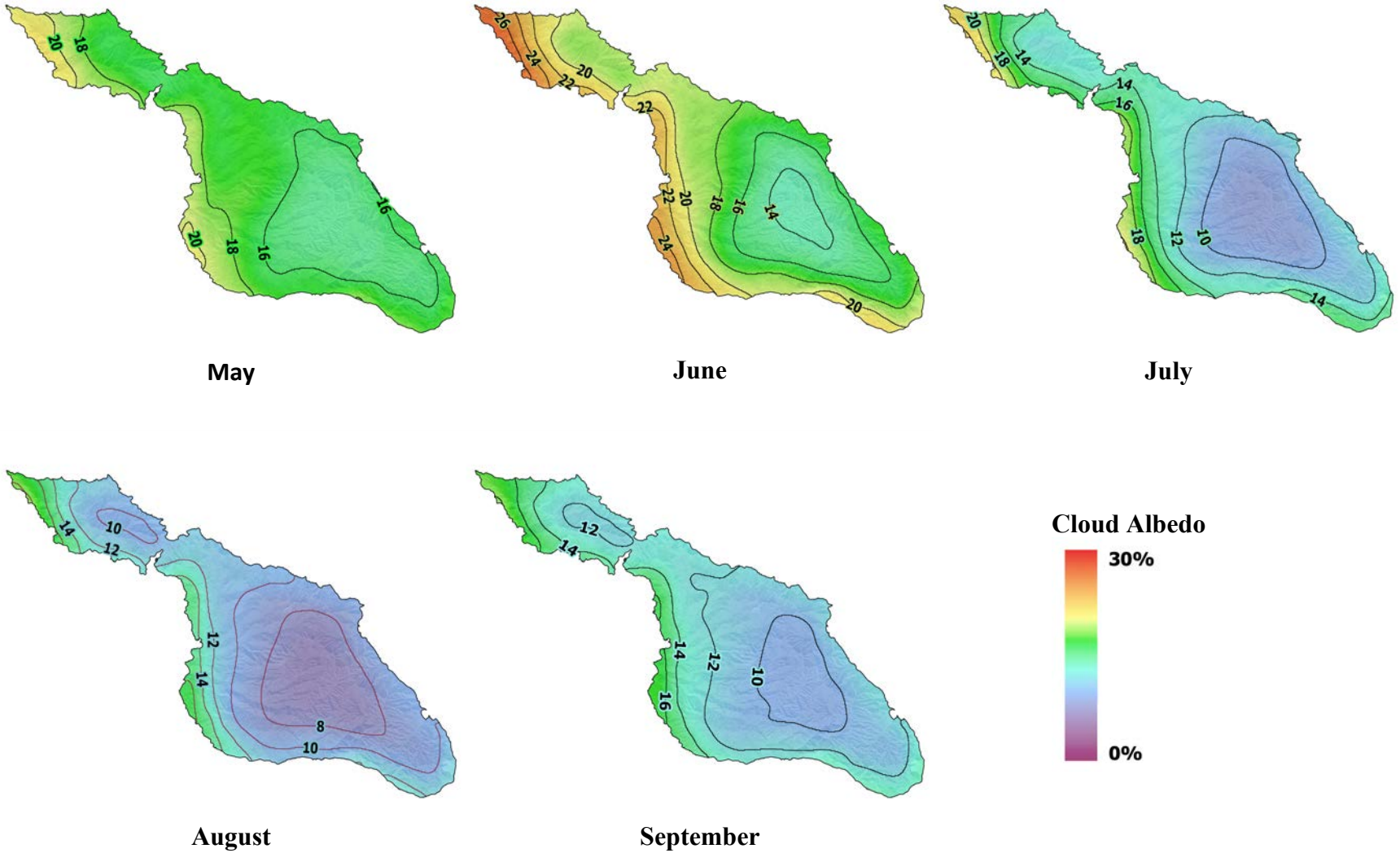

Figure 6-1 Monthly Mean Cloud Albedo (Proxy for Cloudiness) for 1996 to 2018.

Monthly average layers were provided by UCSD Scripps Institution of Oceanography (Clemesha et al. 2021). These 1-km resolution layers were derived from a time series of Geostationary Operational Environmental Satellites (GOES) imagery spanning from 1996 to 2018.

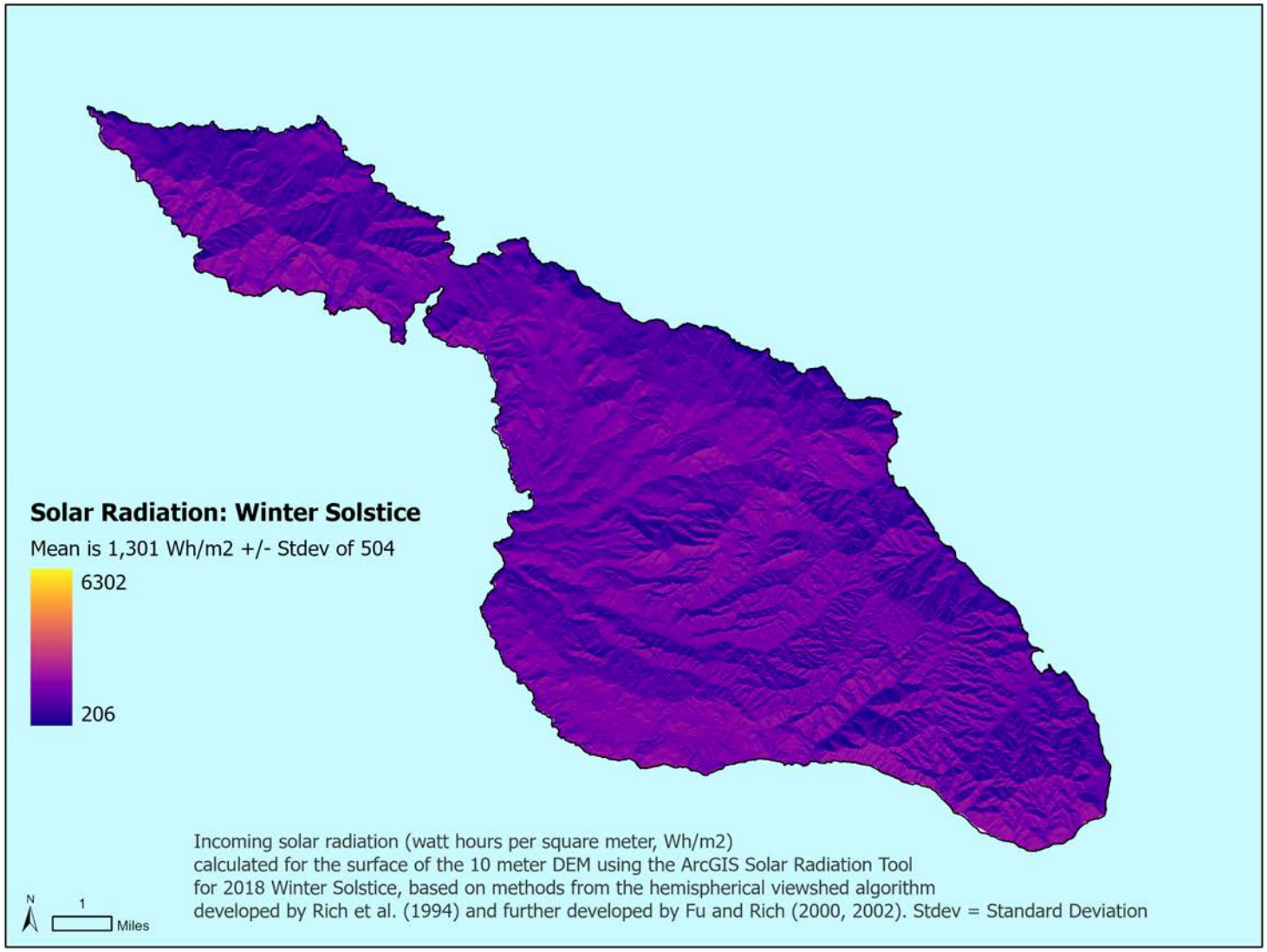

Figure 6-2 Solar Radiation Received During Winter Solstice.

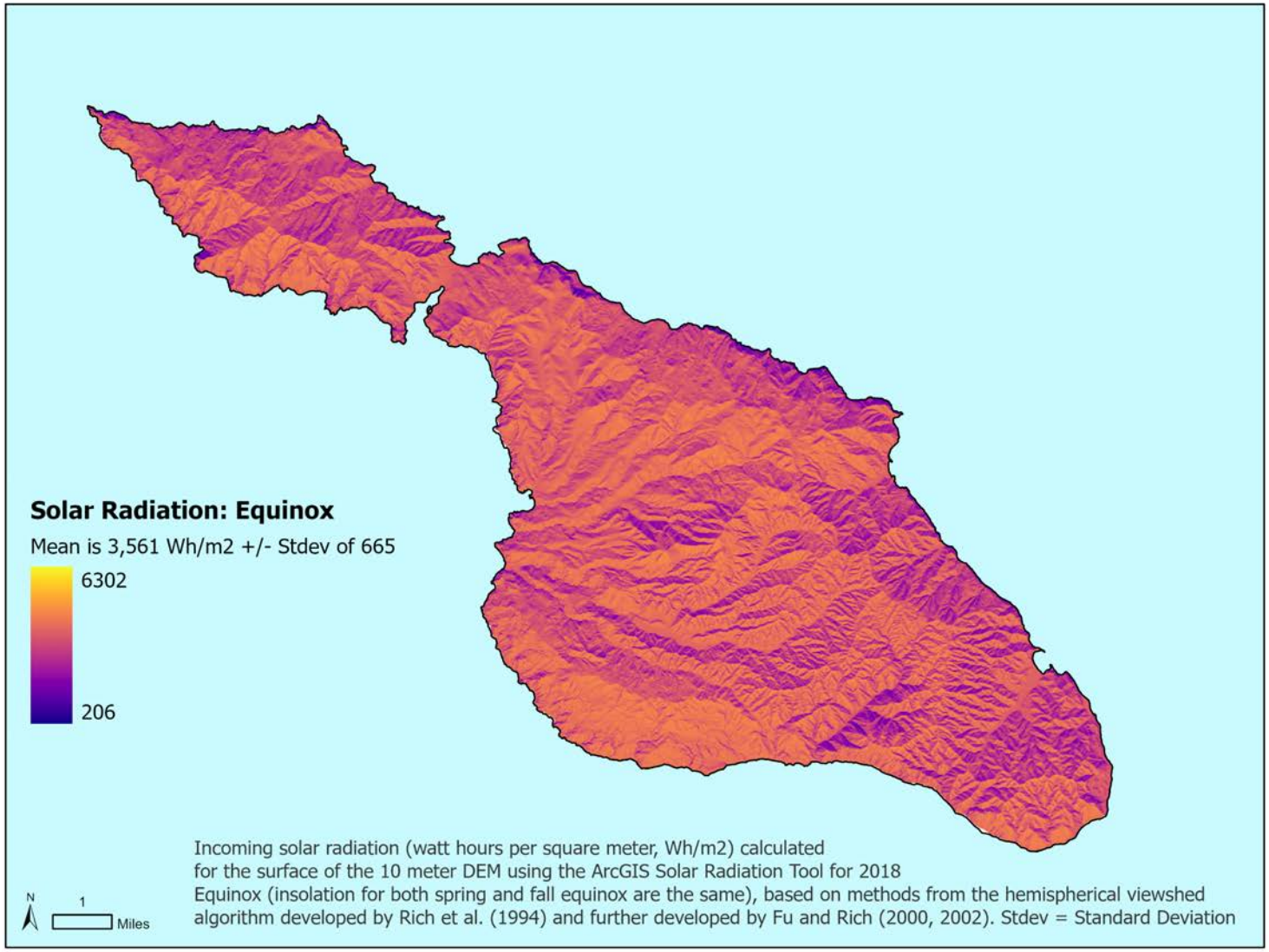

Figure 6-3 Solar Radiation Received During Equinox.

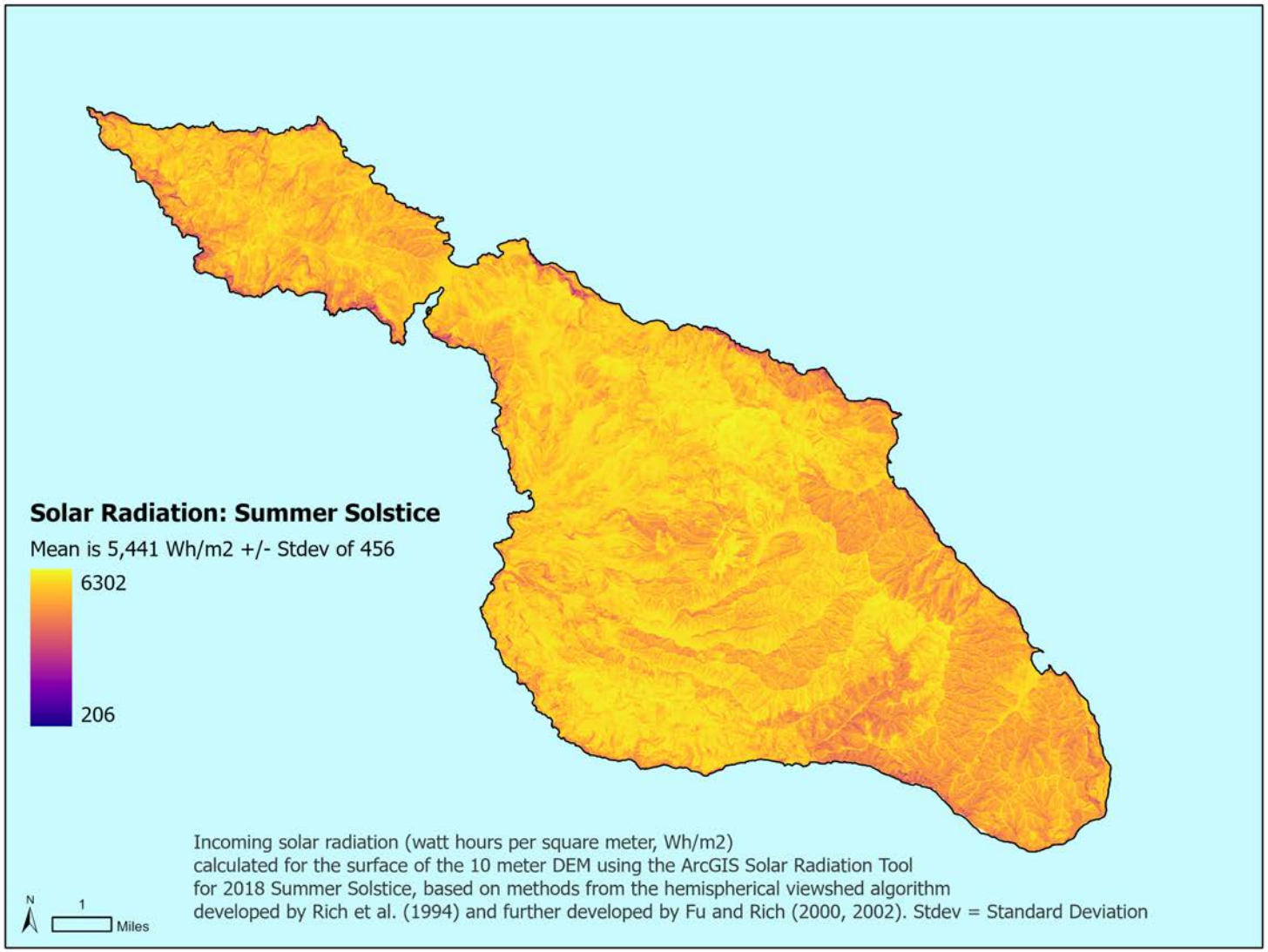

Figure 6-4 Solar Radiation Received During Summer Solstice.

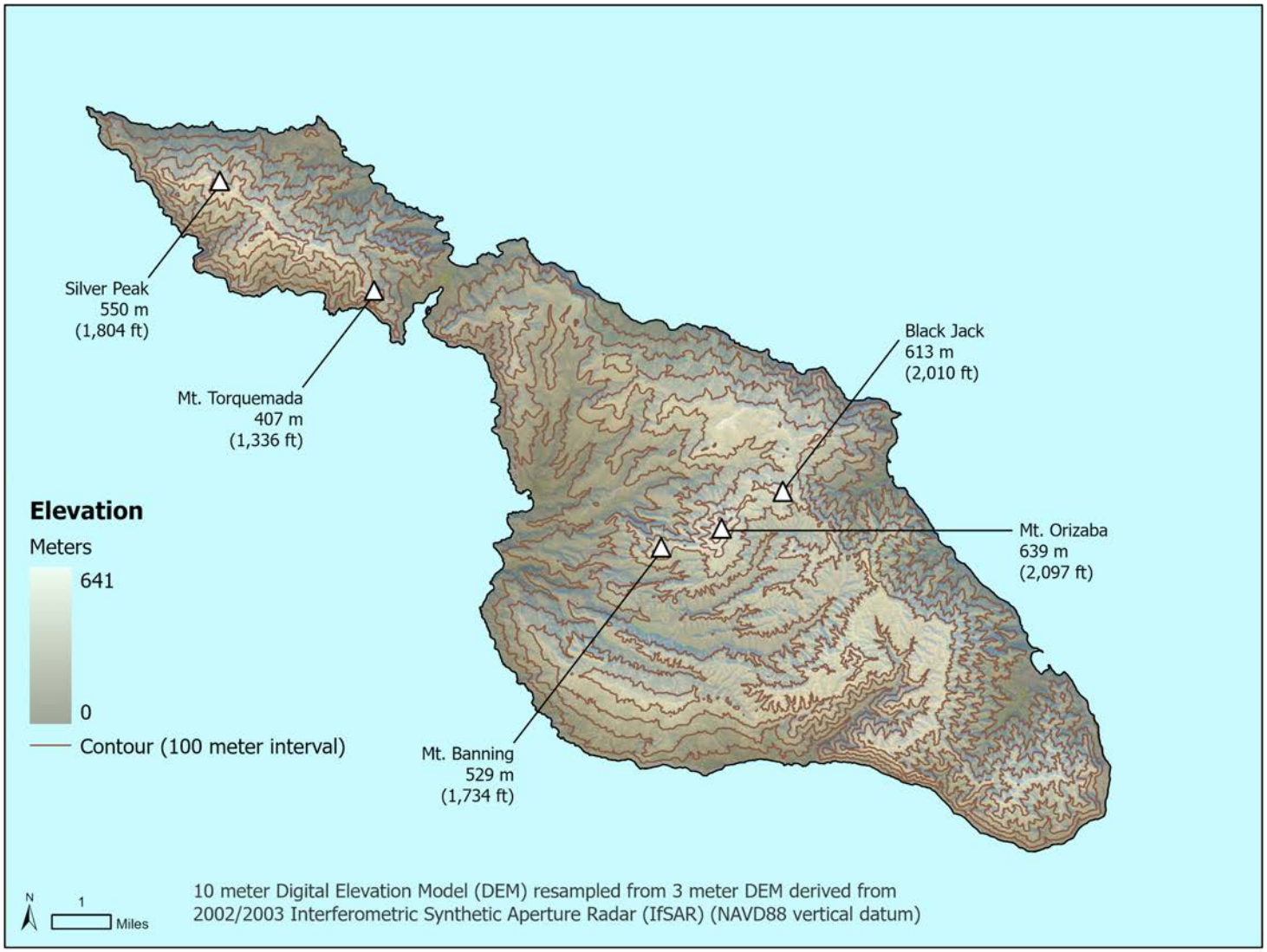

Figure 6-5 Elevation.

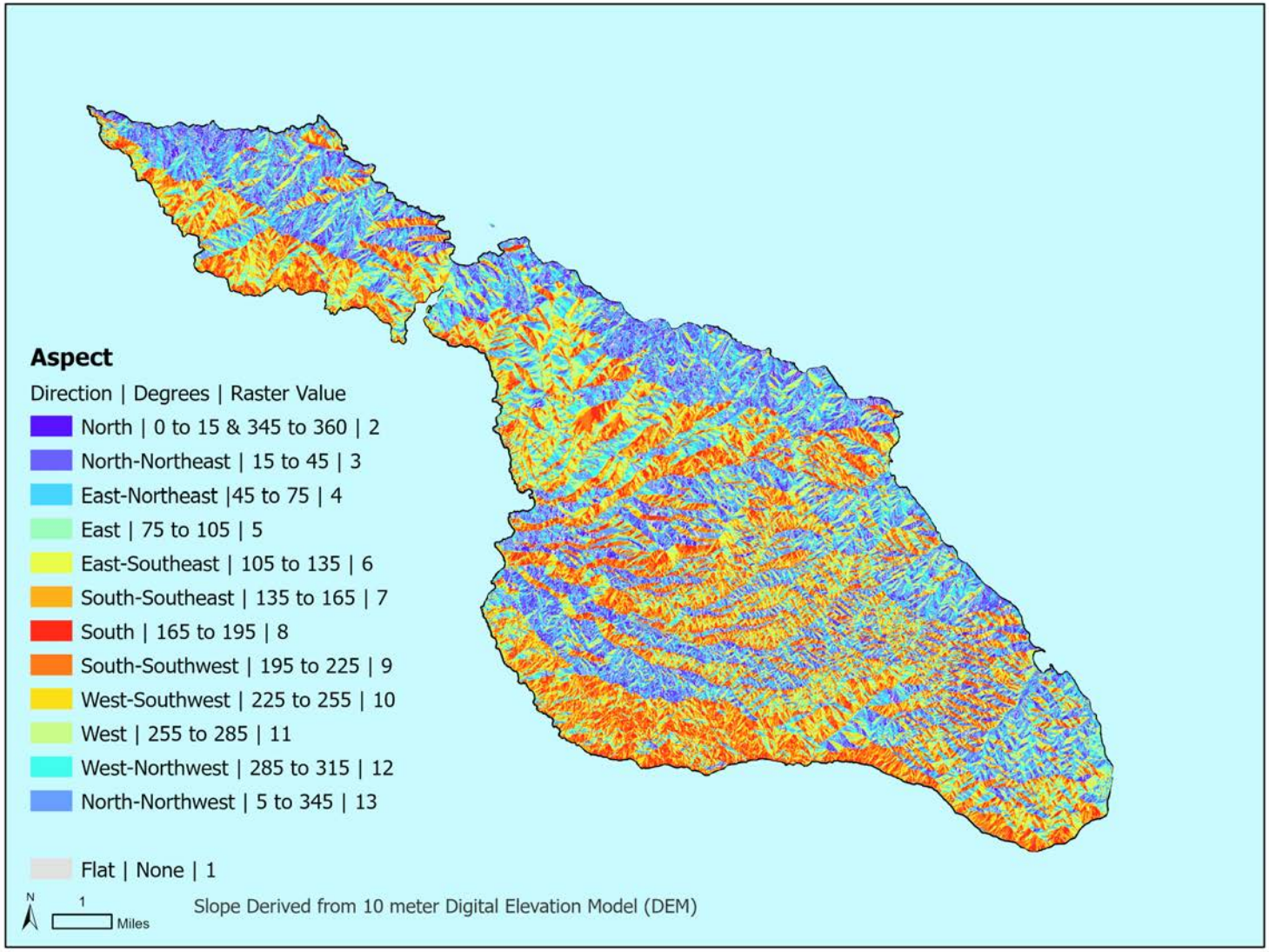

Figure 6-6 Aspect of Slope.

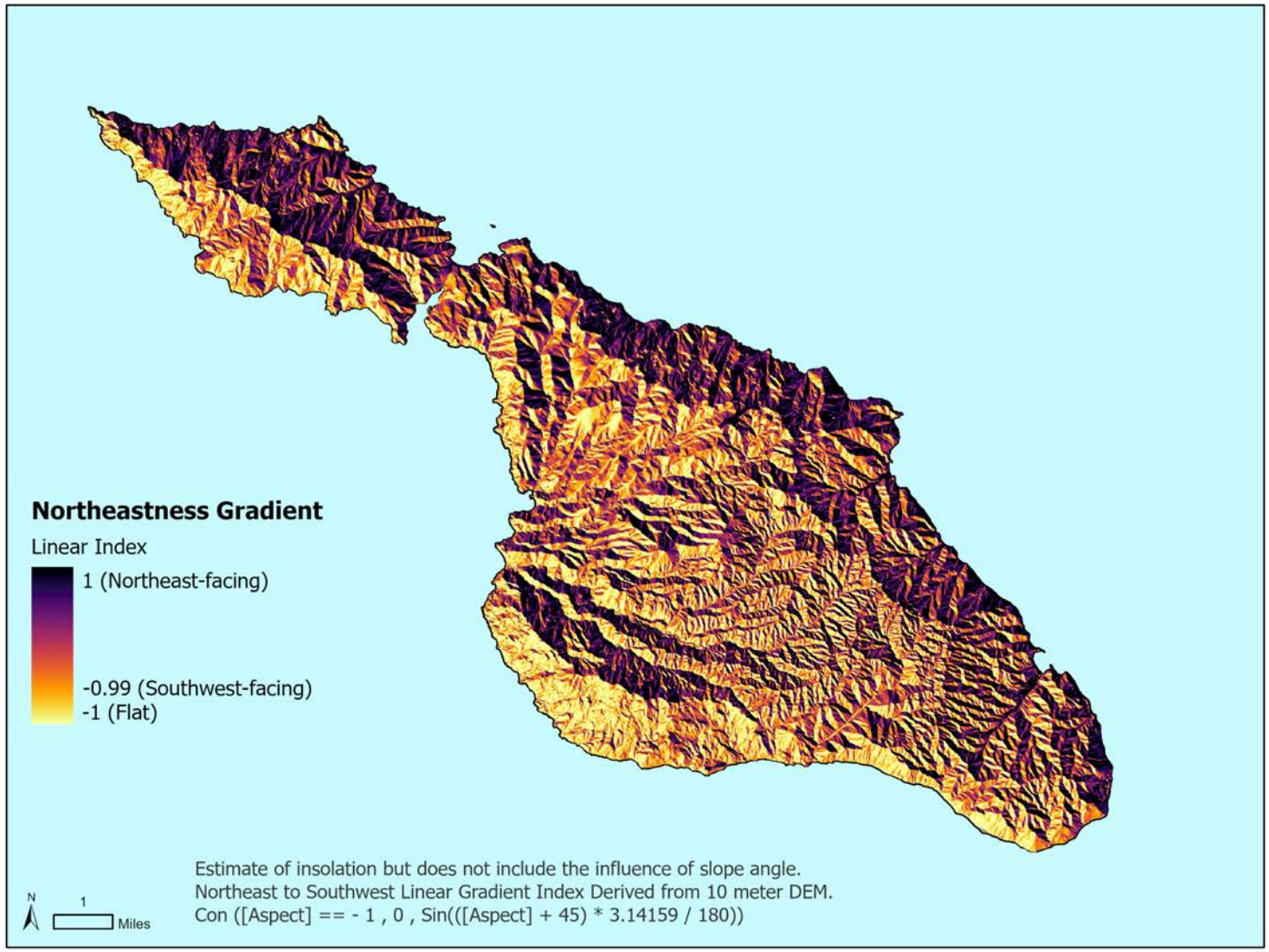

Figure 6-7 Northeastness Index.

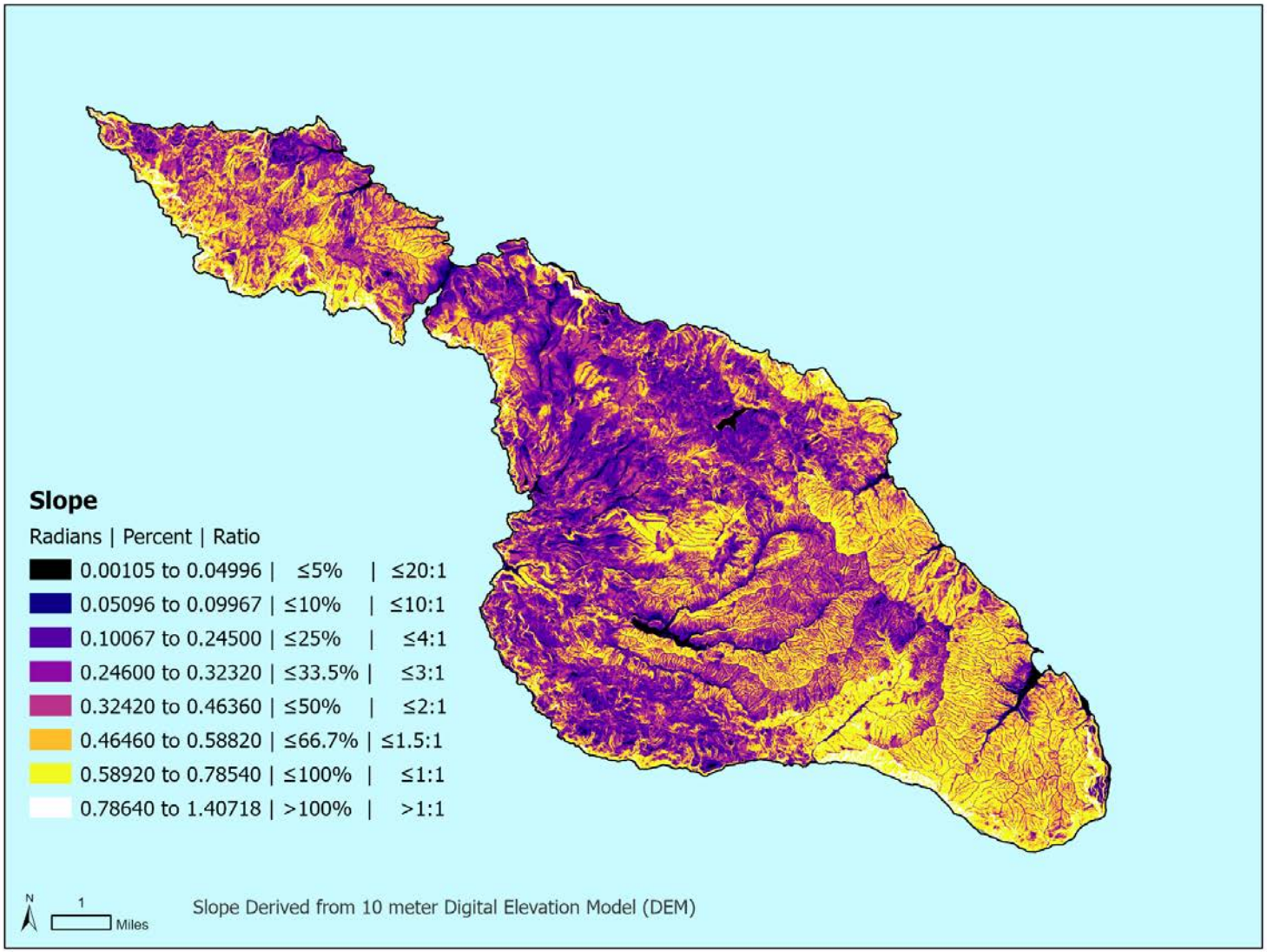

Figure 6-8 Slope Steepness.

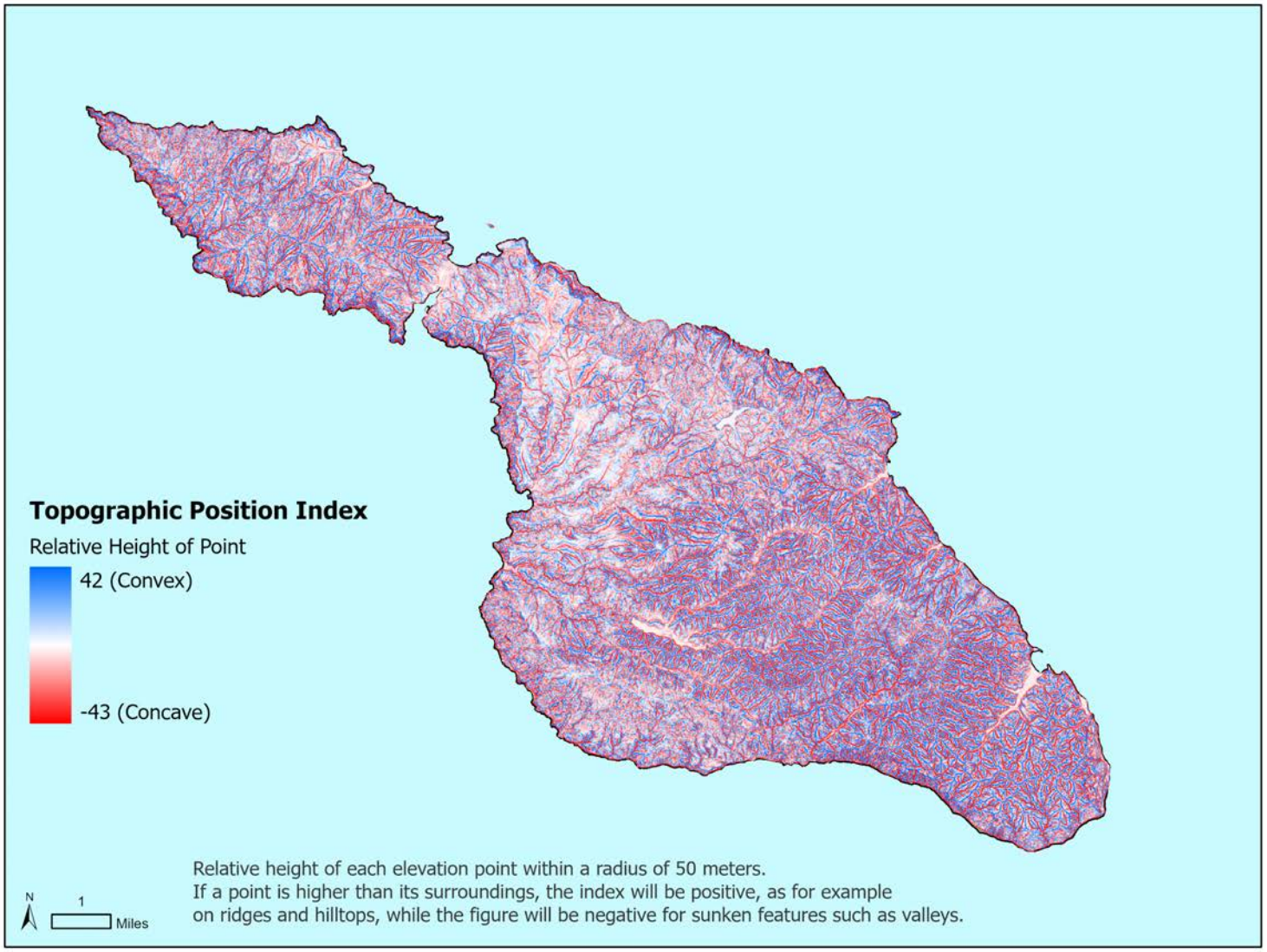

Figure 6-9 Topographic Position Index.

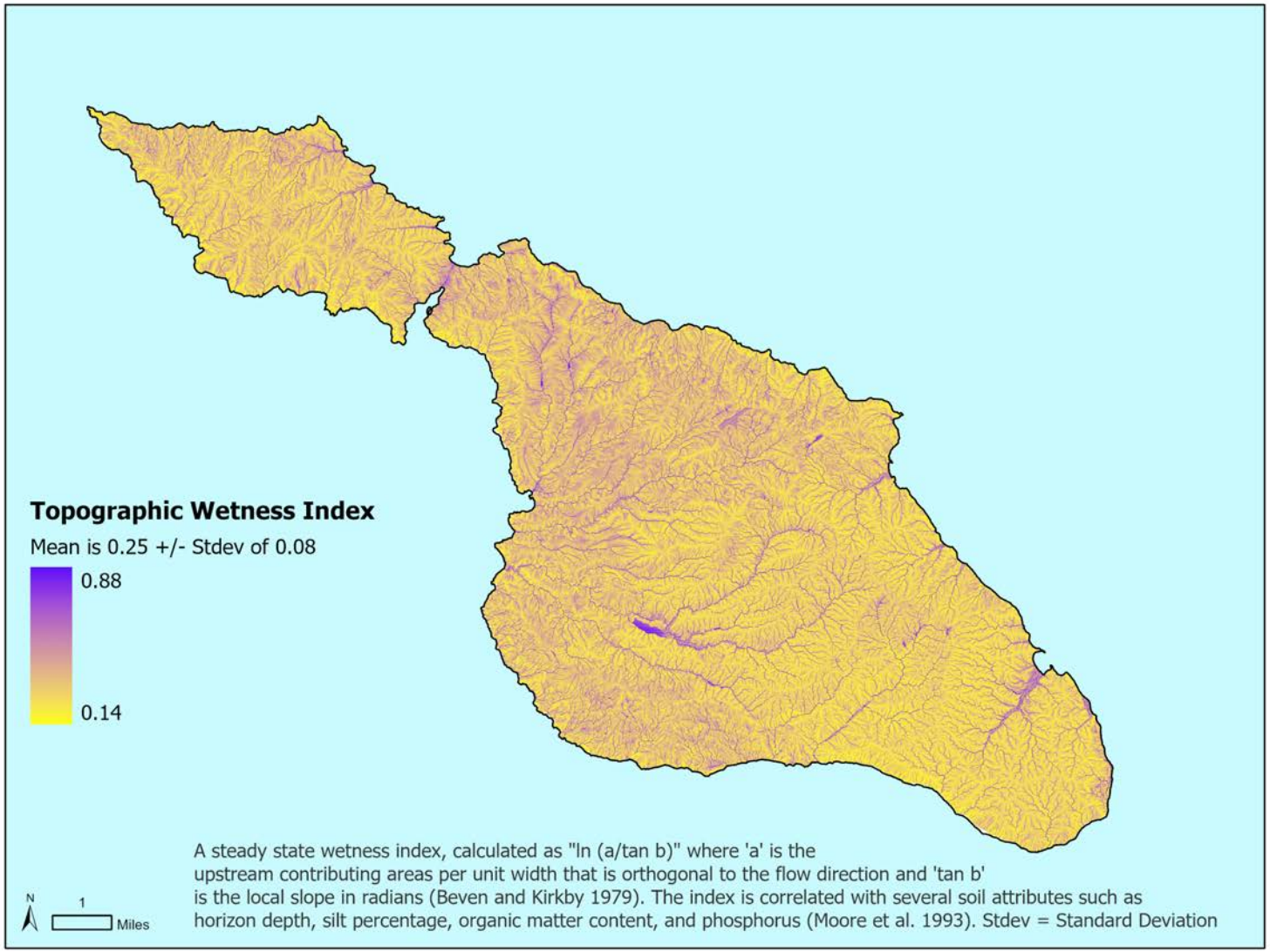

Figure 6-10 Topographic Wetness Index.

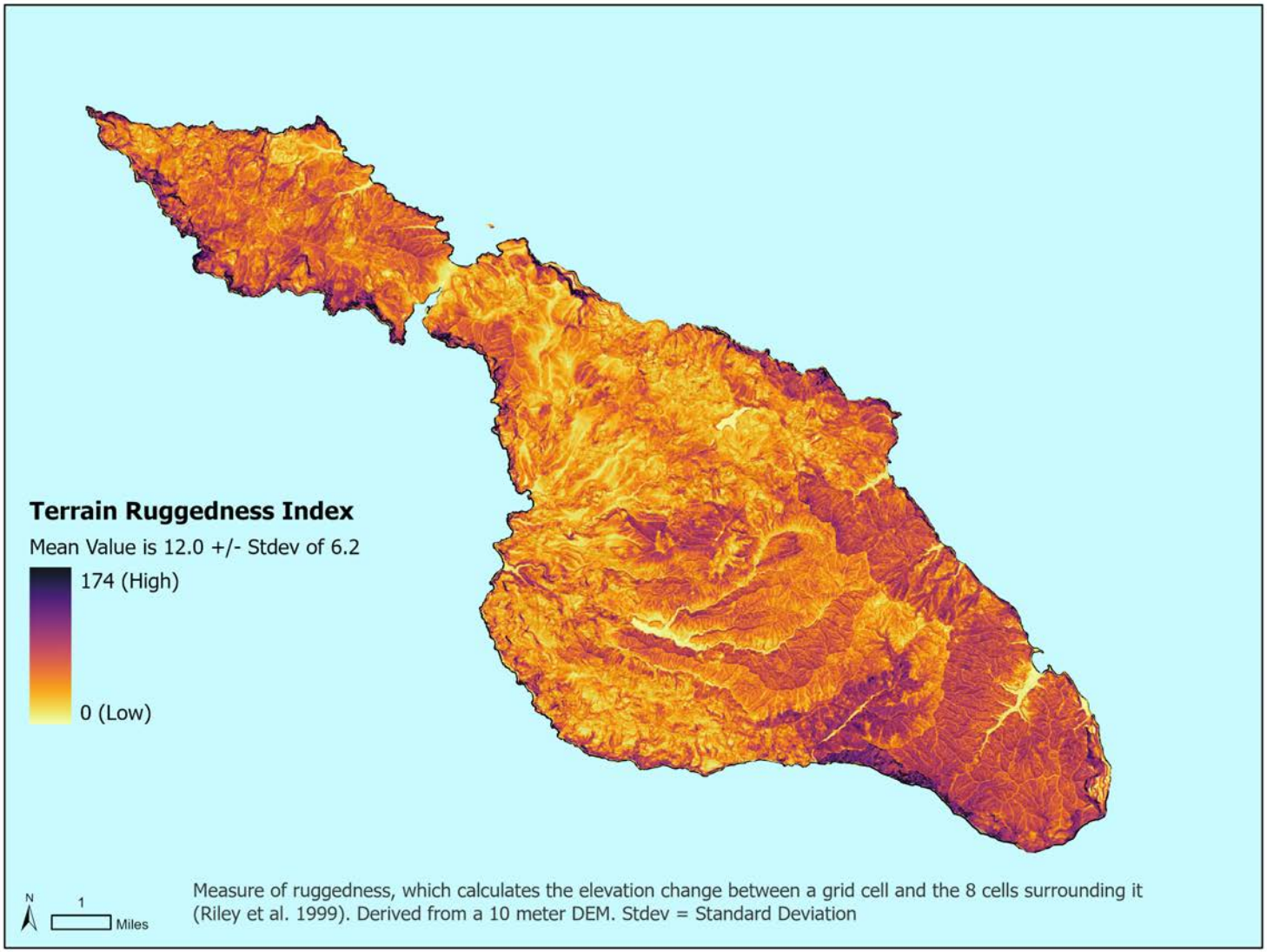

Figure 6-11 Terrain Ruggedness Index.

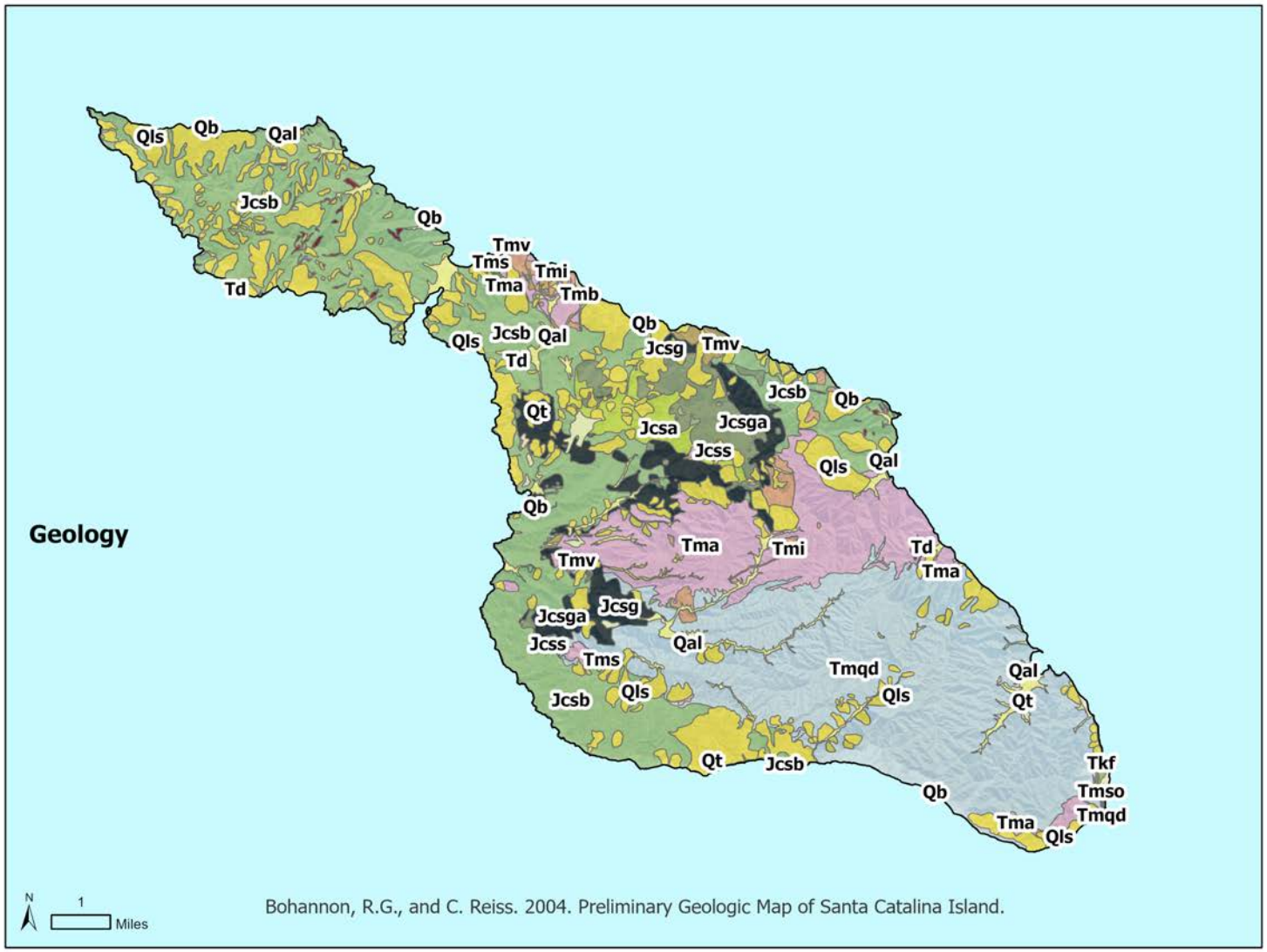

Figure 6-12 Preliminary Geology Map for Catalina Island.

Legend on Next Page.

Map Code | Geological Time Period | Rock Types

Qb | QUARTERNARY | Beach sand deposits
Qal | QUARTERNARY | Alluvium
Qls | QUARTERNARY | Landslide deposits
Qt | QUARTERNARY | Wave-cut bench deposits, marine
Td | MIOCENE | Dikes and small igneous intrusions, fine grained, basalt to rhyolite in composition
Tms | MIOCENE | Sediments, marine, fossiliferous
Tmv | MIOCENE | Volcaniclastic rocks
Tmb | MIOCENE | Breccia, dacite composition, forms cap to intrusive body at Big Fisherman's Cove
Tmi | MIOCENE | Intrusive rocks, fine grained, dacite composition, form dikes, plugs and stocks
Tma | MIOCENE | Mostly andesite, flows and breccia, includes rhyolite near Mount Banning
Tmqd | MIOCENE | Catalina Island pluton, quartz diorite in composition, includes dike swarm in interior of body
Tmso | MIOCENE | San Onofre Breccia
TKf | LATE CRETACEOUS TO OLIGOCENE | Fore-arc sedimentary rocks, marine
Jcss | JURASSIC | Catalina Schist, serpentinite
Jcsg | JURASSIC | Catalina Schist, greenschist facies, includes biotite and garnet schist
Jcsga | JURASSIC | Catalina Schist, garnet-amphibolite blocks
Jcsb | JURASSIC | Catalina Schist, blueschist facies, includes lawsonite, aragonite, and jadeitic pyroxene schist
Jcsa | JURASSIC | Catalina Schist, amphibolite facies, includes biotite and garnet schist

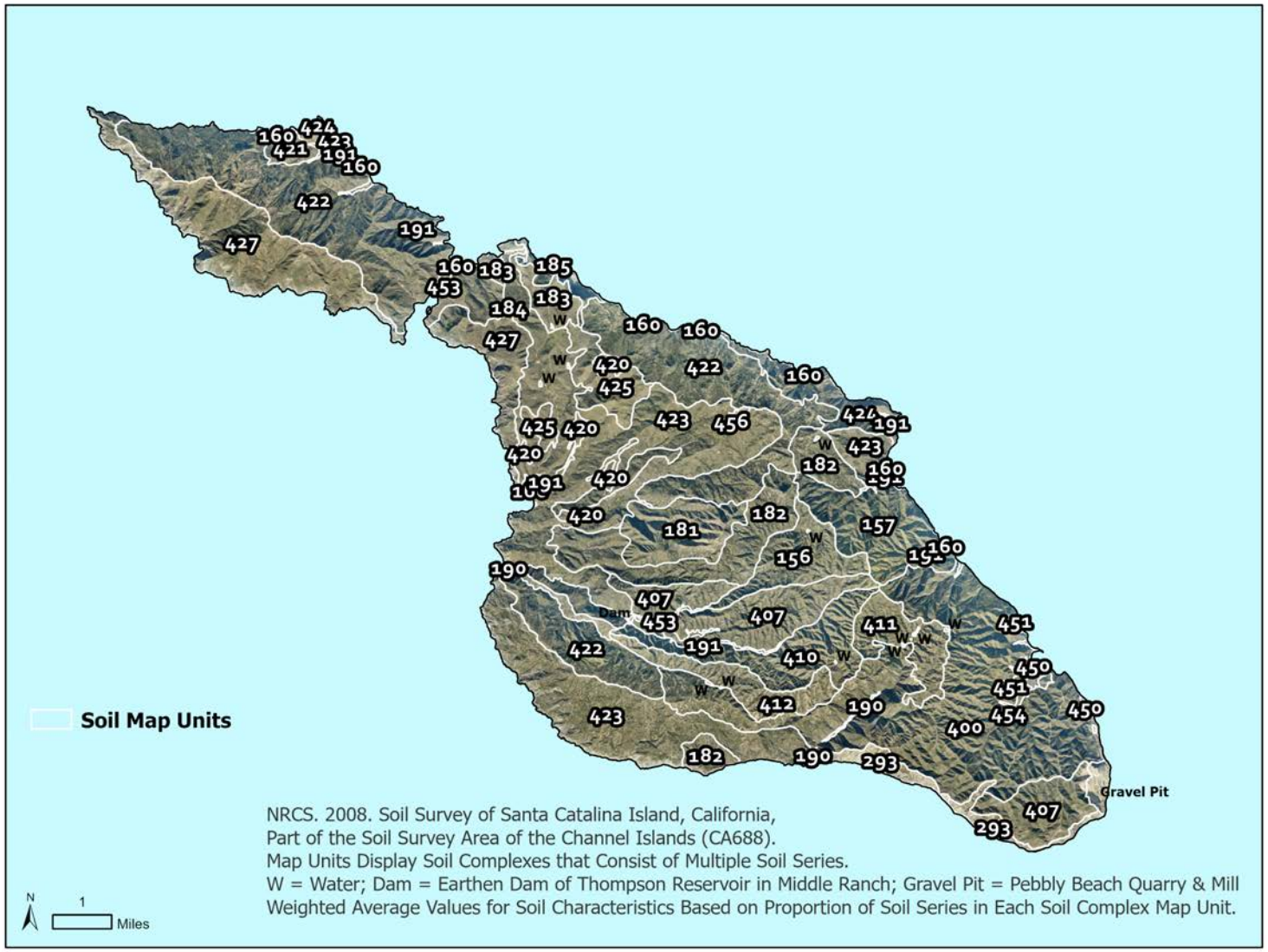

Figure 6-13 Soil Map Units for 2008 NRCS Survey.

See Table 6-2 for Soil Complex Names for the Soil Map Units.

Table 6-2 Soil Complexes with Primary Geology, Soil Series and Soil Texture (2008 Soil Map).

Map Unit Symbol	Soil Map Unit Name Soil Map Complex or Association | Slope Range	Primary Soil Series	Primary Soil Texture	Primary Generalized Geology Map Code | Geological Time Period | Rock Types
160	Beaches-Abaft complex | 0 to 5%	Beach Sand	Sand	Qb | QUARTERNARY | Beach sand
190	Typic Xerofluvents-Riverwash complex | 0 to 8%	Xerofluvents	Sandy loam	Qal | QUARTERNARY | Alluvium
191	Typic Haploxerepts-Xerofluvents-Argixerolls complex | 0 to 8%	Haploxerepts	Very gravelly sand	
184	Dewpoint-Luff association |15 to 45%	Dewpoint	Sandy loam	Qls | QUARTERNARY | Landslide deposits
293	Rock outcrop, coastal cliffs-Nauti-Haploxerepts complex | 50 to 120%	Rock Outcrop	NA	
156	Tongva-Freeboard-Starbright complex | 30 to 55%	Tongva	Loam	Tv | MIOCENE | Volcanic and volcaniclastic rocks
157	Tongva-Pachic Argixerolls-Freeboard complex | 55 to 75%			
181	Haploxerepts-Purser-Rock outcrop complex | 40 to 75%	Haploxerepts	Very gravelly sand	
182	Luff-Haploxerepts-Haploxeralfs complex | 15 to 35%	Luff	Silty loam	
183	Purser-Luff complex | 15 to 35%	Purser	Clay loam	
185	Purser-Rock outcrop complex, coastal cliffs | 45 to 75%			
400	Oboship-Nauti-Bosun complex | 50 to 75%	Oboship	Gravelly loam	Tmqd | MIOCENE | Catalina Island pluton, quartz diorite
407	Nauti-Flyer-Marpol complex | 25 to 55%	Nauti	Loam	
410	Express-Flyer-Loadline complex | 40 to 75%	Express	Sandy loam	
411	Flyer-Loadline-Nauti complex | 15 to 50%	Flyer	Gravelly loamy sand	
412	Flyer, gullied-Express, gullied-Bosun complex | 15 to 50%			
422	Dewpoint-Masthead-Coastwise complex | 20 to 55%	Dewpoint	Sandy loam	Jcs | JURASSIC | Catalina Schist
420	Masthead-Luff complex | 5 to 15%	Masthead	Gravelly silty loam	
421	Masthead-Luff complex | 8 to 30%			
423	Masthead-Coastwise-Dewpoint complex | 20 to 55%			
424	Masthead-Dewpoint-Rock Outcrop complex | 40 to 75%			
427	Masthead-Coastwise-Typic Haploxeralfs complex | 45 to 75%			
425	Coastwise-Masthead complex, cobbly | 40 to 75%	Coastwise	Gravelly sandy loam	

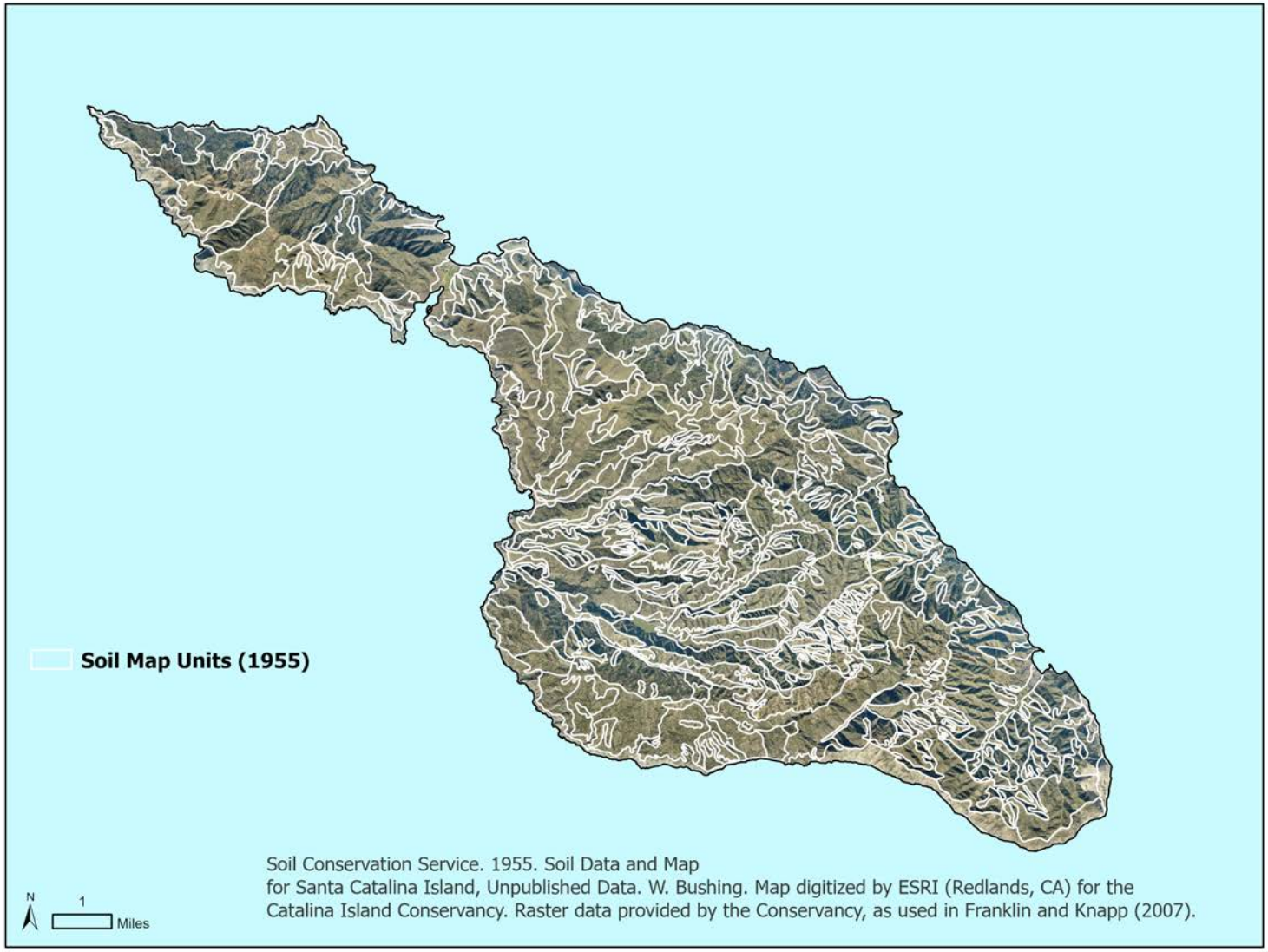

Figure 6-14 Soil Map Units for 1955 Soil Conservation Service Survey.

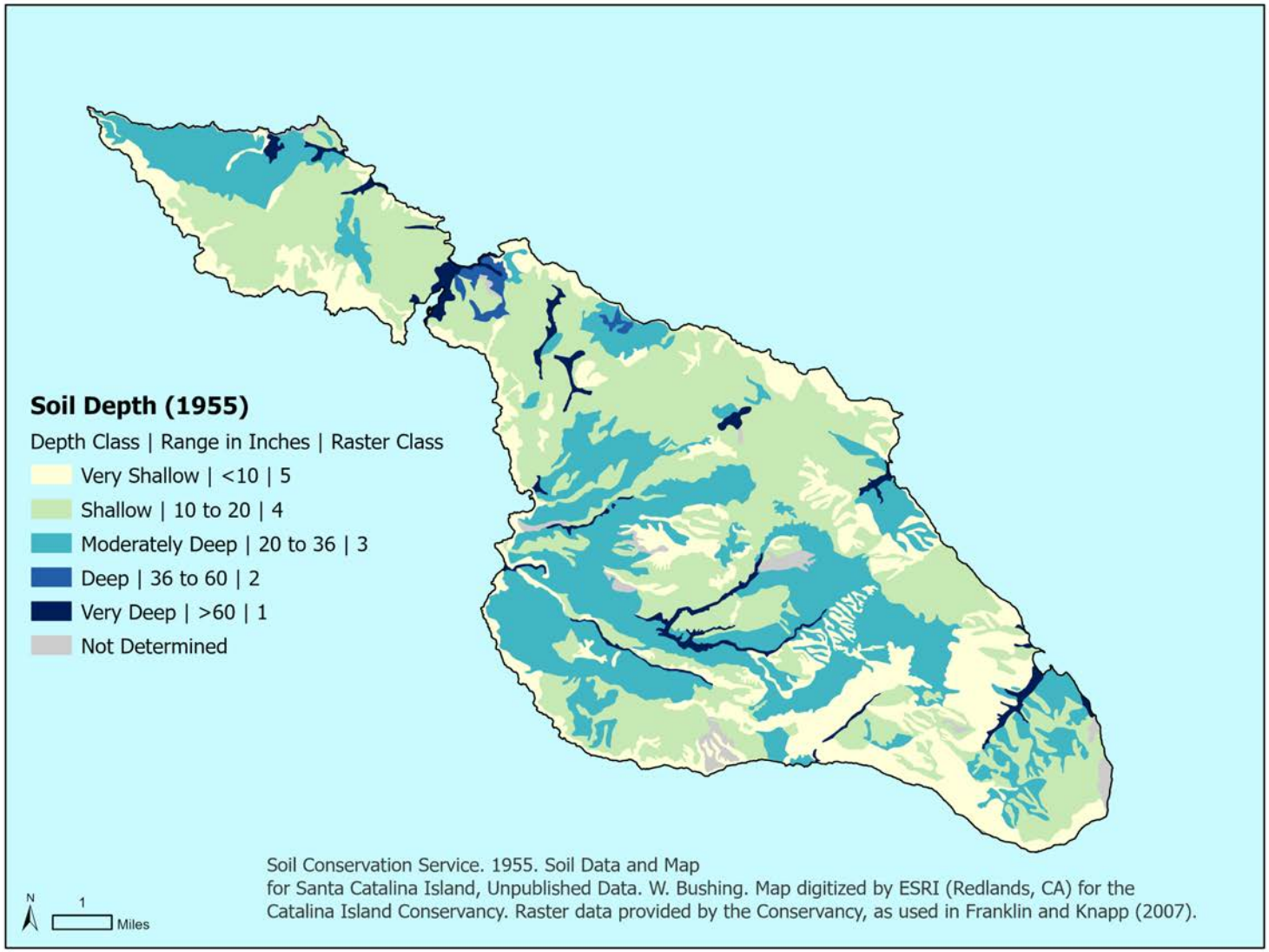

Figure 6-15 Soil Depth (1955 Soil Map).

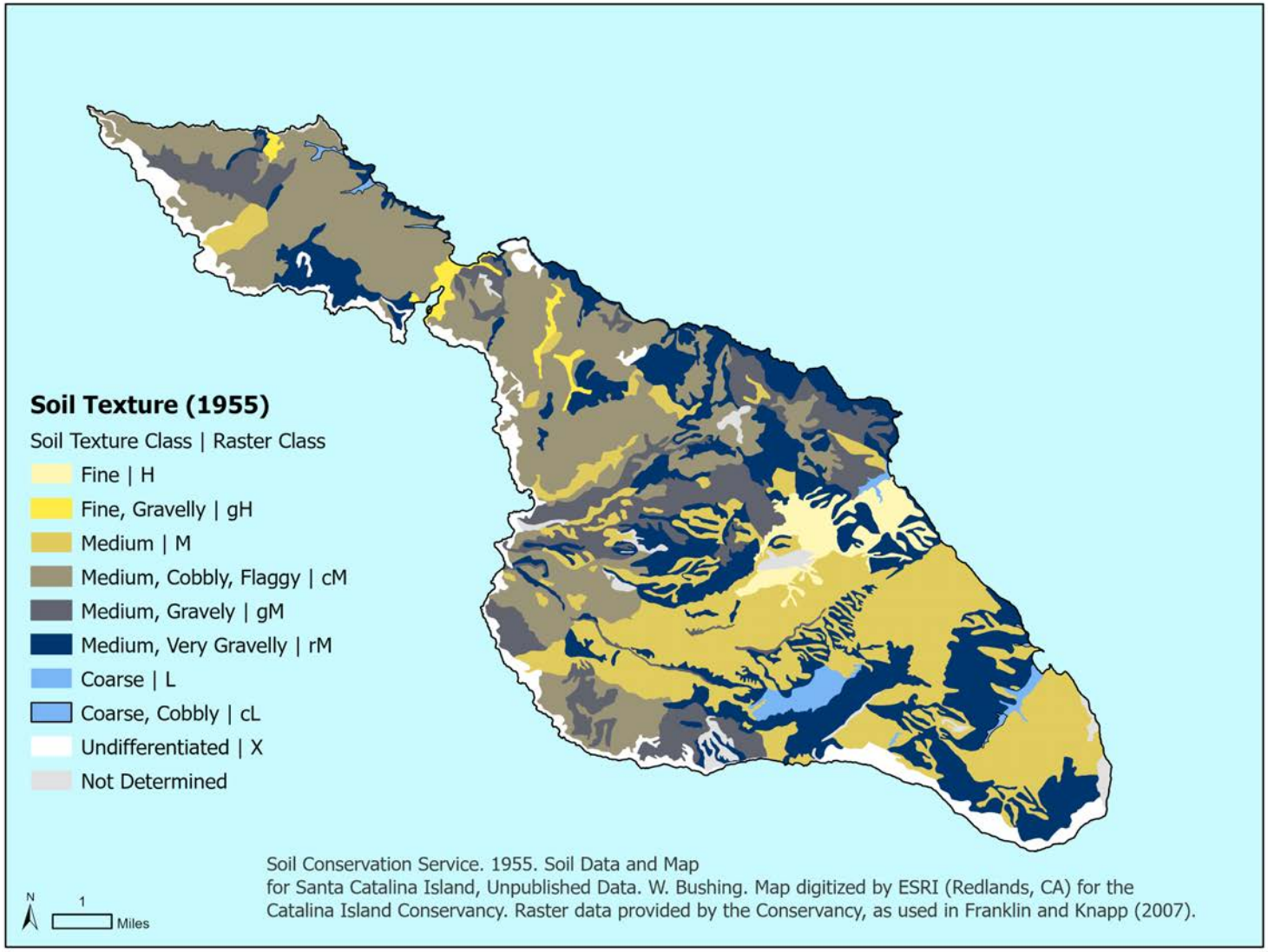

Figure 6-16 Soil Texture (1955 Soil Map).

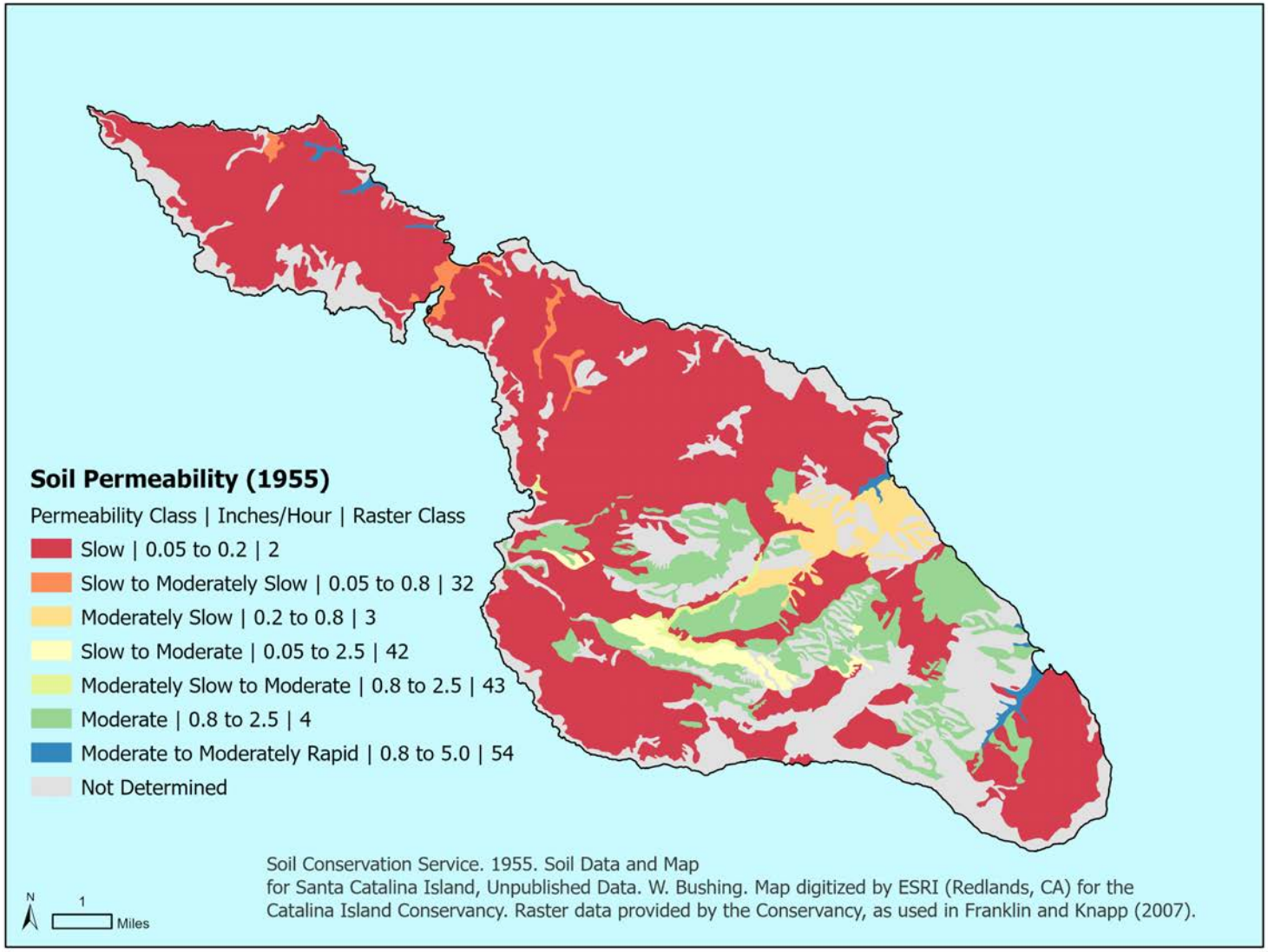

Figure 6-17 Soil Permeability (1955 Soil Map).

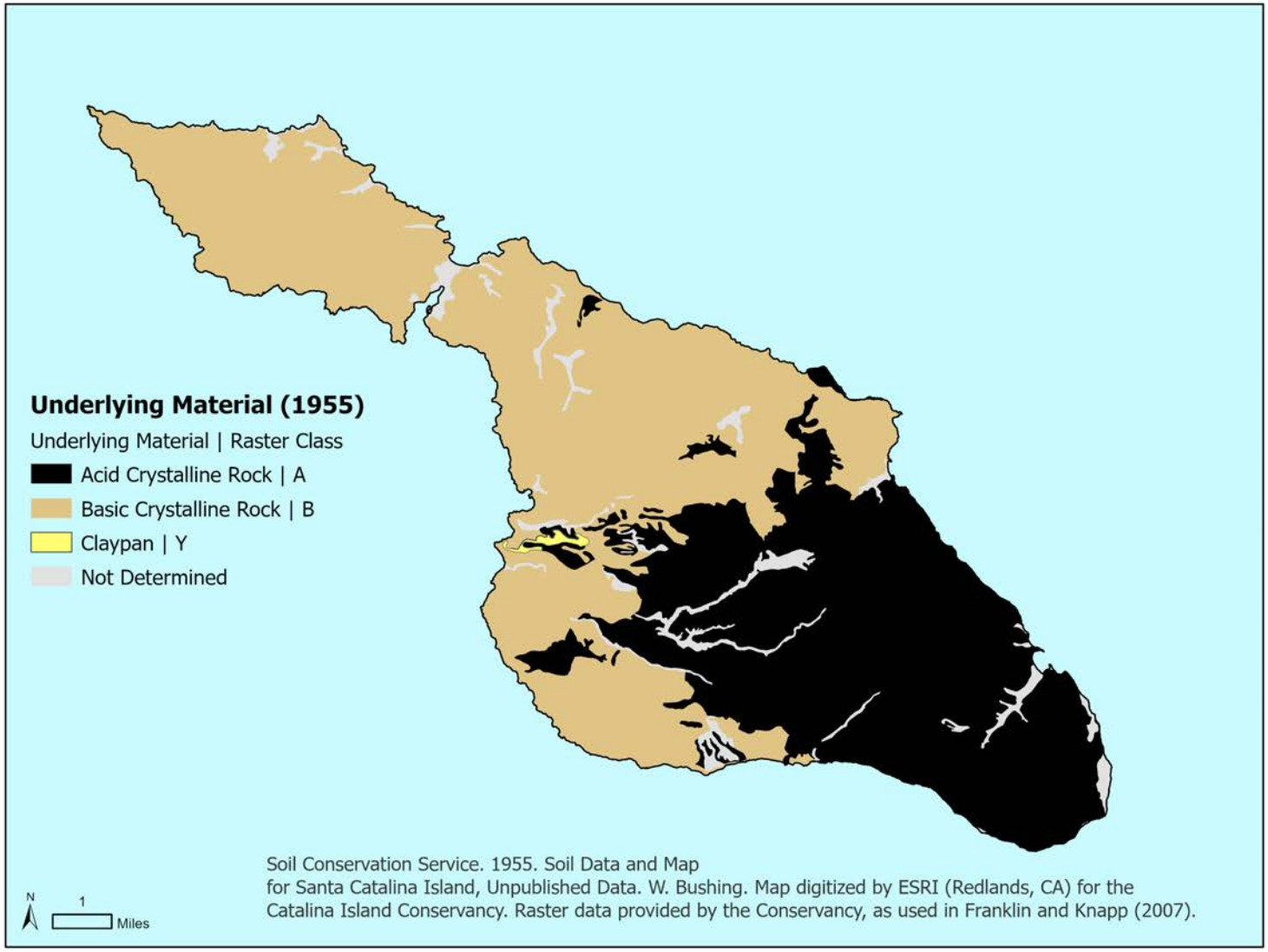

Figure 6-18 Underlying Material (1955 Soil Map).

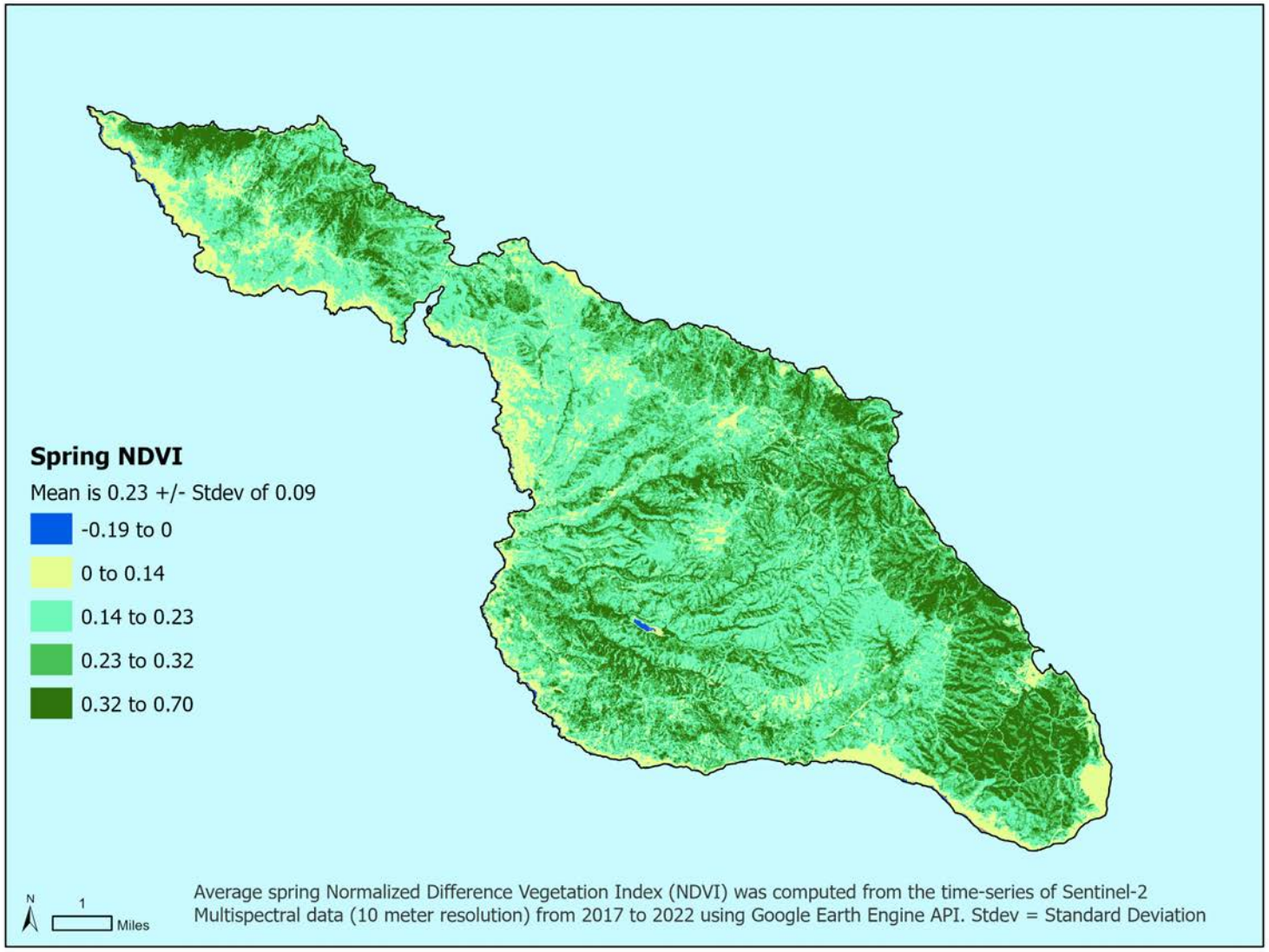

Figure 6-19 Average Spring Normalized Difference Vegetation Index (NDVI) from 2017 to 2022.

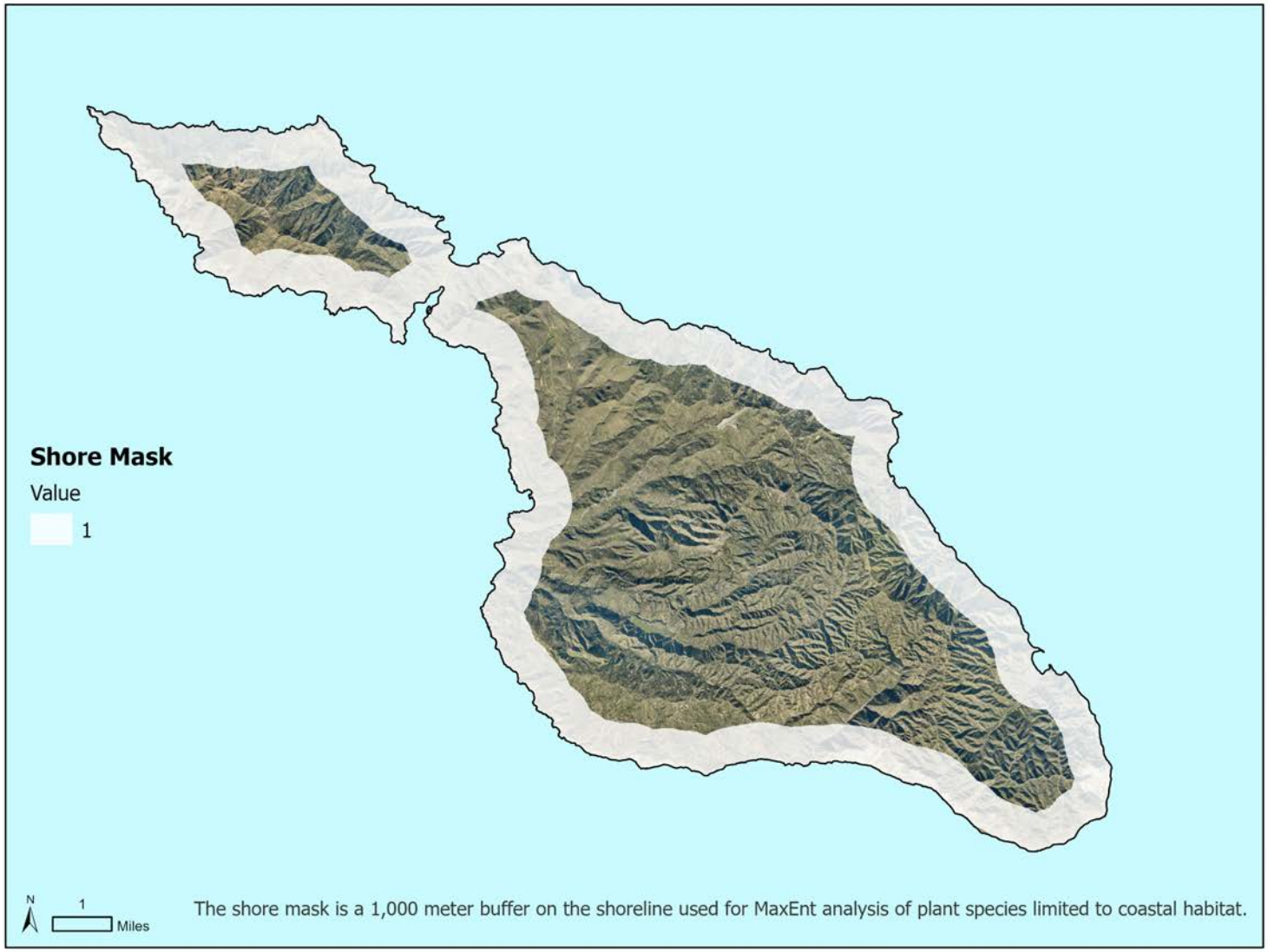

Figure 6-20 Shore Mask for Modeling.

Table 6-3. Habitat Suitability Model Performance.

Scientific Name	Common Name	Code	Minimum Allowed Distance Between Samples (m)	Number of Samples	Resampling Method	Number of Replicates	AUC Mean ± Standard Deviation	Suitability Threshold
Abronia maritima	red sand verbena	abrmar	10	23	Cross-Validation	30	0.96 ± 0.05	0.360
Achillea millefolium	common yarrow	achmil	200	7	Cross-Validation	30	0.89 ± 0.11	0.482
Acmispon argophyllus	silver birds foot trefoil	acmarg	200	5	Cross-Validation	40	0.56 ± 0.18	0.703
Acmispon grandifloras	large leaved lotus	acmgra	200	22	Cross-Validation	30	0.83 ± 0.25	0.124
Adenostoma fasciculatum	chamise	adefas	200	24	Cross-Validation	20	0.82 ± 0.23	0.363
Anemopsis californica	yerba mansa	anecal	200	15	Cross-Validation	20	0.97 ± 0.06	0.593
Aphanisma blitoides	aphanisma	aphbli	10	28	Cross-Validation	20	0.99 ± 0.02	0.489
Arctostaphylos catalinae - SCIE	Catalina Island manzanita	arccat	200	114	Subsampling	10	0.78 ± 0.04	0.297
Artemisia californica	California sagebrush	artcal	100	81	Subsampling	20	0.77 ± 0.05	0.373
*Arundo donax**	giant reed	arudon	10	15	Cross-Validation	30	0.99 ± 0.02	0.666
Asclepias fascicularis	narrowleaf milkweed	ascfas	10	27	Cross-Validation	30	0.93 ± 0.13	0.221
Atriplex coulteri	Coulter's saltbush	atrcou	200	46	Subsampling	30	0.78 ± 0.05	0.274
Atriplex pacifica	South Coast saltscale	atrpac	200	19	Cross-Validation	30	0.85 ± 0.16	0.292
Baccharis pilularis	coyote bush	bacpil	10	15	Cross-Validation	30	0.89 ± 0.12	0.334
Bergerocactus emoryi - CIE	velvet cactus	beremo	30	16	Subsampling	10	0.97 ± 0.01	0.548
Bothriochloa barbinodis	cane bluestem	botbar	200	23	Cross-Validation	30	0.95 ± 0.08	0.207
*Brassica nigra**	black mustard	branig	10	27	Cross-Validation	30	0.93 ± 0.18	0.334
Bromus sitchensis (*carinatus*)	California brome	brocar	200	23	Subsampling	30	0.64 ± 0.1	0.242
*Cakile maritima**	sea rocket	cakmar	10	30	Subsampling	30	0.97 ± 0.04	0.132
*Carduus pycnocephalus**	Italian thistle	carpyc	200	32	Subsampling	30	0.95 ± 0.03	0.332
Ceanothus arboreus - CIE	felt-leaf ceanothus	ceaarb	200	119	Cross-Validation	40	0.81 ± 0.11	0.300
Ceanothus megacarpus var. *insularis* - CIE	island ceanothus	ceamegins	10	7	Cross-Validation	30	0.83 ± 0.26	0.213

Scientific Name	Common Name	Code	Minimum Allowed Distance Between Samples (m)	Number of Samples	Resampling Method	Number of Replicates	AUC Mean ± Standard Deviation	Suitability Threshold
Ceanothus megacarpus var. *megacarpus*	bigpod ceanothus	ceamegmeg	100	17	Cross-Validation	30	0.77 ± 0.25	0.326
*Centranthus ruber**	red valerian	cenrub	10	7	Cross-Validation	30	0.94 ± 0.08	0.694
Cercocarpus traskiae - SCIE	Catalina Island mountain-mahogany	certra	10	29	Cross-Validation	40	0.92 ± 0.19	0.091
Chlorogalum pomeridianum	soap plant	chlpom	100	23	Cross-Validation	30	0.93 ± 0.07	0.412
*Cirsium vulgare**	bull thistle	cirvul	200	27	Subsampling	30	0.9 ± 0.04	0.141
Comarostaphylis diversifolia subsp. *planifolia*	summer holly	comdivpla	200	14	Cross-Validation	30	0.86 ± 0.17	0.319
*Cortaderia selloana**	pampas grass	corsel	200	37	Subsampling	30	0.81 ± 0.09	0.156
Cressa truxillensis	alkali weed	cretru	10	28	Cross-Validation	30	0.99 ± 0.03	0.220
Crocanthemum greenei - CIE	island rush-rose	crogre	100	39	Subsampling	30	0.78 ± 0.06	0.269
Crossosoma californicum - CIE/PVP	Catalina Island crossosoma	crocal	200	29	Cross-Validation	40	0.74 ± 0.23	0.338
Cylindropuntia prolifera	coastal cholla	cylpro	100	39	Subsampling	30	0.98 ± 0.01	0.274
*Cynara cardunculus**	artichoke thistle	cyncar	20	19	Cross-Validation	30	0.93 ± 0.19	0.088
Cyperus spp.	flatsedge	cypspp	200	21	Cross-Validation	30	0.88 ± 0.14	0.268
Deinandra clementina - CIE	island tarplant	deicle	50	39	Cross-Validation	30	0.9 ± 0.15	0.137
Deinandra fasciculata	clustered tarplant	deifas	200	8	Cross-Validation	30	0.8 ± 0.24	0.351
Delphinium parryi subsp. *maritimum*	maritime larkspur	delparmar	100	34	Subsampling	30	0.85 ± 0.07	0.201
Dendromecon harfordii	Channel Island tree poppy	denhar	100	51	Subsampling	30	0.76 ± 0.05	0.346
Dichondra occidentalis	western dichondra	dicocc	200	44	Subsampling	30	0.71 ± 0.21	0.328
Dissanthelium californicum - CIE	California dissanthelium	discal	10	17	Cross-Validation	40	0.63 ± 0.32	0.166

Scientific Name	Common Name	Code	Minimum Allowed Distance Between Samples (m)	Number of Samples	Resampling Method	Number of Replicates	AUC Mean ± Standard Deviation	Suitability Threshold
Dudleya virens ssp. *hassei* - SCIE	Catalina Island dudleya	dudvirhas	200	24	Cross-Validation	40	0.91 ± 0.13	0.108
Dudleya virens subsp. *insularis*	island green dudleya	dudvirins	200	63	Subsampling	30	0.84 ± 0.05	0.268
Elymus (Leymus) condensatus	giant wild rye	elycon	100	31	Subsampling	30	0.81 ± 0.21	0.260
Encelia californica	California sunflower bush	enccal	200	12	Cross-Validation	30	0.92 ± 0.13	0.522
Ericameria palmeri	Palmer's goldenbush	eripal	200	14	Cross-Validation	30	0.84 ± 0.19	0.449
Eriodictyon traskiae ssp. *traskiae* - SCIE	Trask's yerba santa	eritra	10	54	Cross-Validation	40	0.92 ± 0.12	0.142
Eriogonum giganteum var. *giganteum* - SCIE	St. Catherine's lace	erigig	200	103	Cross-Validation	40	0.81 ± 0.12	0.232
Eriogonum grande var. *grande*	island buckwheat	erigra	100	64	Subsampling	30	0.84 ± 0.05	0.160
Eschscholzia ramosa - CIE	Island poppy	escram	30	39	Cross-Validation	40	0.8 ± 0.24	0.146
Euphorbia misera - CIE	cliff spurge	eupmis	200	5	Cross-Validation	5	0.99 ± 0.01	0.699
*Foeniculum vulgare**	sweet fennel	foevul	200	91	Subsampling	30	0.79 ± 0.05	0.252
Frankenia salina	alkali heath	frasal	100	16	Cross-Validation	30	0.78 ± 0.26	0.212
Galium catalinense ssp. *catalinense* - SCIE	Catalina Island bedstraw	galcat	200	39	Subsampling	10	0.85 ± 0.07	0.097
Gambelia speciosa (Galvezia speciosa) - CIE	showy island snapdragon	gamspe	10	27	Cross-Validation	40	0.92 ± 0.15	0.145
*Genista linifolia**	Mediterranean broom	genlin	300	111	Subsampling	30	0.71 ± 0.04	0.241
Gilia nevinii - CIE	Nevin's gilia	gilnev	200	9	Cross-Validation	40	0.71 ± 0.3	0.238
Heteromeles arbutifolia	toyon	hetarb	100	85	Subsampling	30	0.79 ± 0.04	0.362
Hordeum intercedens	vernal barley	horint	200	90	Subsampling	30	0.83 ± 0.03	0.310
Isocoma menziesii var. *menziesii*	Menzie's goldenbush	isomen	200	23	Cross-Validation	30	0.9 ± 0.12	0.375
Jepsonia malvifolia - CIE	island jepsonia	jepmal	200	84	Cross-Validation	40	0.82 ± 0.13	0.239

Scientific Name	Common Name	Code	Minimum Allowed Distance Between Samples (m)	Number of Samples	Resampling Method	Number of Replicates	AUC Mean ± Standard Deviation	Suitability Threshold
Lepechinia fragrans	fragrant pitcher sage	lepfra	100	47	Cross-Validation	30	0.9 ± 0.03	0.128
Leptosyne gigantea (Coreopsis gigantea)	giant coreopsis	lepgig	10	42	Subsampling	30	0.96 ± 0.03	0.113
Lycium californicum	California boxthorn	lyccal	200	74	Subsampling	30	0.94 ± 0.02	0.298
Lyonothamnus floribundus ssp. *floribundus* - SCIE	Catalina Island ironwood	lyoflo	200	82	Cross-Validation	40	0.79 ± 0.15	0.262
Malacothamnus fasciculatus var. *catalinensis* - SCIE	Catalina Island bushmallow	malfascat	10	29	Cross-Validation	40	0.78 ± 0.19	0.353
Malosma laurina	laurel sumac	mallau	200	43	Subsampling	30	0.73 ± 0.08	0.304
Muhlenbergia microsperma	littleseed muhly	muhmic	200	28	Subsampling	30	0.71 ± 0.08	0.398
Opuntia littoralis	coastal prickly pear	opulit	200	86	Subsampling	30	0.67 ± 0.05	0.404
*Pennisetum setaceum**	fountaingrass	penset	30	43	Subsampling	30	0.97 ± 0.02	0.362
Peritoma arborea	bladderpod	perarb	200	5	Cross-Validation	30	0.86 ± 0.15	0.856
*Phalaris aquatica**	Harding grass	phaaqu	200	68	Subsampling	30	0.85 ± 0.04	0.116
Piperia spp.	orchid	pipspp	100	26	Subsampling	30	0.78 ± 0.08	0.231
Plagiobothrys collinus	popcornflower	placol	100	25	Subsampling	30	0.78 ± 0.1	0.364
Prunus ilicifolia ssp. *lyonii* - CIE	Catalina cherry	pruililyo	200	13	Cross-Validation	40	0.83 ± 0.23	0.280
Quercus pacifica - CIE	island scrub oak	quepac	200	82	Cross-Validation	40	0.64 ± 0.18	0.375
Quercus tomentella - CIE	island live oak	quetom	200	63	Cross-Validation	40	0.84 ± 0.21	0.147
Quercus x macdonaldii - CIE	MacDonald oak	quemac	10	31	Subsampling	30	0.87 ± 0.05	0.341
Rhamnus pirifolia - CIE	island redberry	rhapir	200	22	Cross-Validation	40	0.67 ± 0.32	0.216
Rhus integrifolia	lemonade berry	rhuint	200	80	Subsampling	30	0.73 ± 0.05	0.383
Ribes viburnifolium - CIE	Catalina Island currant	ribvib	200	56	Cross-Validation	40	0.83 ± 0.16	0.412

Scientific Name	Common Name	Code	Minimum Allowed Distance Between Samples (m)	Number of Samples	Resampling Method	Number of Replicates	AUC Mean ± Standard Deviation	Suitability Threshold
Salvia apiana	white sage	salapi	200	32	Subsampling	30	0.92 ± 0.05	0.265
Salvia mellifera	black sage	salmel	200	41	Subsampling	30	0.83 ± 0.06	0.213
Sambucus mexicana	blue elderberry	sammex	200	9	Cross-Validation	30	0.75 ± 0.23	0.322
Scrophularia villosa - CIE	Catalina Island figwort	scrvil	200	46	Cross-Validation	40	0.82 ± 0.23	0.209
Sibara filifolia - CIE	island rockcress	sibfil	10	56	Subsampling	30	0.98 ± 0.02	0.296
*Silybum marianum**	milk thistle	silmar	200	73	Subsampling	30	0.91 ± 0.03	0.141
Solanum wallacei - CIE	Wallace's nightshade	solwal	200	39	Cross-Validation	40	0.8 ± 0.21	0.289
Stipa cernua	nodding needlegrass	sticer	200	40	Subsampling	30	0.85 ± 0.05	0.162
Stipa spp.	needlegrass	stipa	200	40	Subsampling	30	0.87 ± 0.03	0.328
*Tamarix ramosissima**	saltcedar	tamram	100	18	Subsampling	30	0.92 ± 0.07	0.134
Trifolium palmeri - CIE	southern island clover	tripal	200	15	Cross-Validation	40	0.97 ± 0.04	0.343
Typha domingensis	southern cattail	typdom	200	28	Subsampling	30	0.88 ± 0.07	0.335
Xylococcus bicolor	Mission manzanita	xylbic	100	41	Subsampling	30	0.84 ± 0.04	0.305

**Invasive Plant; SCIE = Santa Catalina Island Endemic; CIE = Channel Island Endemic; PVP = Palos Verdes Peninsula Endemic*

Minimum Allowed Distance Between Samples *is the distance, in meters (m), that occurrence data was required to be for the model. A minimum distance of 200 m was considered optimal but for rare species that have clustered observations, smaller minimum distances were allowed.*

Number of Samples *are the number of samples used in developing and testing the model, after the source data was reduced by randomly removing occurrence datapoints that were within the minimum distance allowed.*

Resampling Method *is the method used to assess the performance and robustness of the model, either Cross-Validation or Subsampling. Subsampling was performed by using 70% of the occurrence data for calibrating the model and 30% for testing the model.*

Number of Replicates *are the amount of resampling runs or model iterations, either by cross-validation or subsampling, performed during the model training process.*

AUC *is the "Area Under the Curve" for the Cloglog output. It is a threshold-independent measure that assesses the model's ability to discriminate between suitable and unsuitable habitats for a species based on the predicted probability of occurrence. A larger AUC value indicates better model performance, with values ranging from 0.5 (indicating a random prediction) to 1 (indicating a perfect prediction). A model with an AUC close to 1 suggests that it can effectively distinguish between locations where a species is present or absent.*

Suitability Threshold *is established as the "10th Percentile Training Presence Cloglog Threshold". When determining a binary (presence/absence) suitability, any species that falls below this threshold is deemed not suitable.*

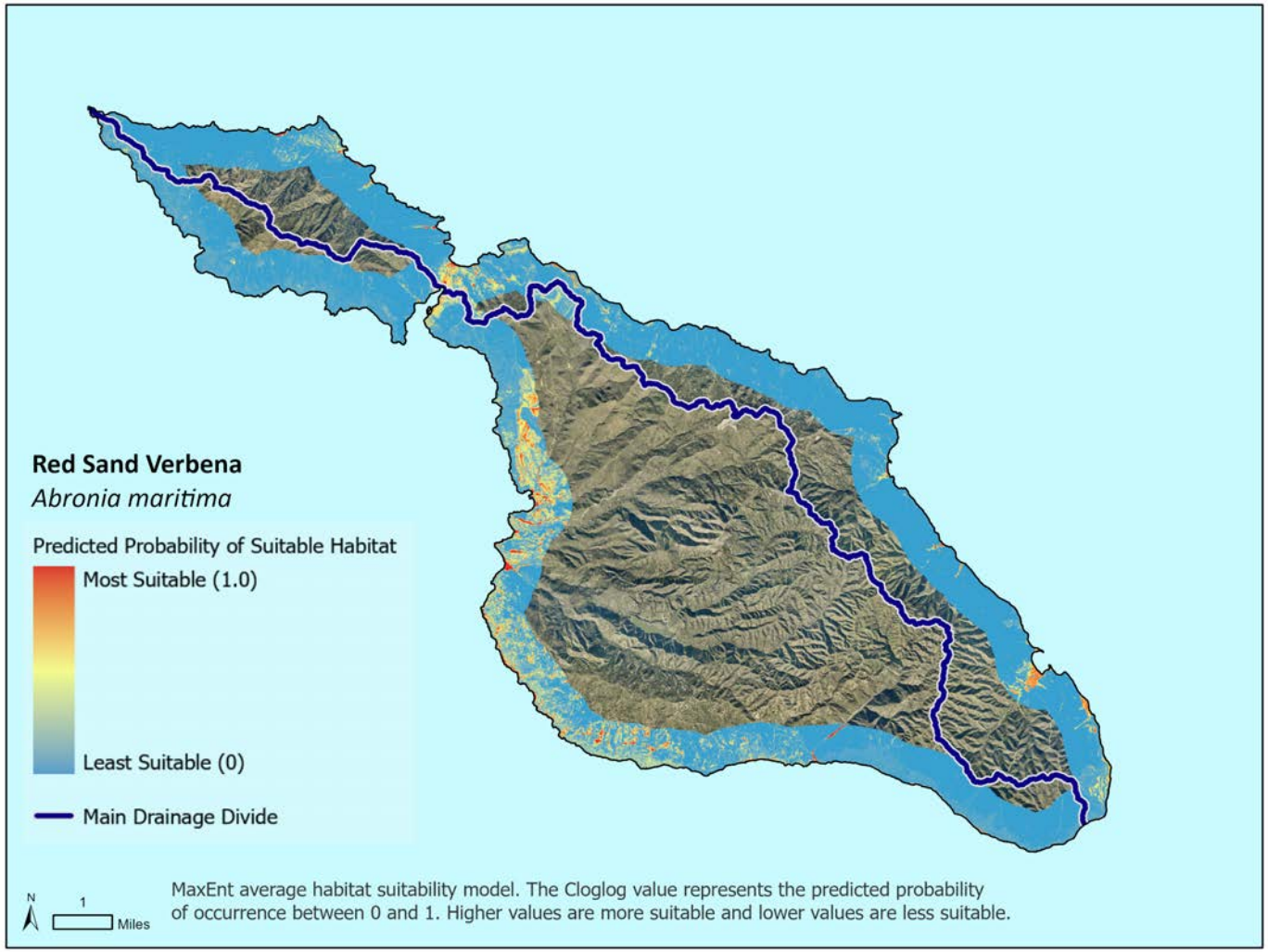

Figure 6-21 Potential Vegetation Map for Red Sand Verbena (*Abronia maritima*).

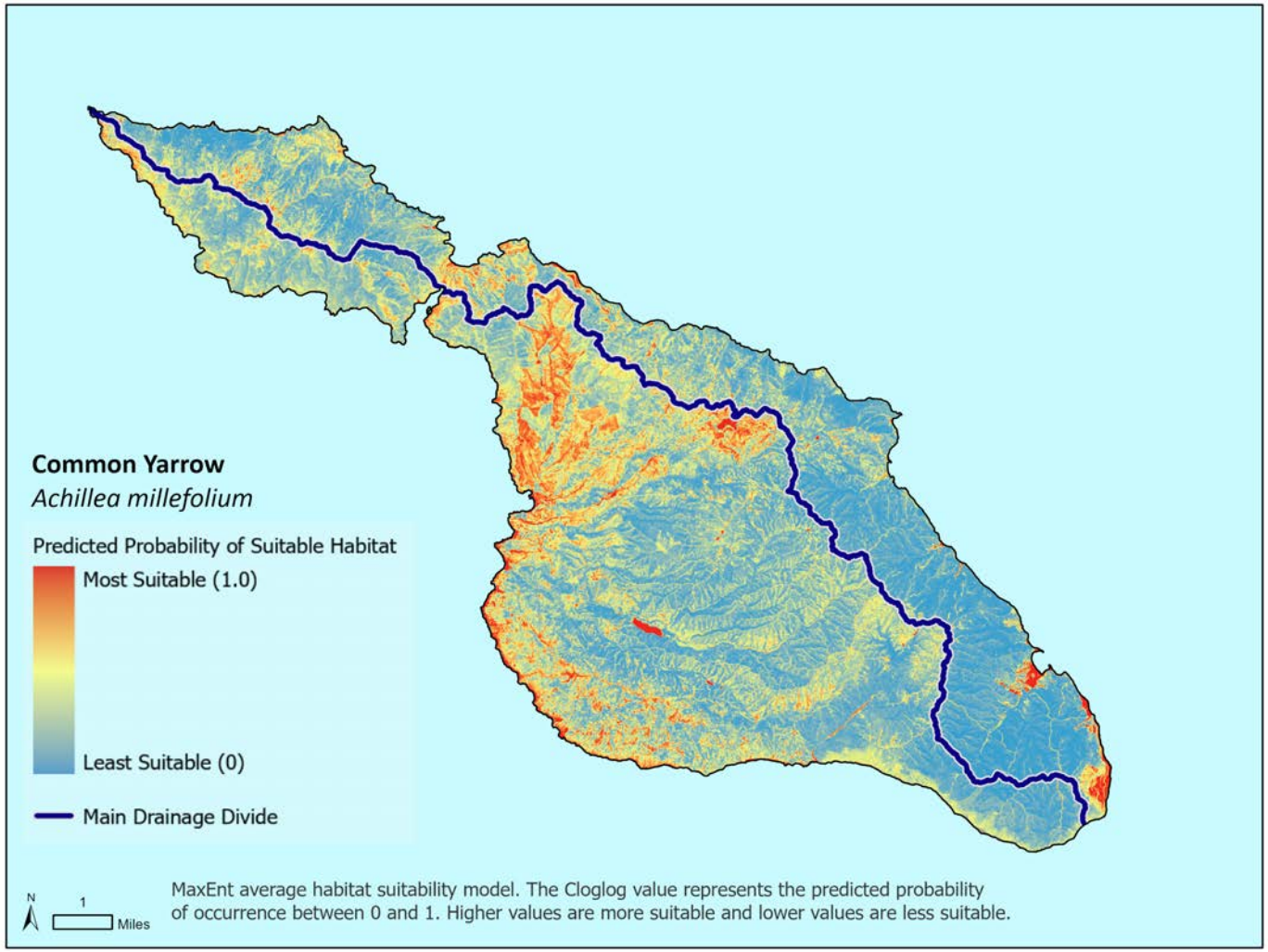

Figure 6-22 Potential Vegetation Map for Common Yarrow (*Achillea millefolium*).

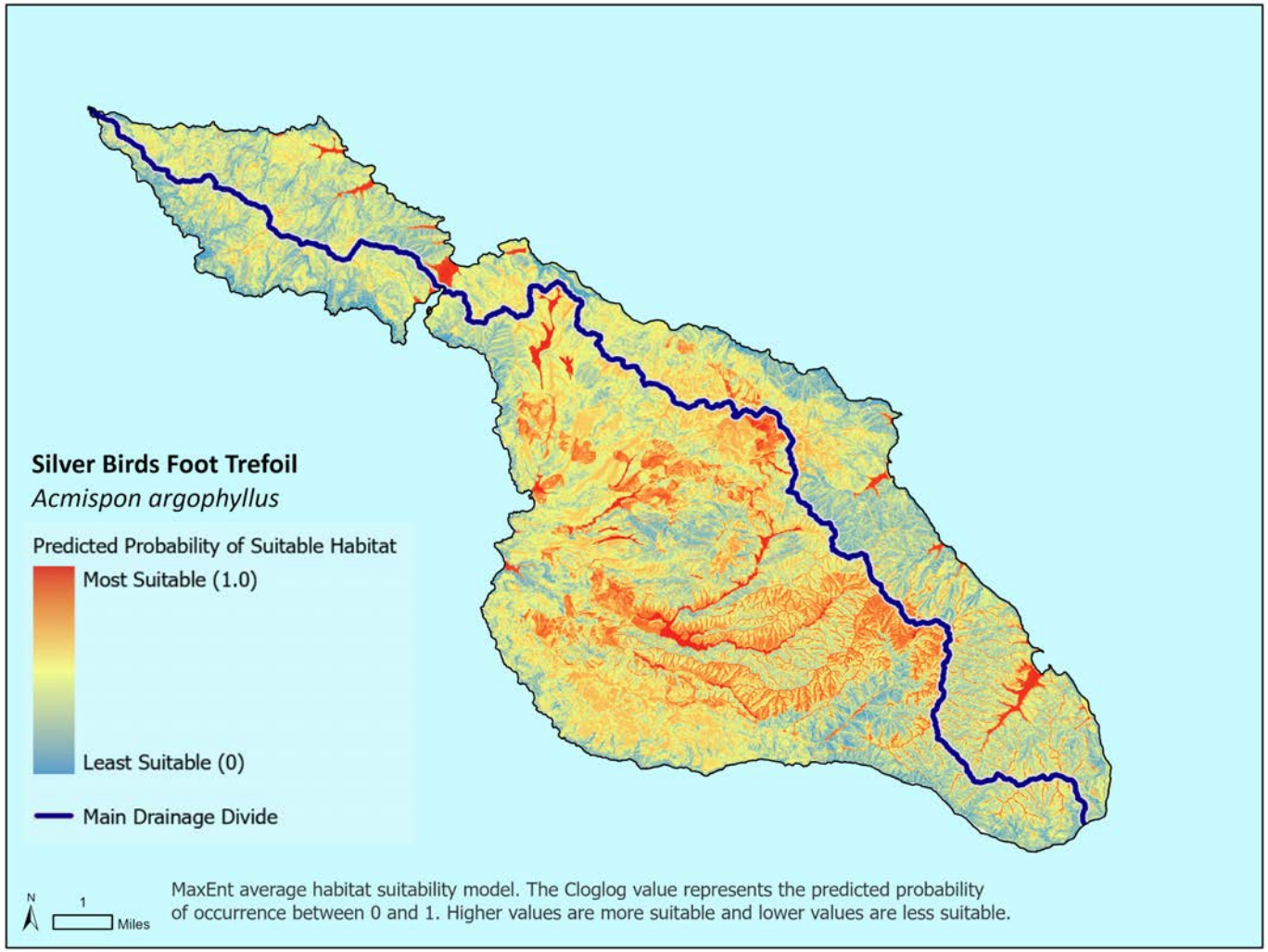

Figure 6-23 Potential Vegetation Map for Silver Birds Foot Trefoil (*Acmispon argophyllus*).

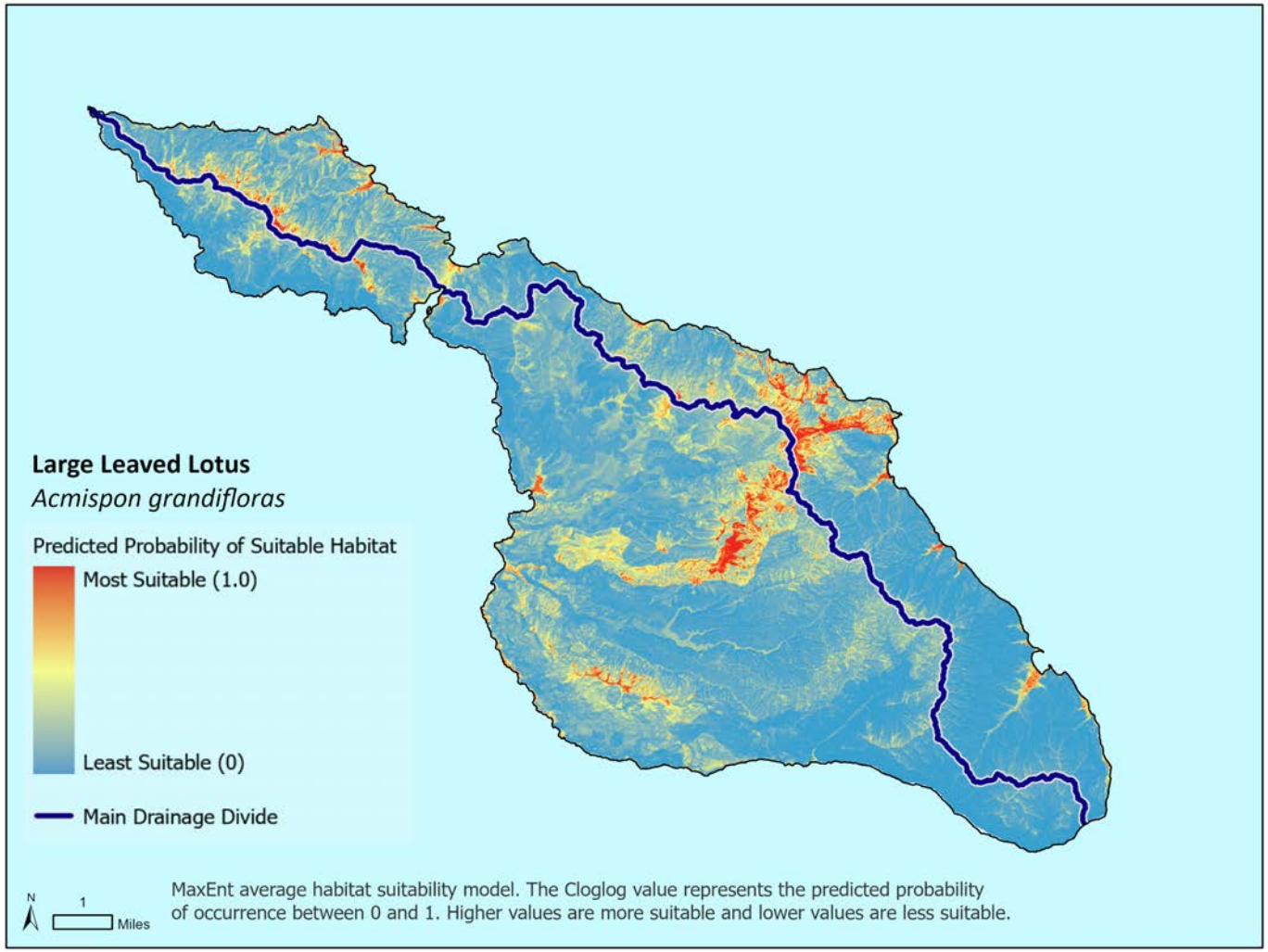

Figure 6-24 Potential Vegetation Map for Large Leaved Lotus (*Acmispon grandifloras*).

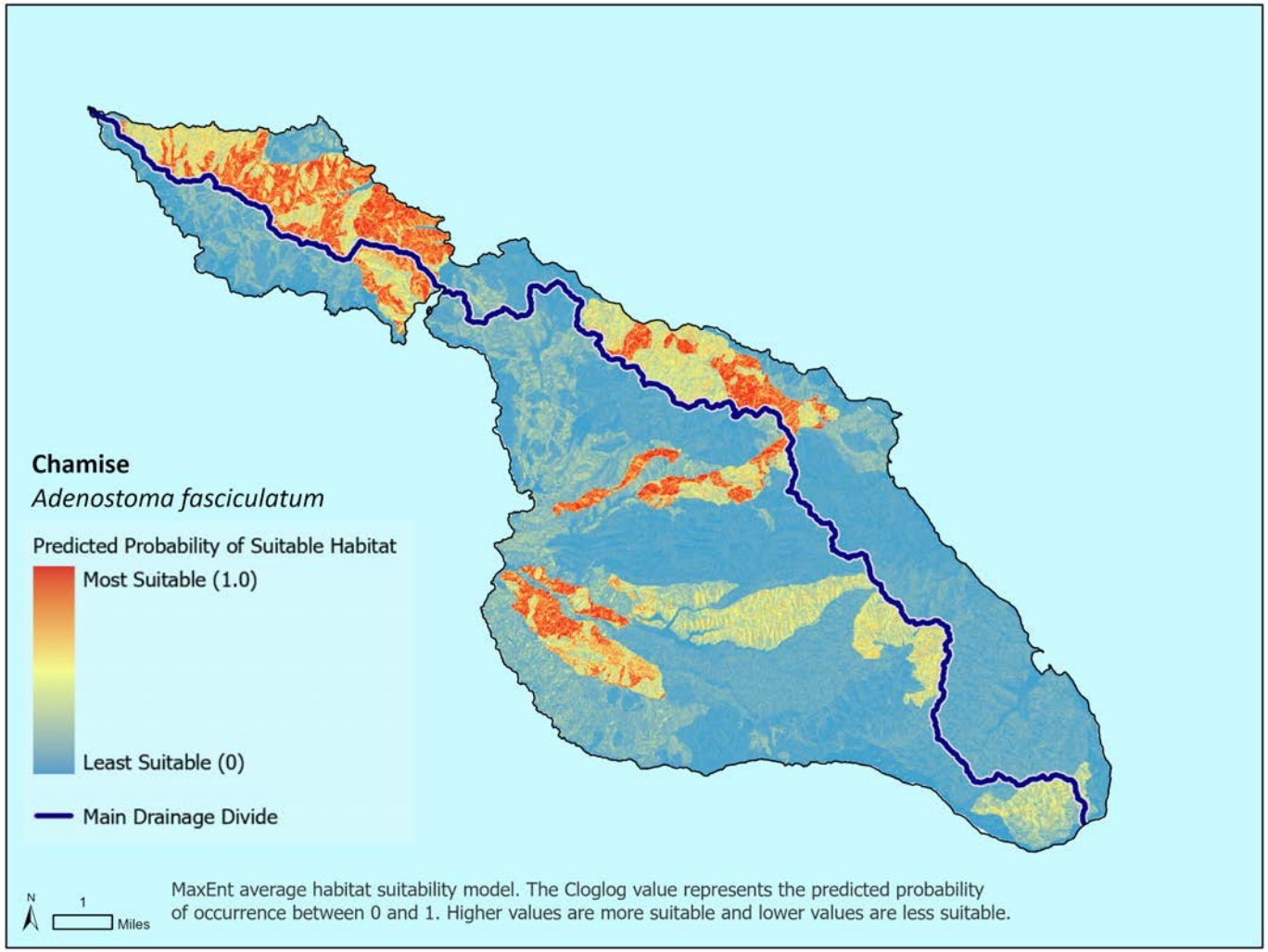

Figure 6-25 Potential Vegetation Map for Chamise (*Adenostoma fasciculatum*).

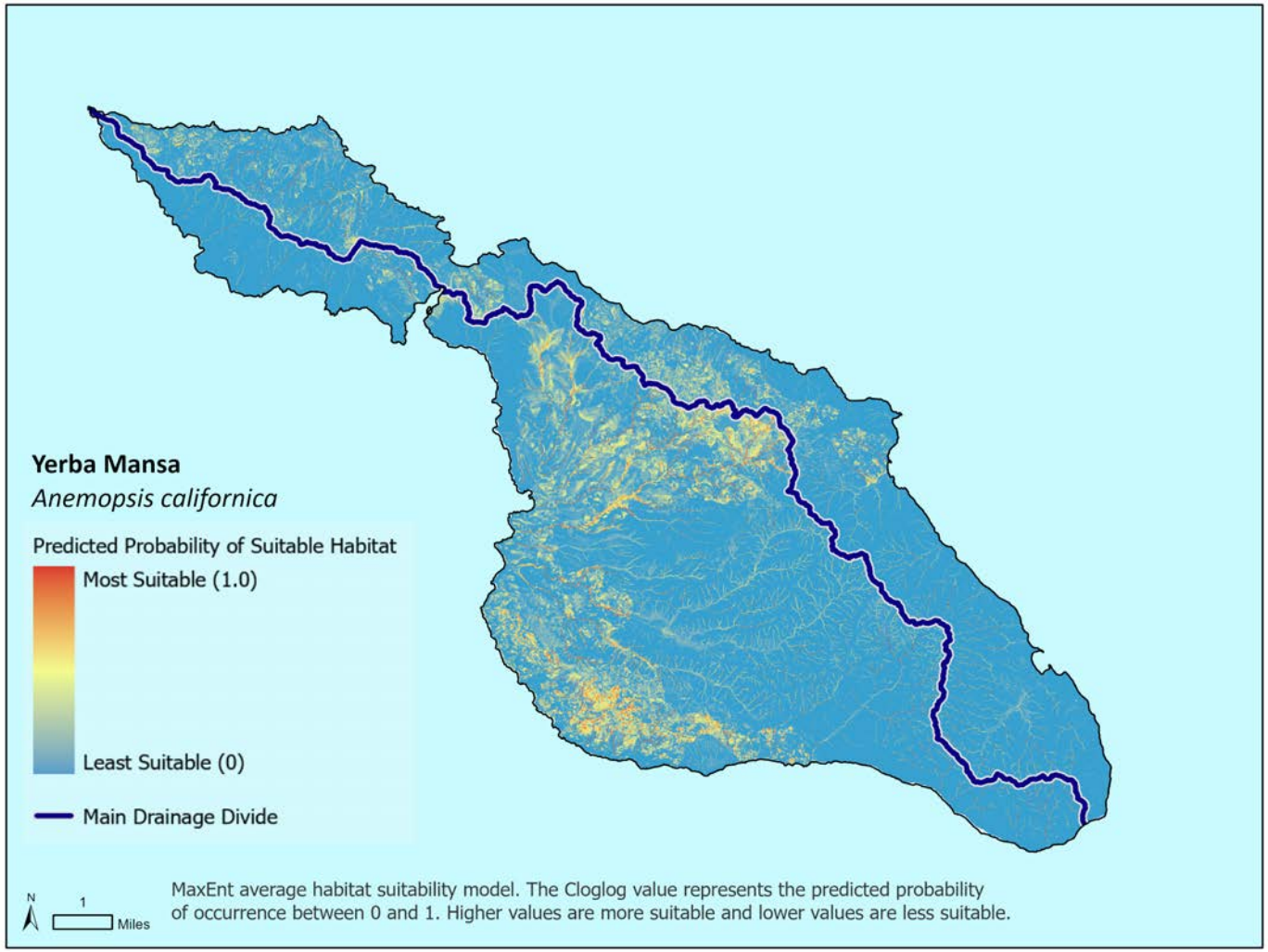

Figure 6-26 Potential Vegetation Map for Yerba Mansa (*Anemopsis californica*).

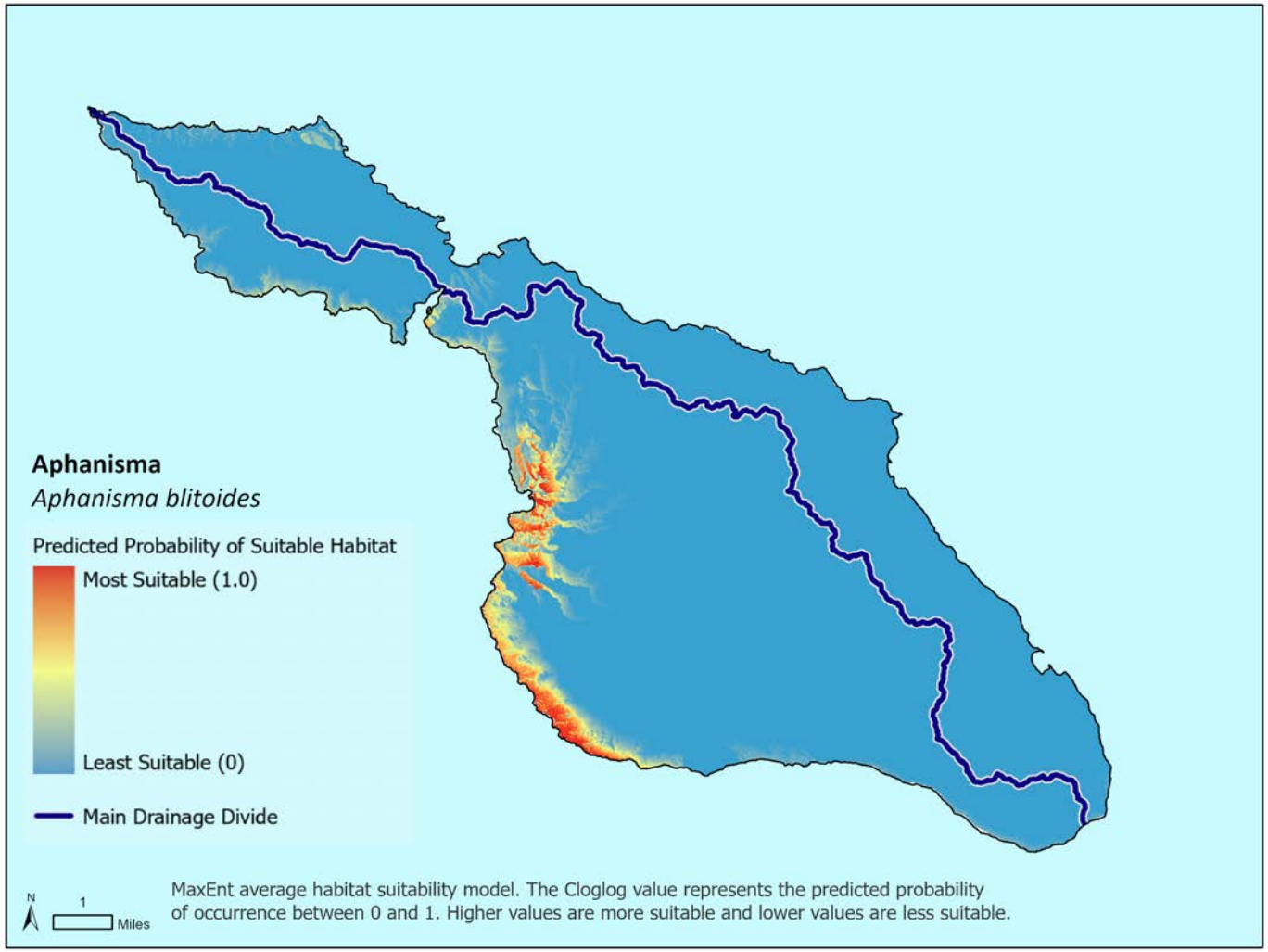

Figure 6-27 Potential Vegetation Map for Aphanisma (*Aphanisma blitoides*).

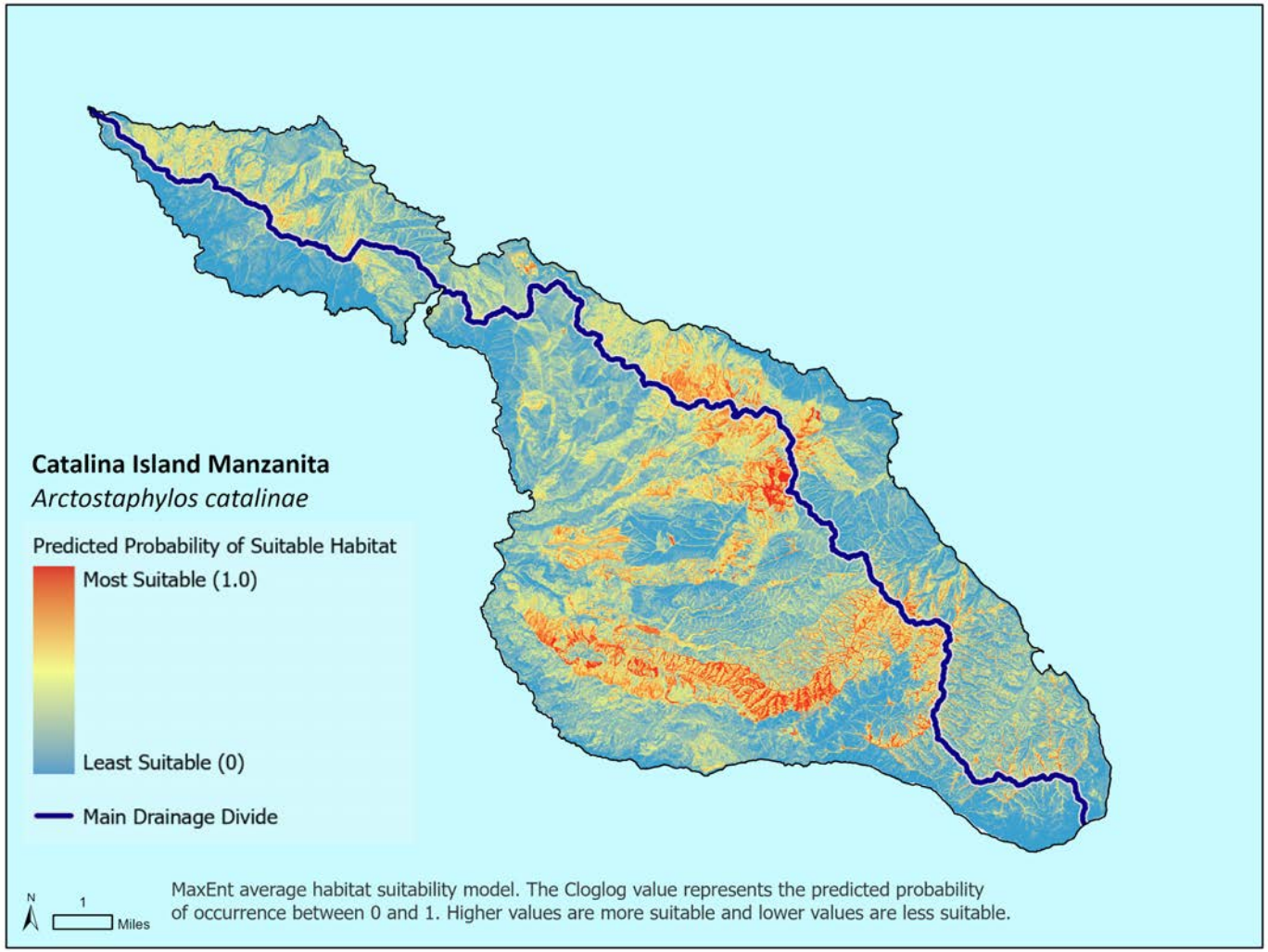

Figure 6-28 Potential Vegetation Map for Catalina Island Manzanita (*Arctostaphylos catalinae*), a Santa Catalina Island Endemic.

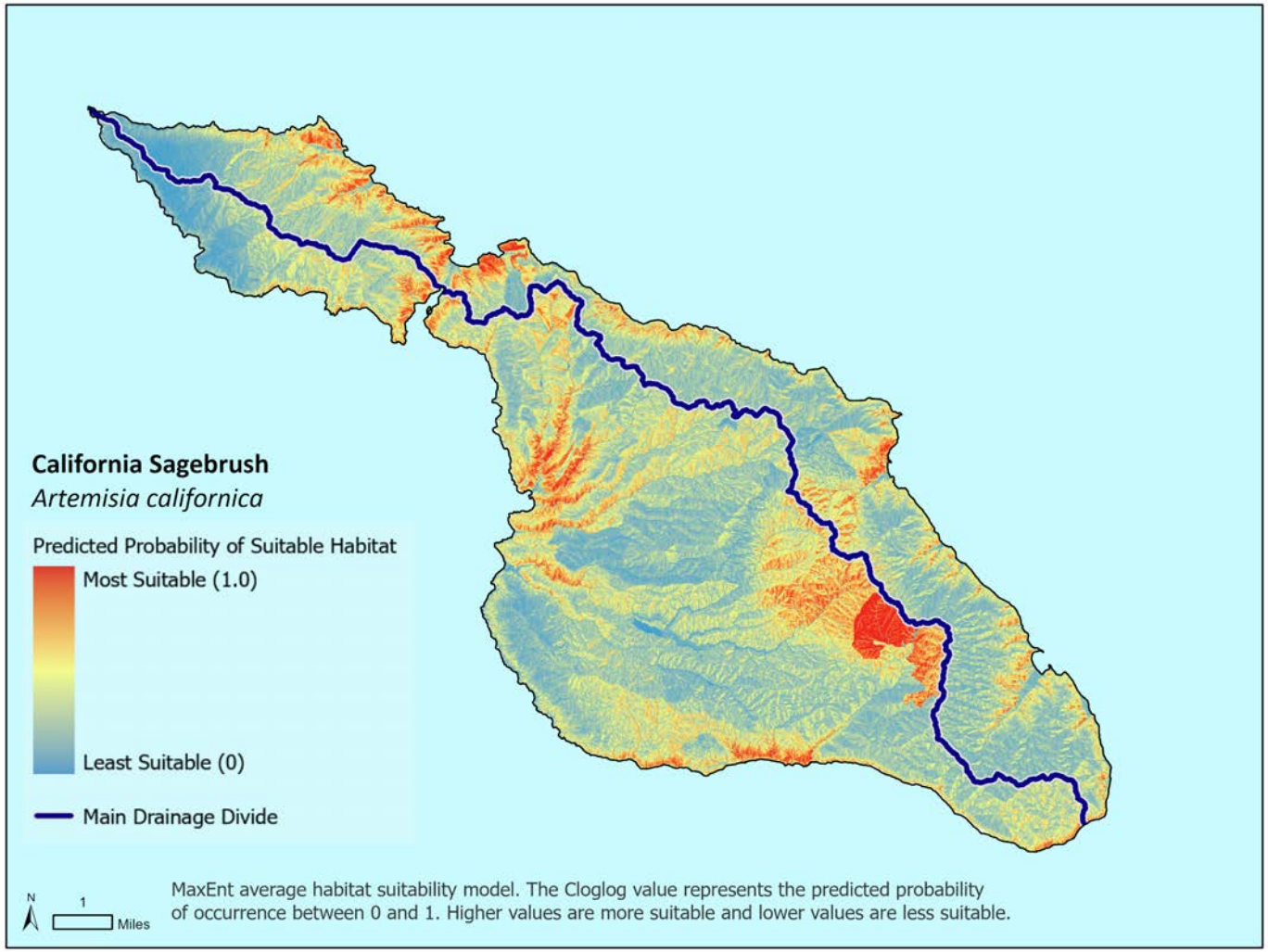

Figure 6-29 Potential Vegetation Map for California Sagebrush (*Artemisia californica*).

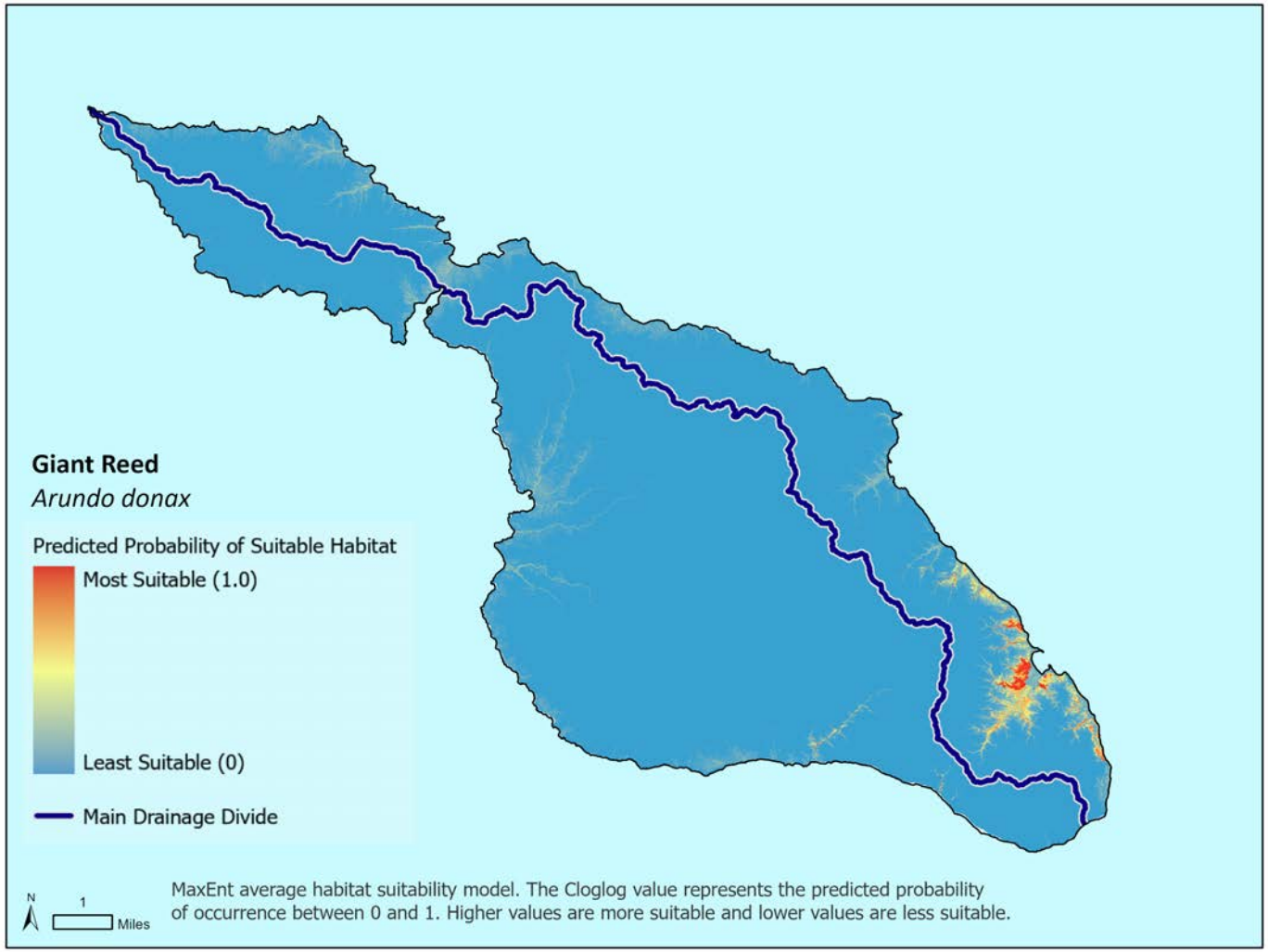

Figure 6-30 Potential Vegetation Map for Giant Reed (*Arundo donax*), an Invasive Plant.

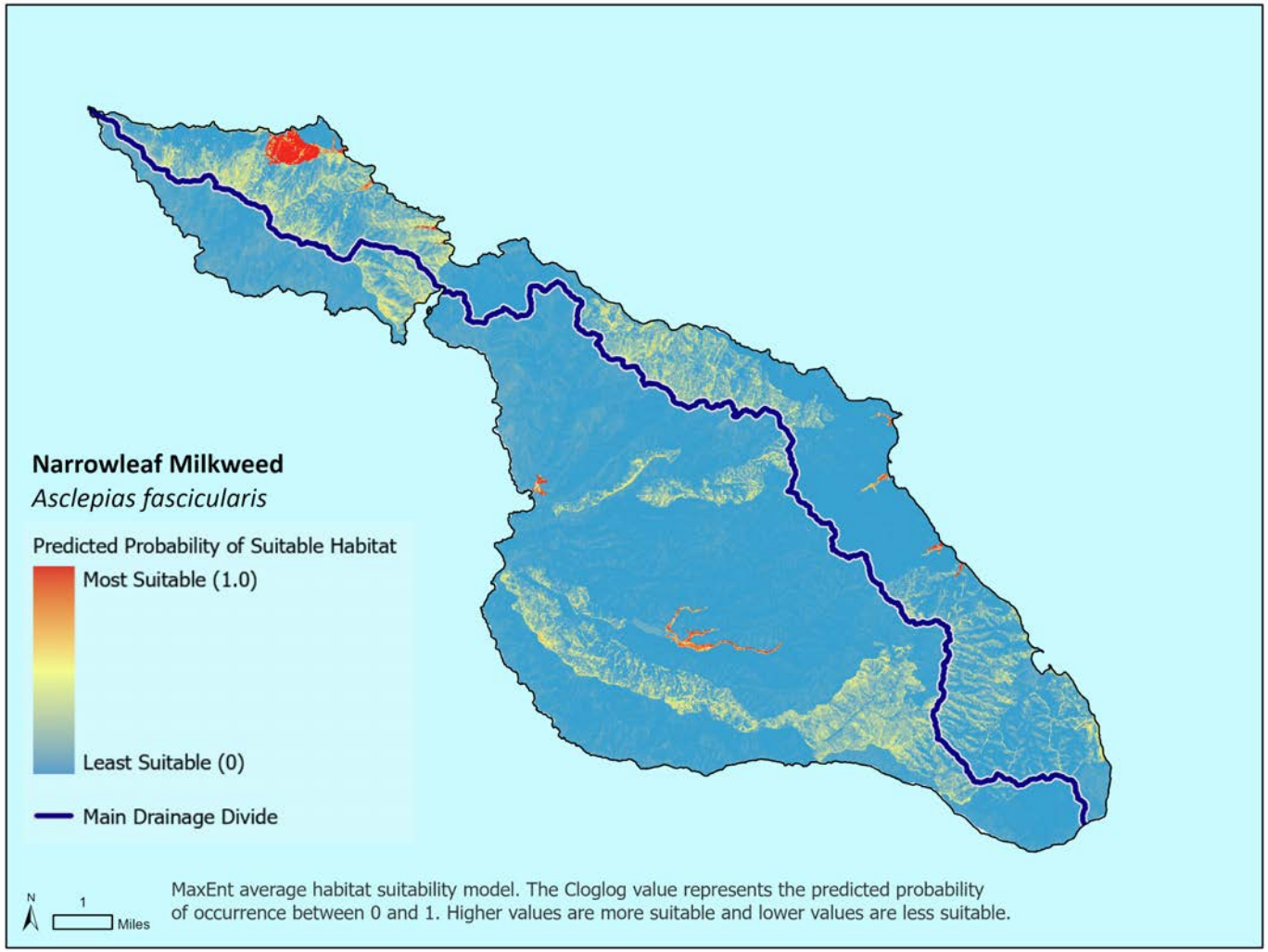

Figure 6-31 Potential Vegetation Map for Narrowleaf Milkweed (*Asclepias fascicularis*).

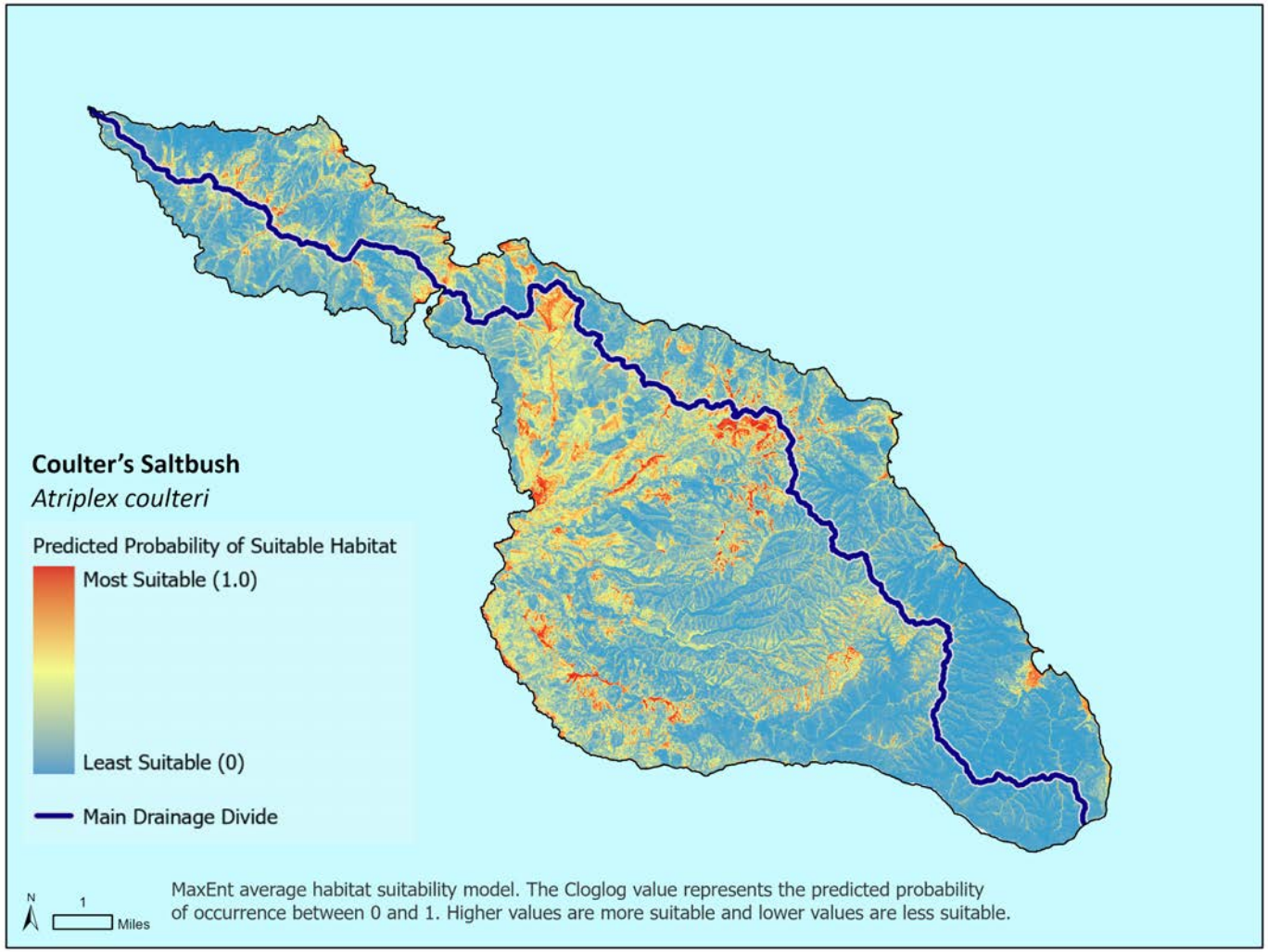

Figure 6-32 Potential Vegetation Map for Coulter's Saltbush (*Atriplex coulteri*).

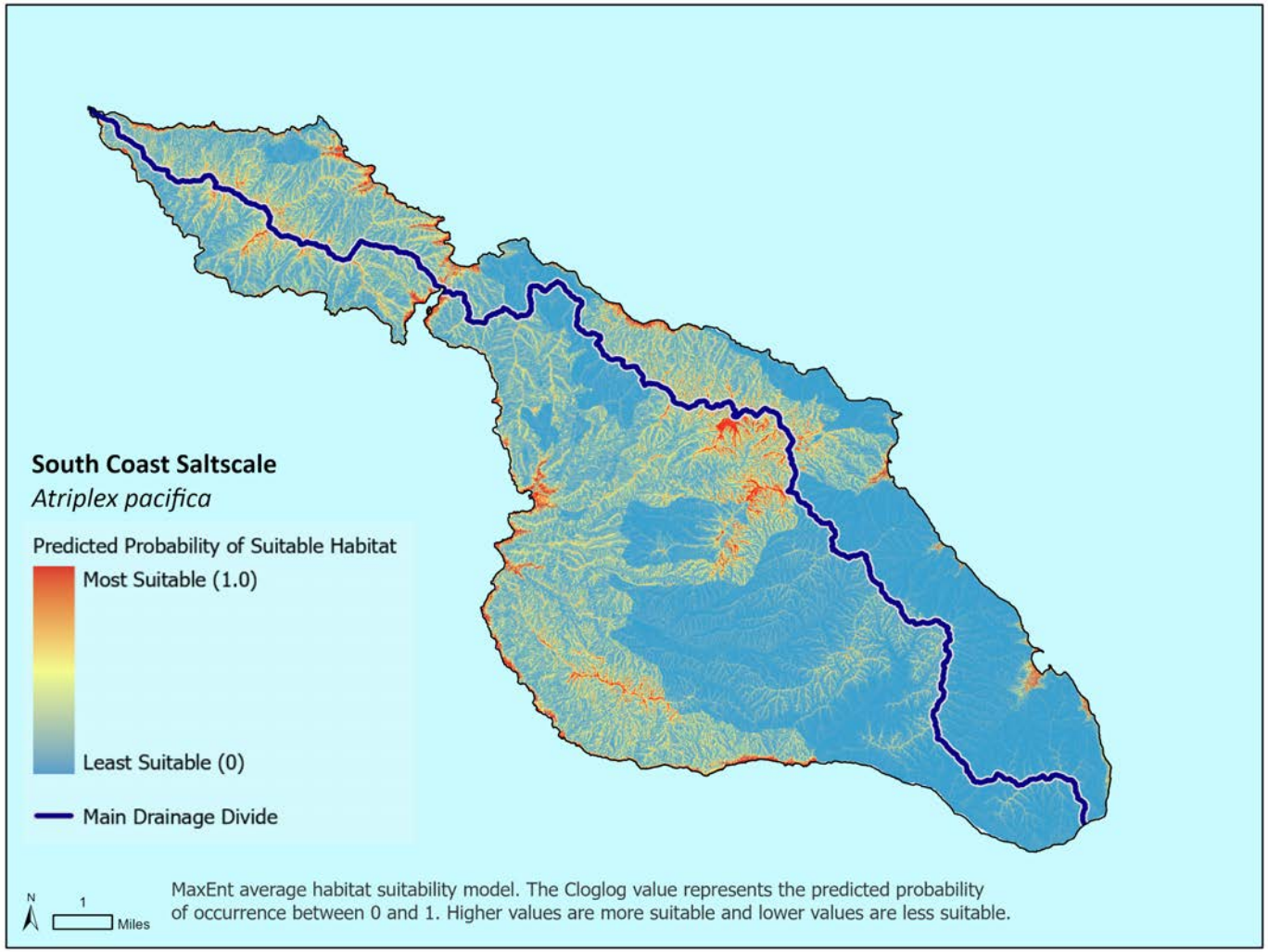

Figure 6-33 Potential Vegetation Map for South Coast Saltscale (*Atriplex pacifica*).

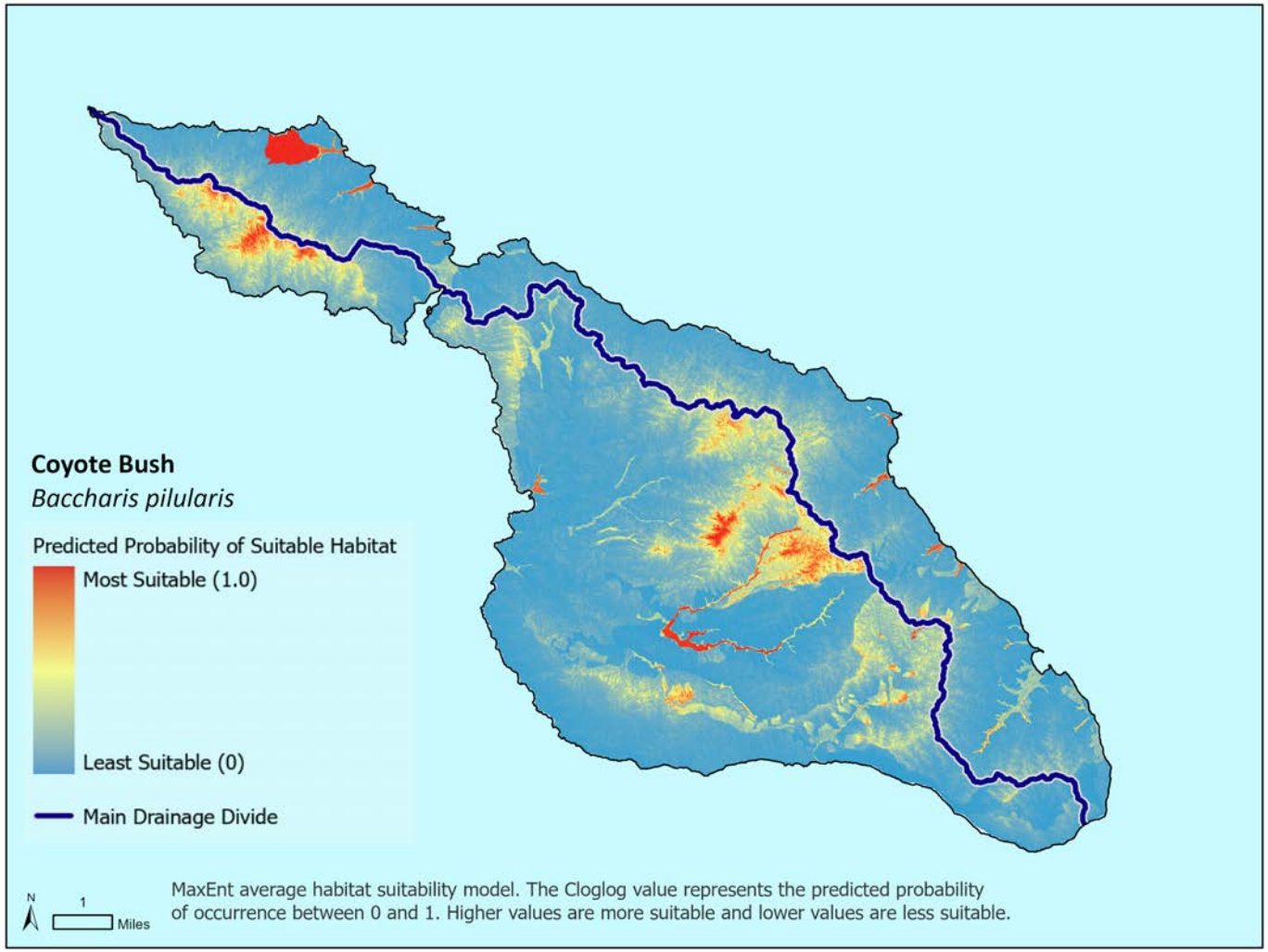

Figure 6-34 Potential Vegetation Map for Coyote Bush (*Baccharis pilularis*).

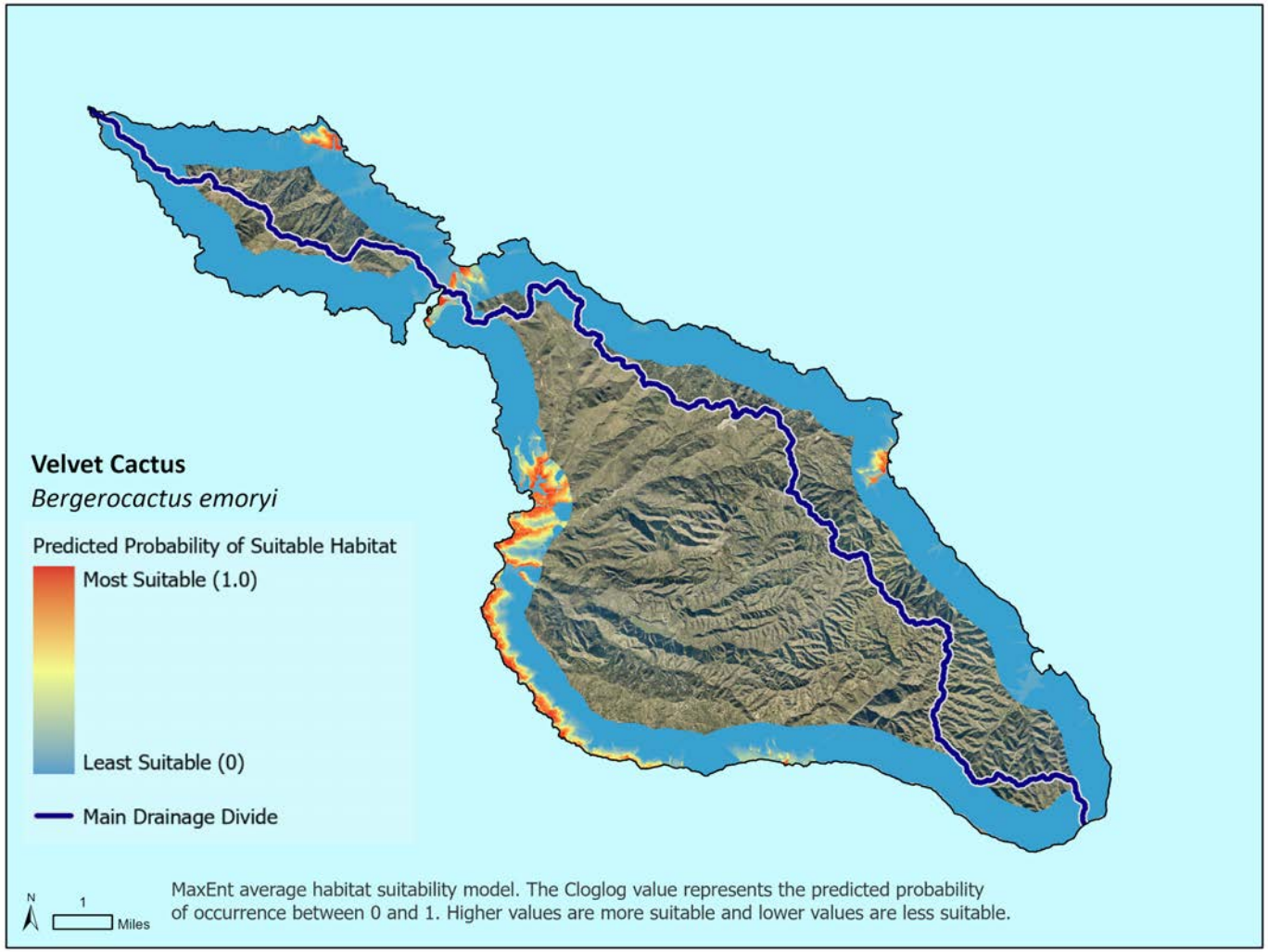

Figure 6-35 Potential Vegetation Map for Velvet Cactus (*Bergerocactus emoryi*), a Channel Island Endemic.

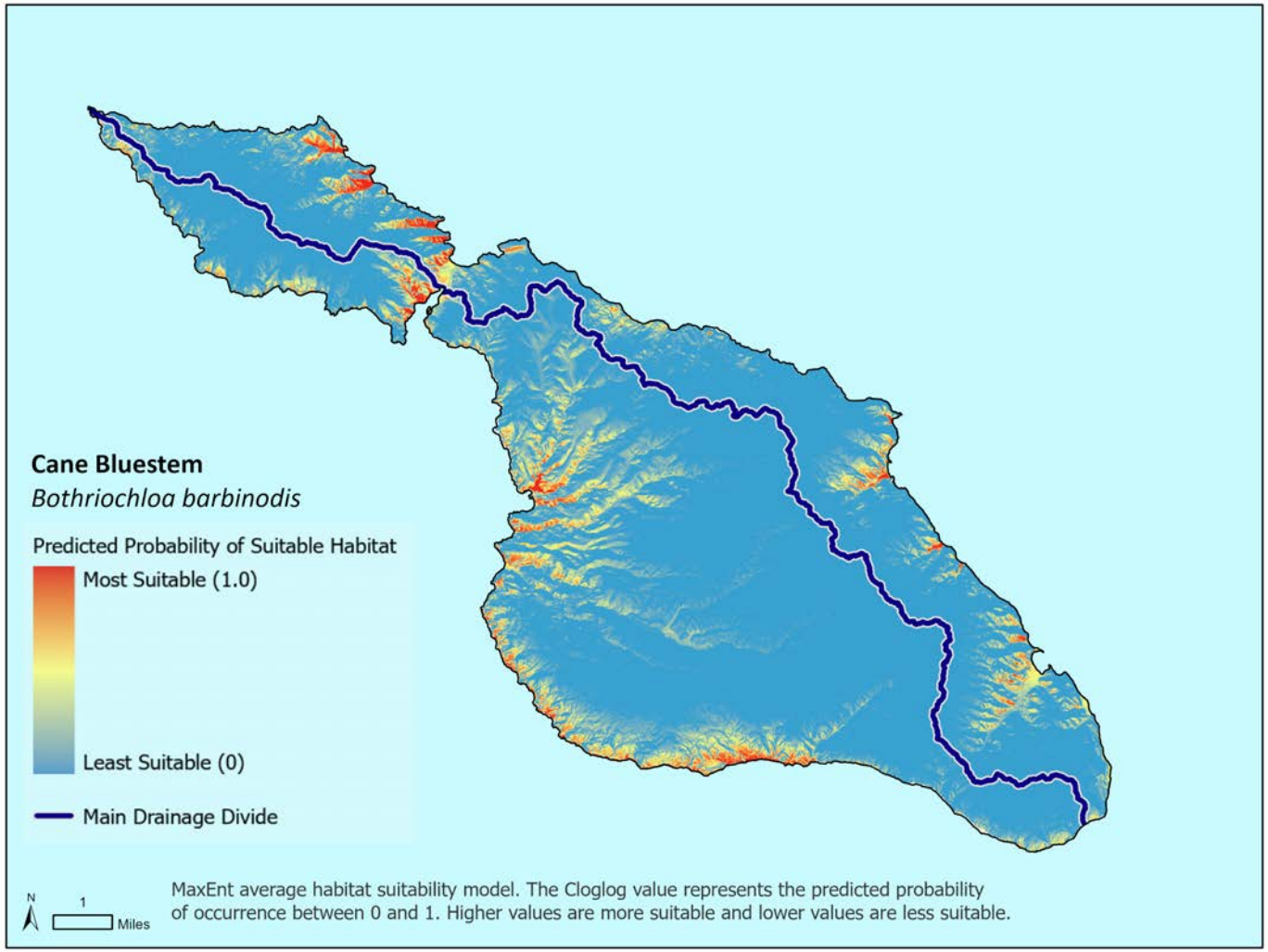

Figure 6-36 Potential Vegetation Map for Cane Bluestem (*Bothriochloa barbinodis*).

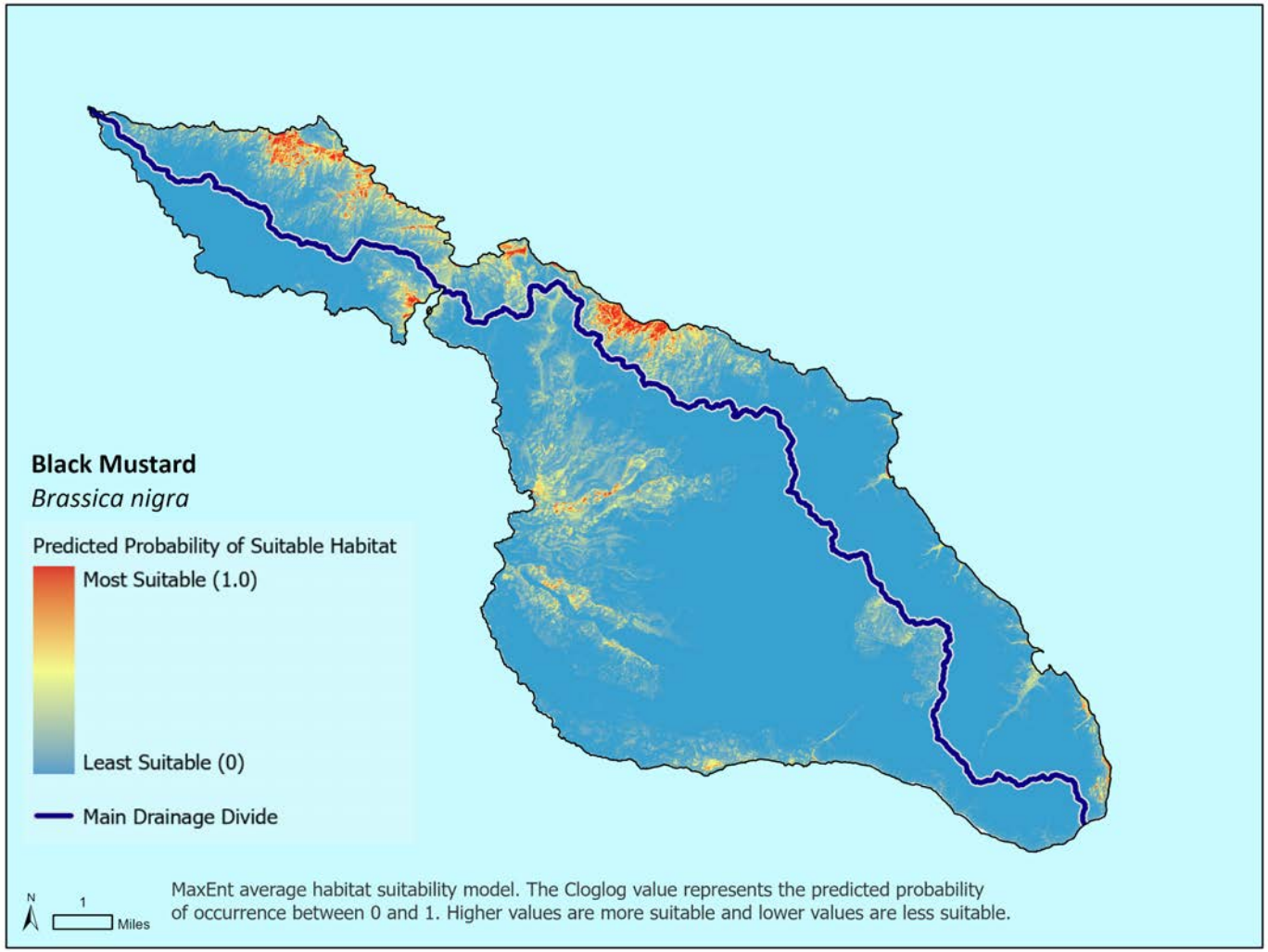

Figure 6-37 Potential Vegetation Map for Black Mustard (*Brassica nigra*), an Invasive Plant.

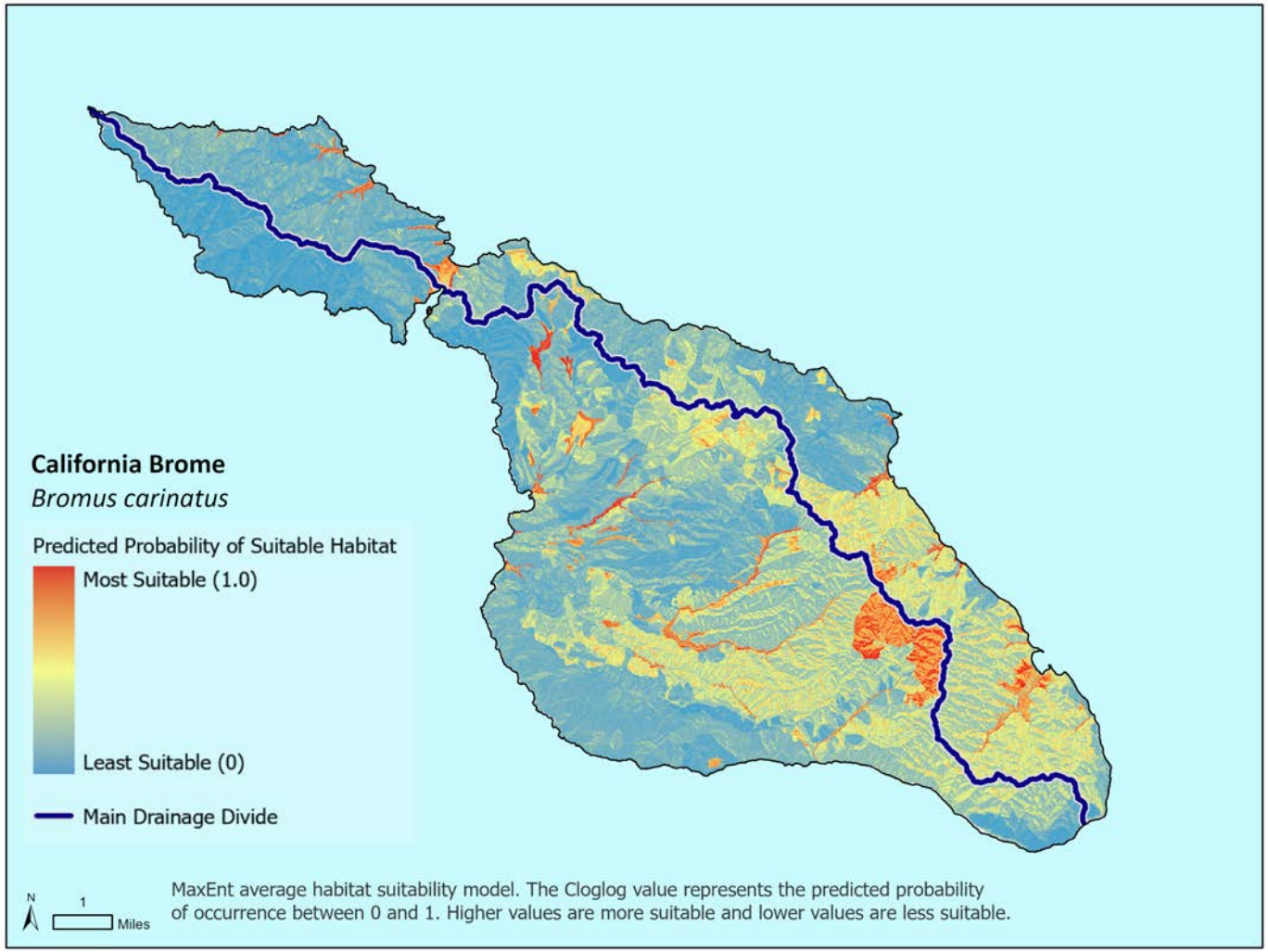

Figure 6-38 Potential Vegetation Map for California Brome (*Bromus sitchensis*).

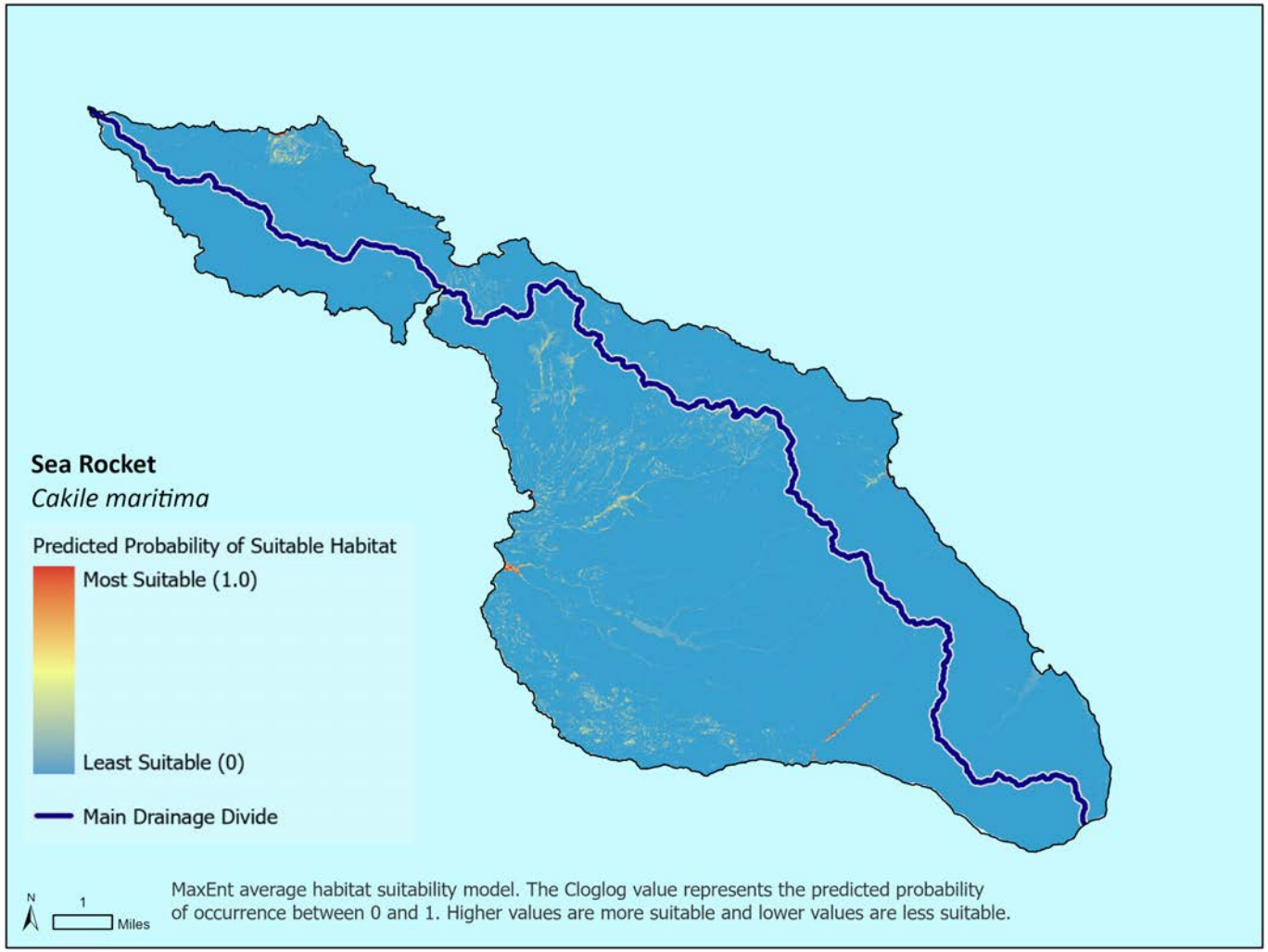

Figure 6-39 Potential Vegetation Map for Sea Rocket (*Cakile maritima*), an Invasive Plant.

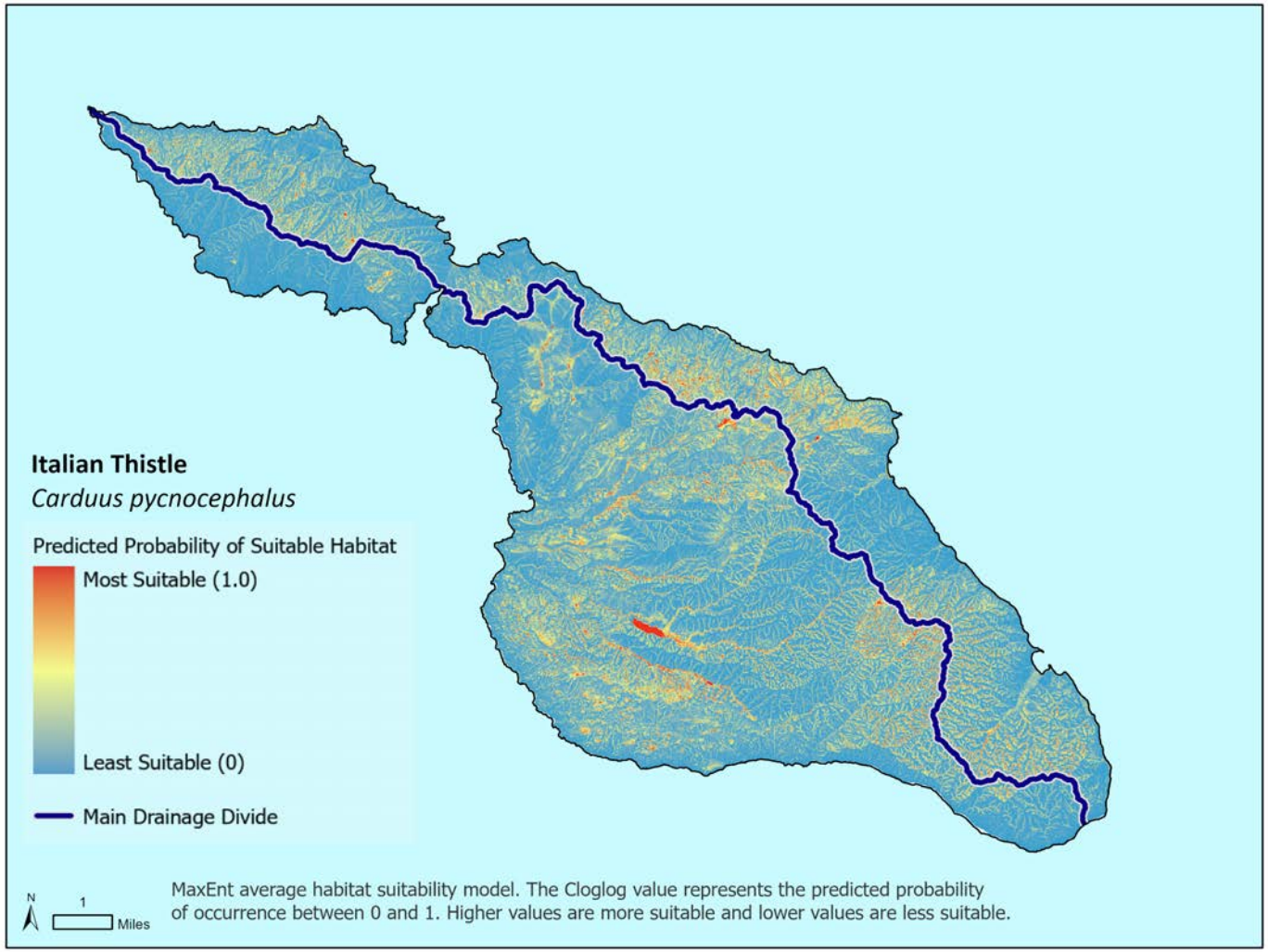

Figure 6-40 Potential Vegetation Map for Italian Thistle (*Carduus pycnocephalus*), an Invasive Plant.

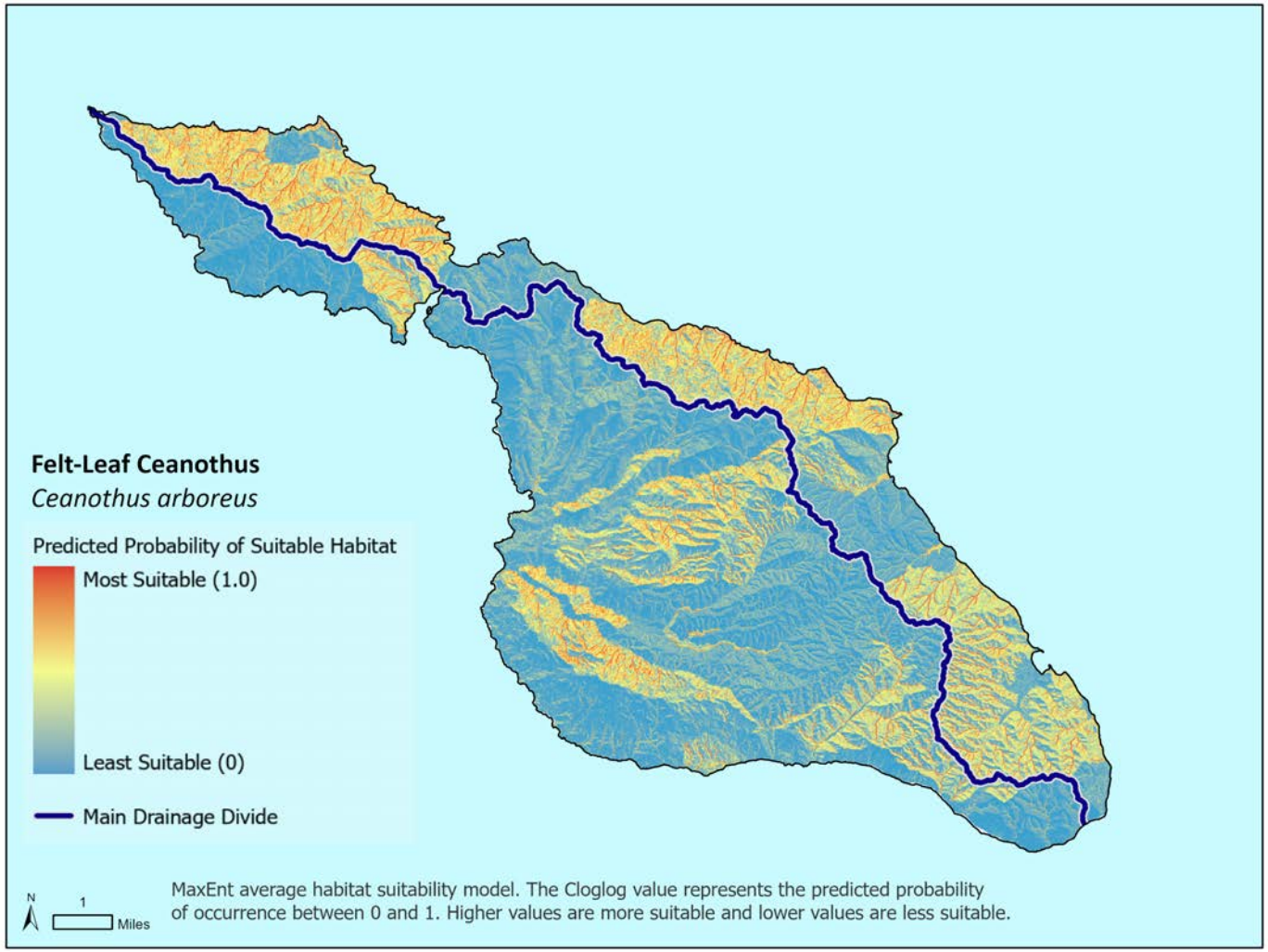

Figure 6-41 Potential Vegetation Map for Felt-Leaf Ceanothus (*Ceanothus arboreus*), a Channel Island Endemic.

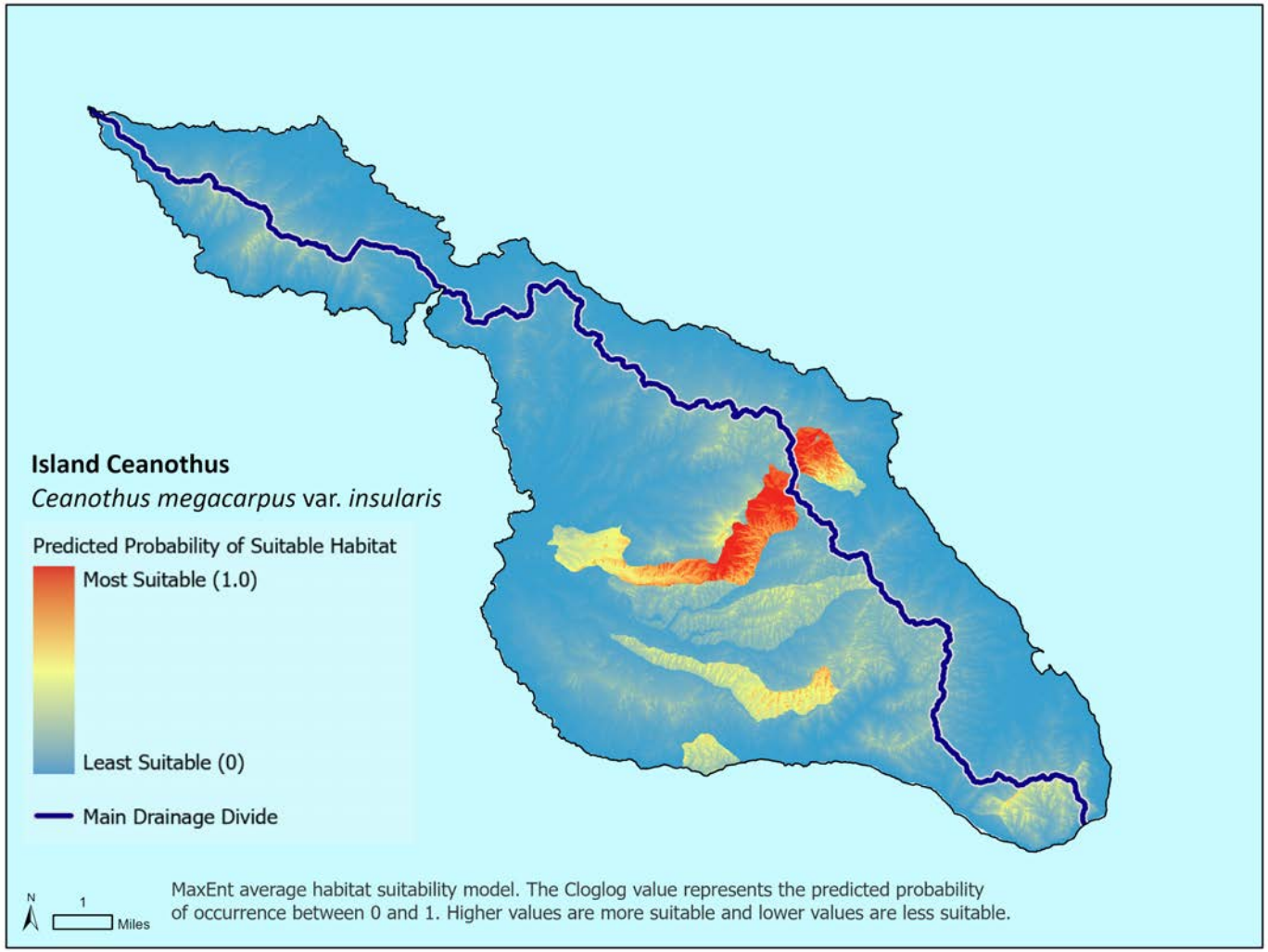

Figure 6-42 Potential Vegetation Map for Island Ceanothus (*Ceanothus megacarpus* var. *insularis*), a Channel Island Endemic.

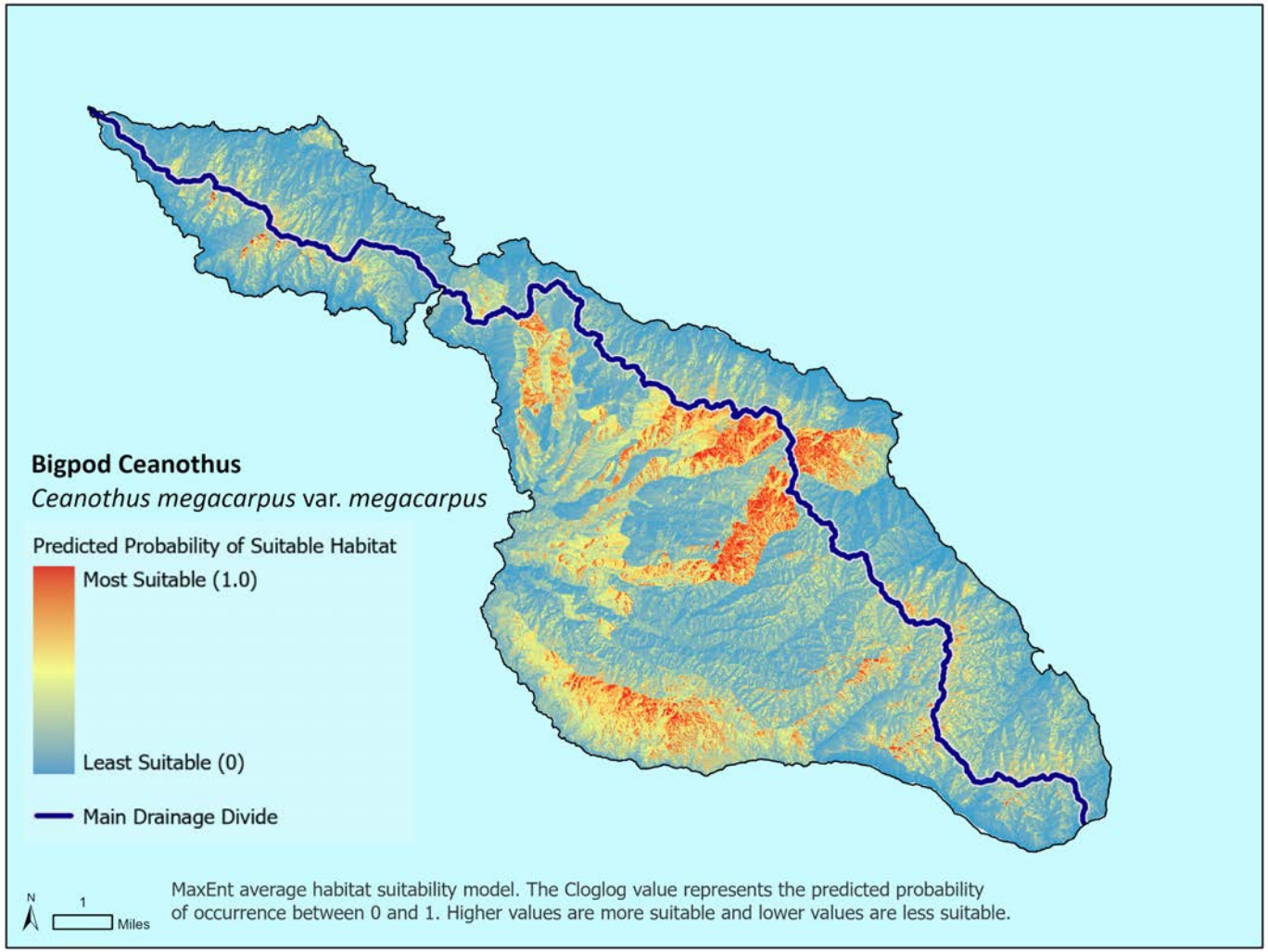

Figure 6-43 Potential Vegetation Map for Bigpod Ceanothus (*Ceanothus megacarpus* var. *megacarpus*).

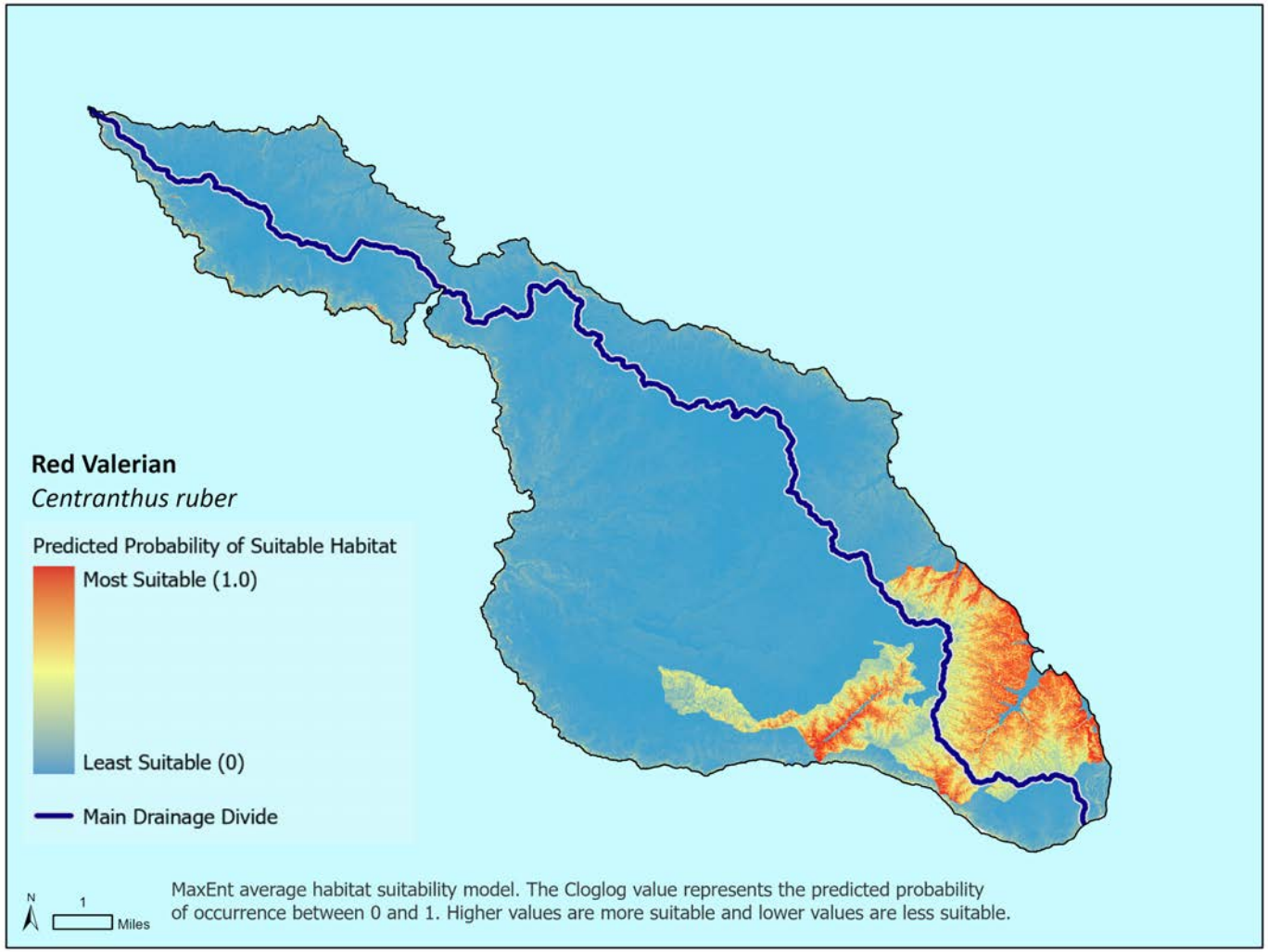

Figure 6-44 Potential Vegetation Map for Red Valerian (*Centranthus ruber*), an Invasive Plant.

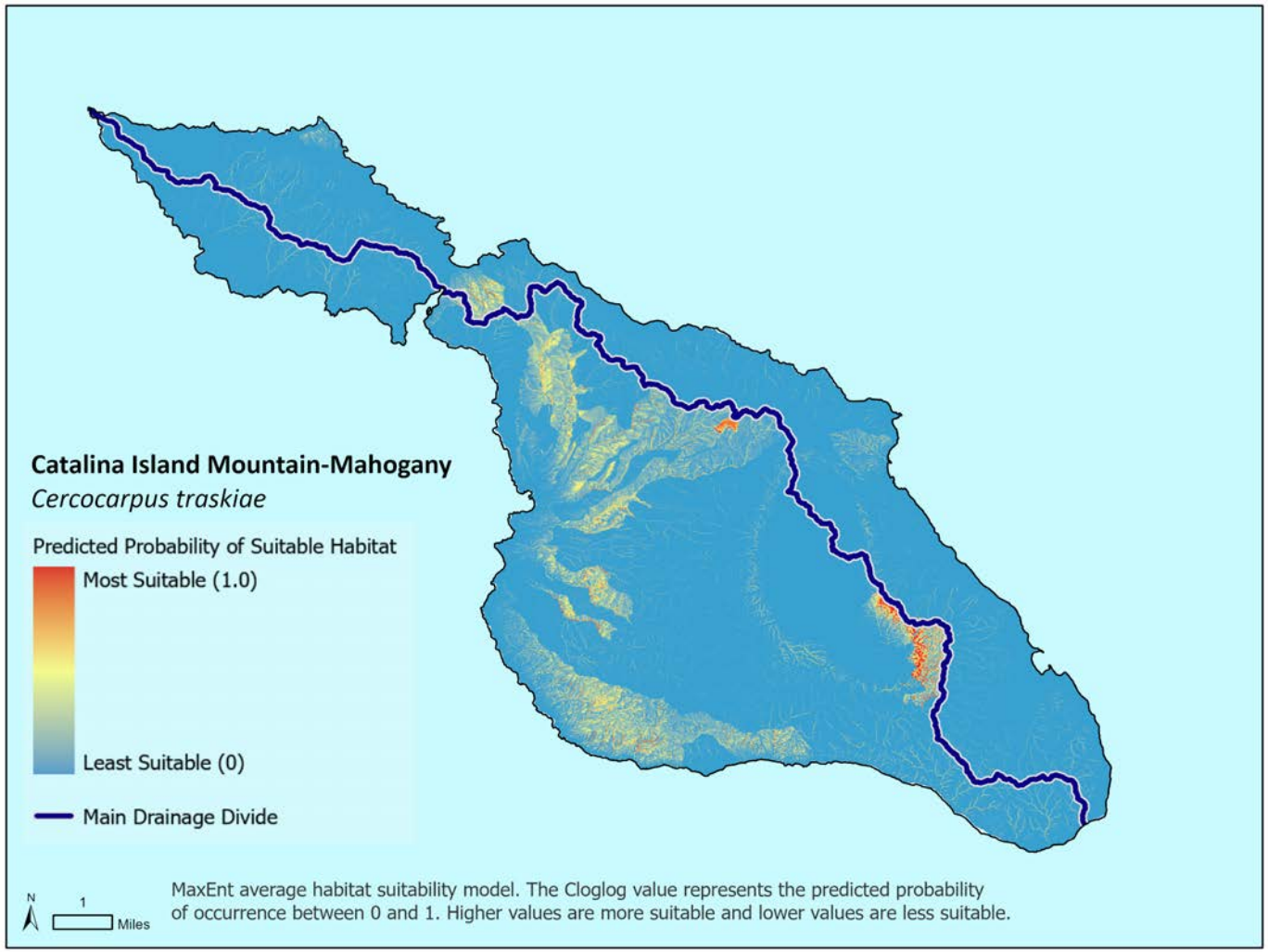

Figure 6-45 Potential Vegetation Map for Catalina Island Mountain-Mahogany (*Cercocarpus traskiae*), a Santa Catalina Island Endemic, State and Federally Endangered Plant.

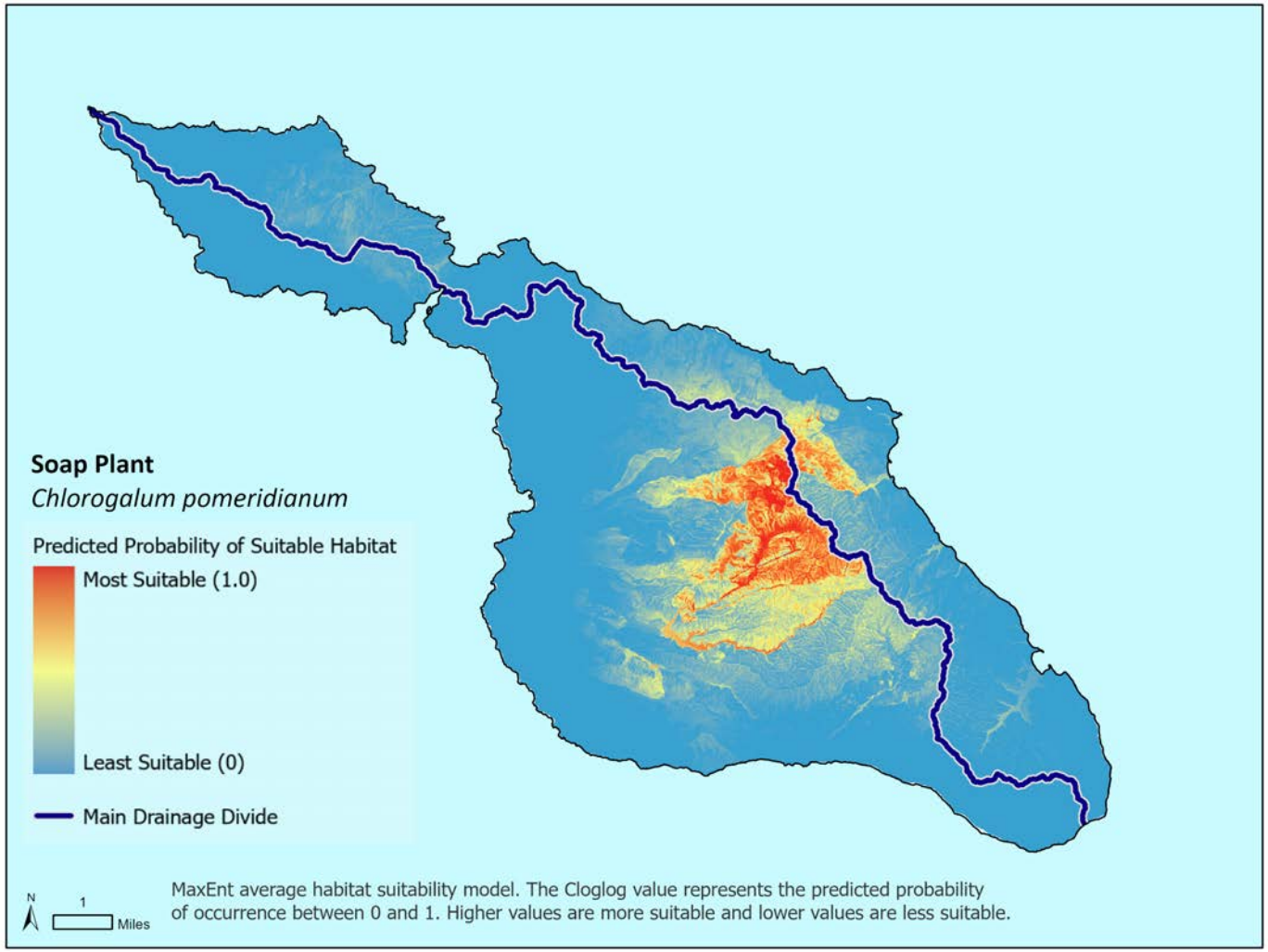

Figure 6-46 Potential Vegetation Map for Soap Plant (*Chlorogalum pomeridianum*).

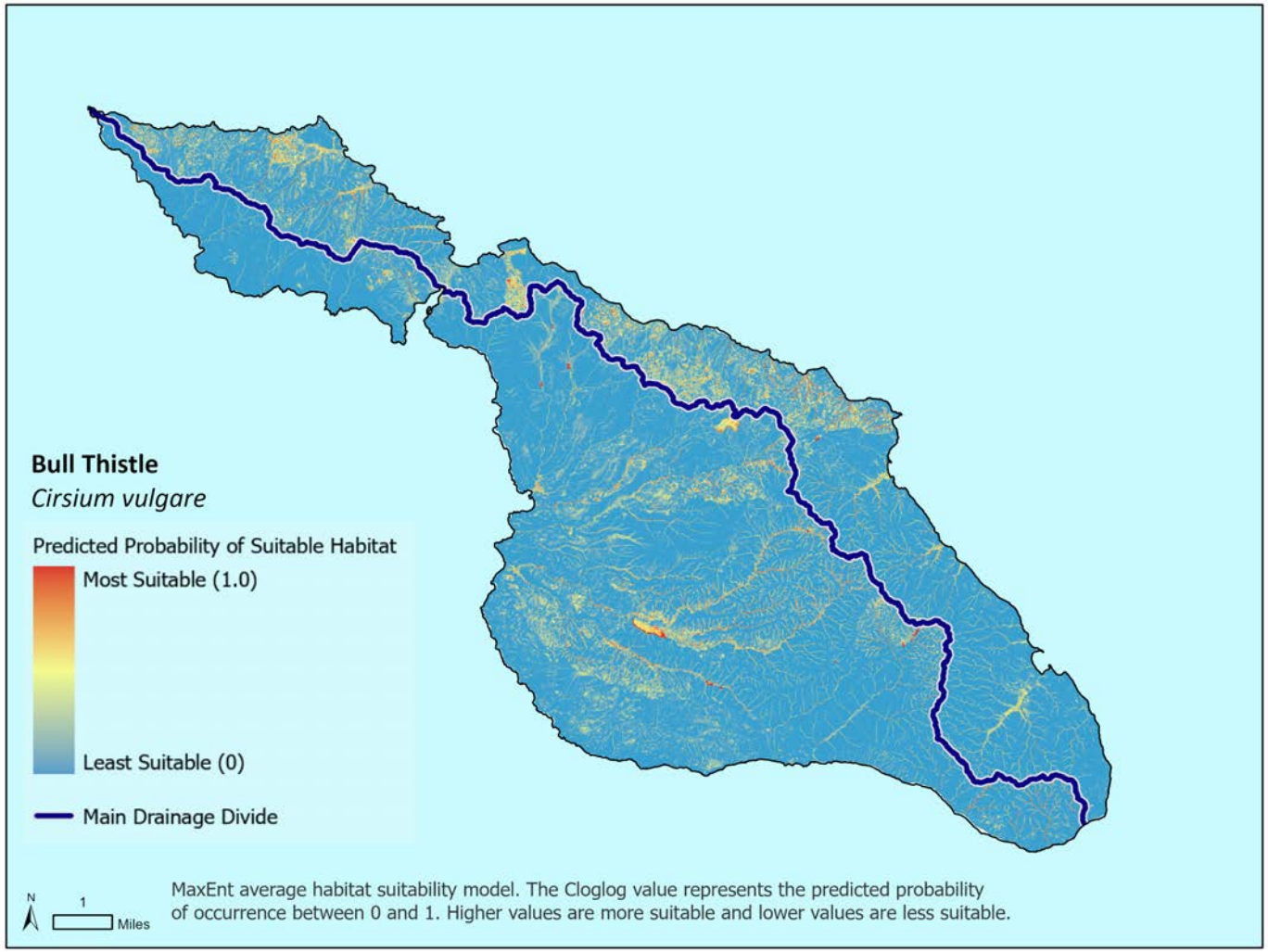

Figure 6-47 Potential Vegetation Map for Bull Thistle (*Cirsium vulgare*), an Invasive Plant.

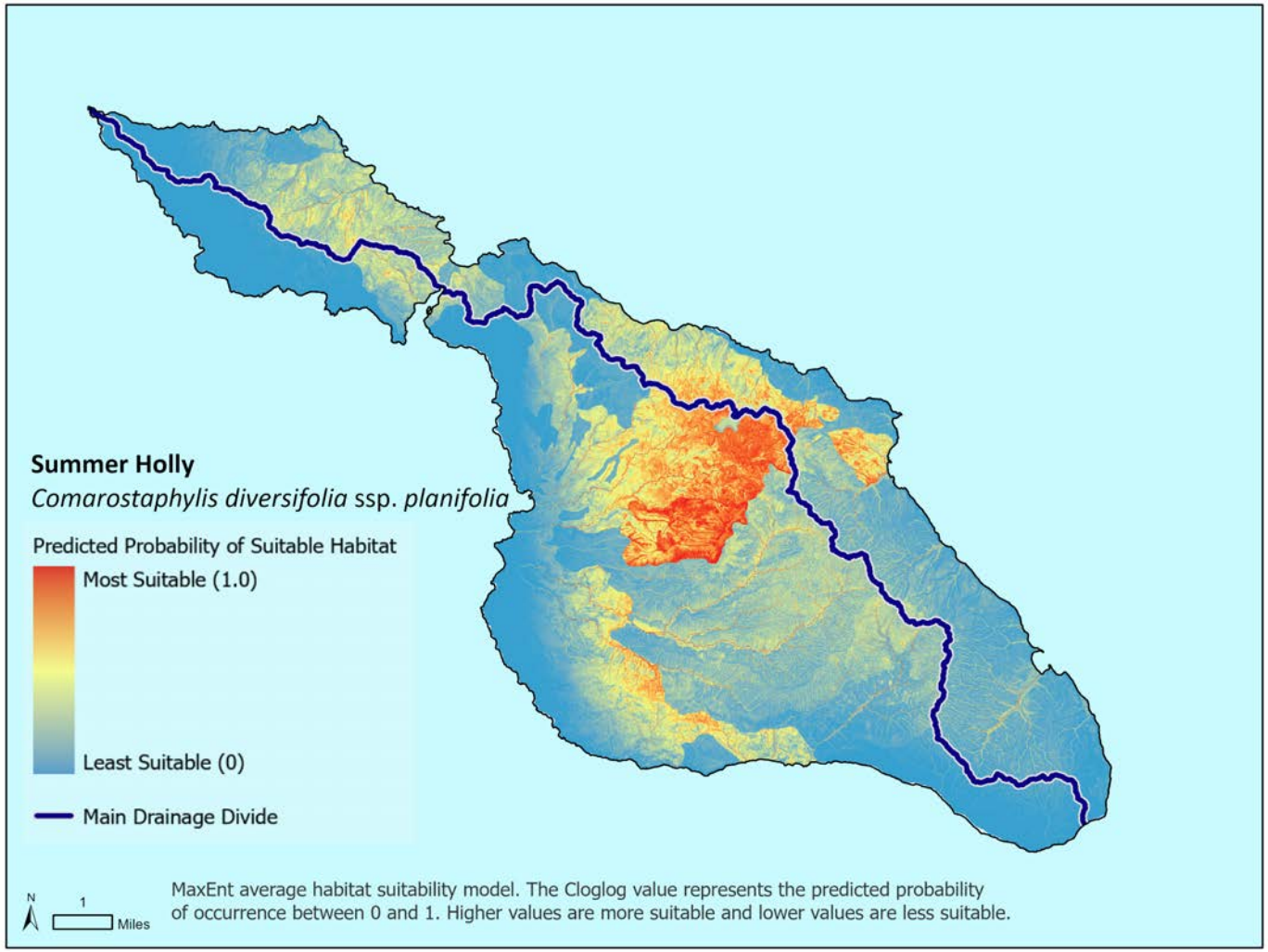

Figure 6-48 Potential Vegetation Map for Summer Holly (*Comarostaphylis diversifolia* subsp. *planifolia*).

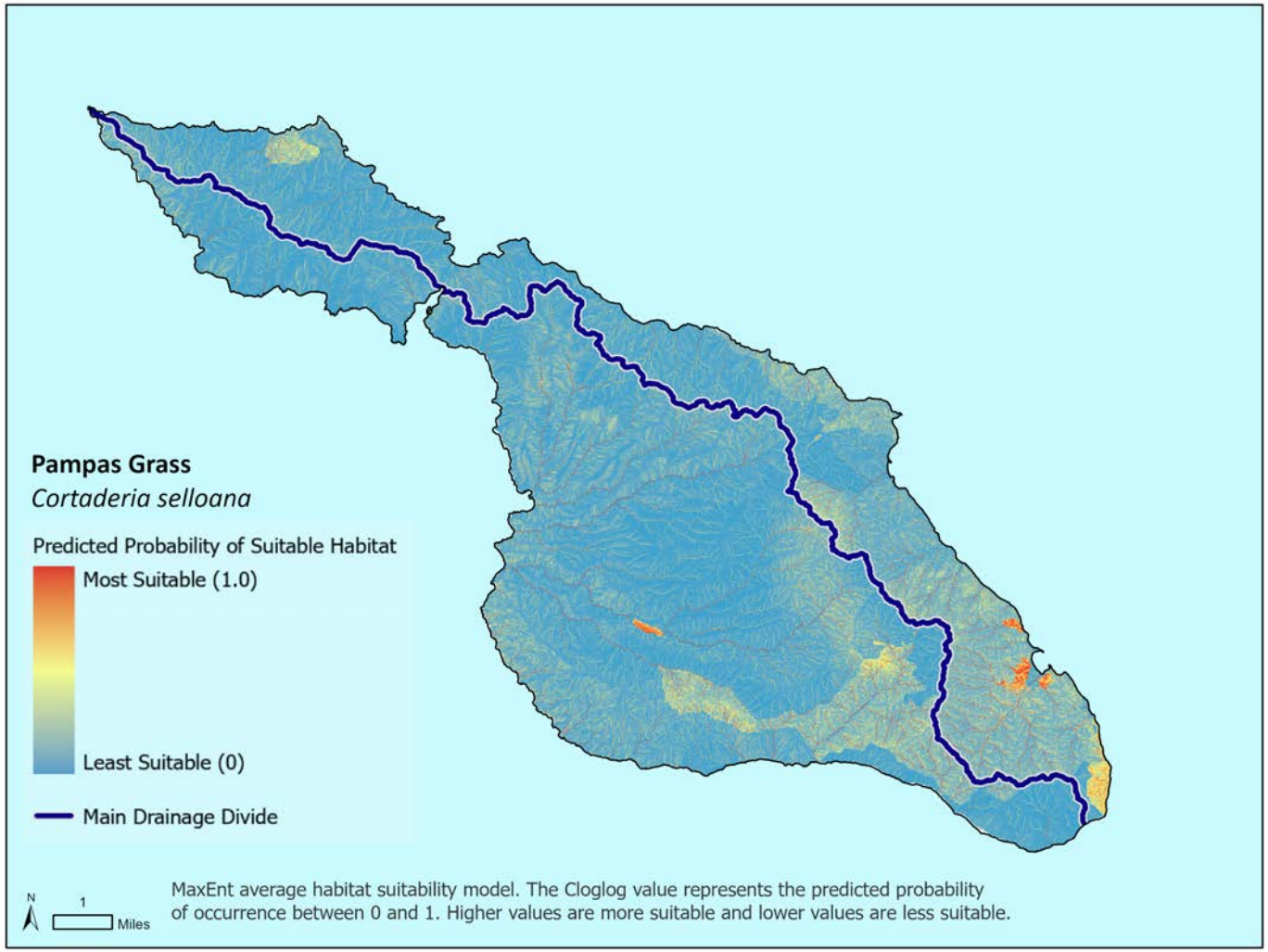

Figure 6-49 Potential Vegetation Map for Pampas Grass (*Cortaderia selloana*), an Invasive Plant.

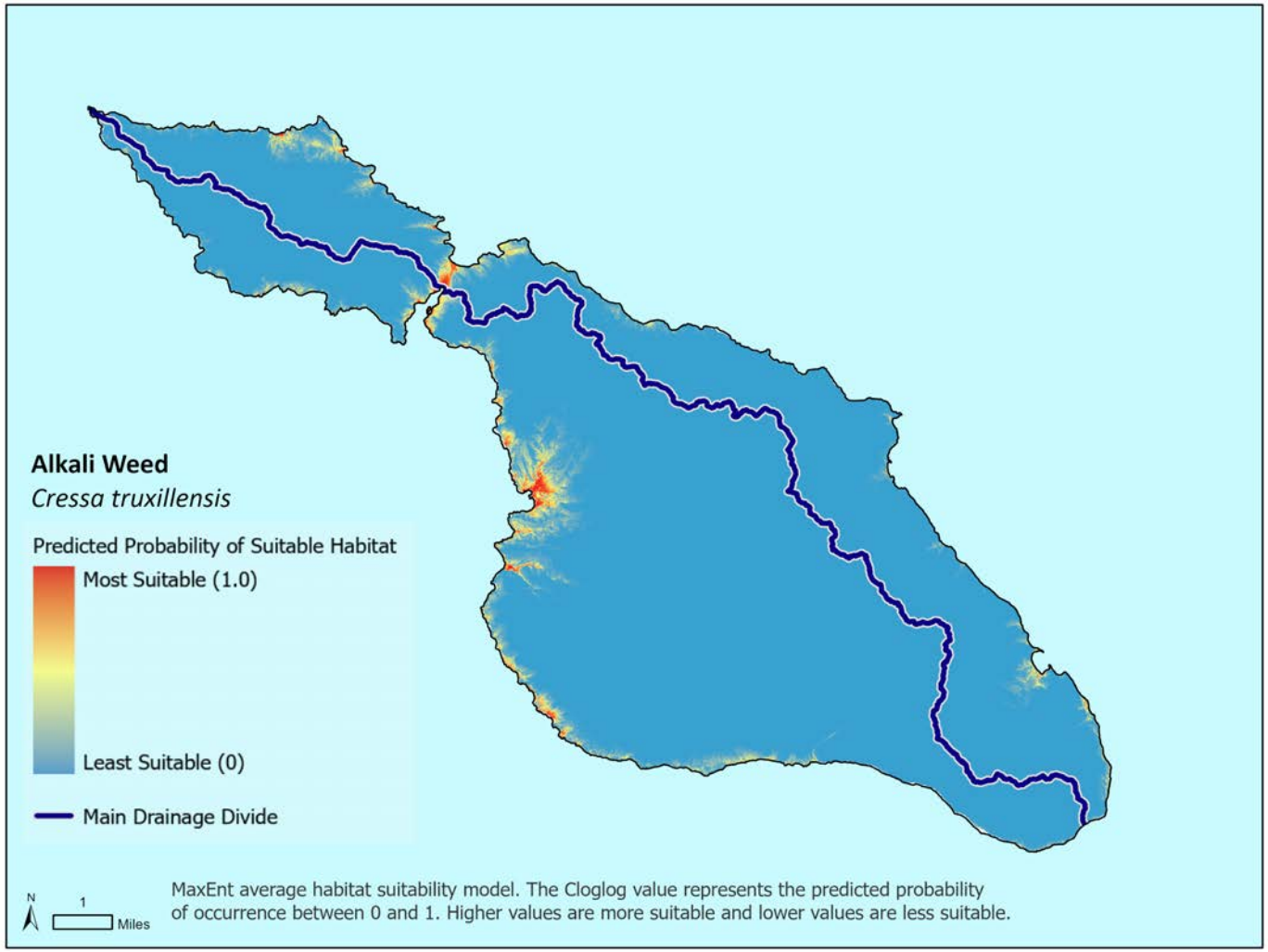

Figure 6-50 Potential Vegetation Map for Alkali Weed (*Cressa truxillensis*).

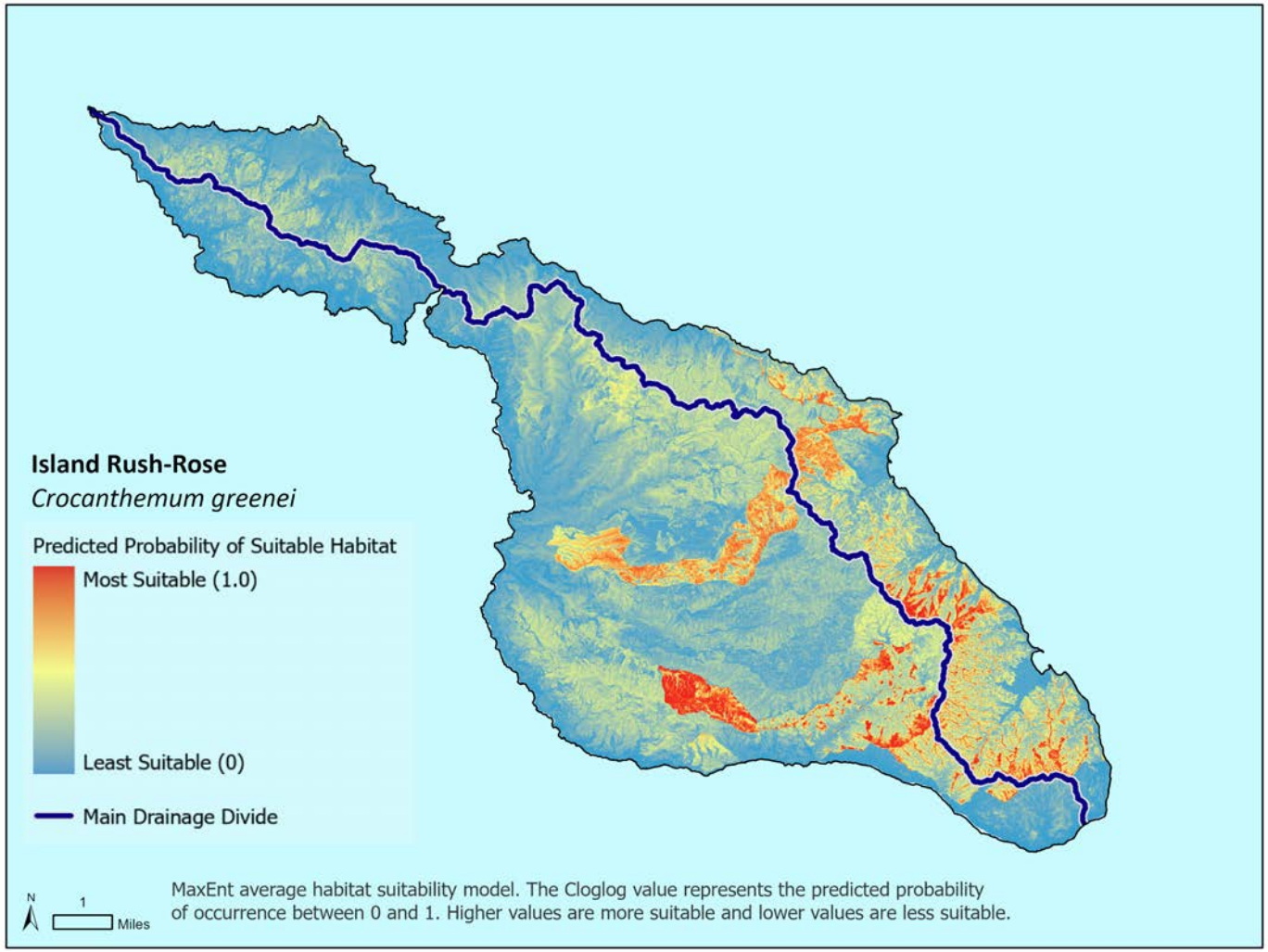

Figure 6-51 Potential Vegetation Map for Island Rush-Rose (*Crocanthemum greenei*), a Channel Island Endemic and Federally Threatened Plant.

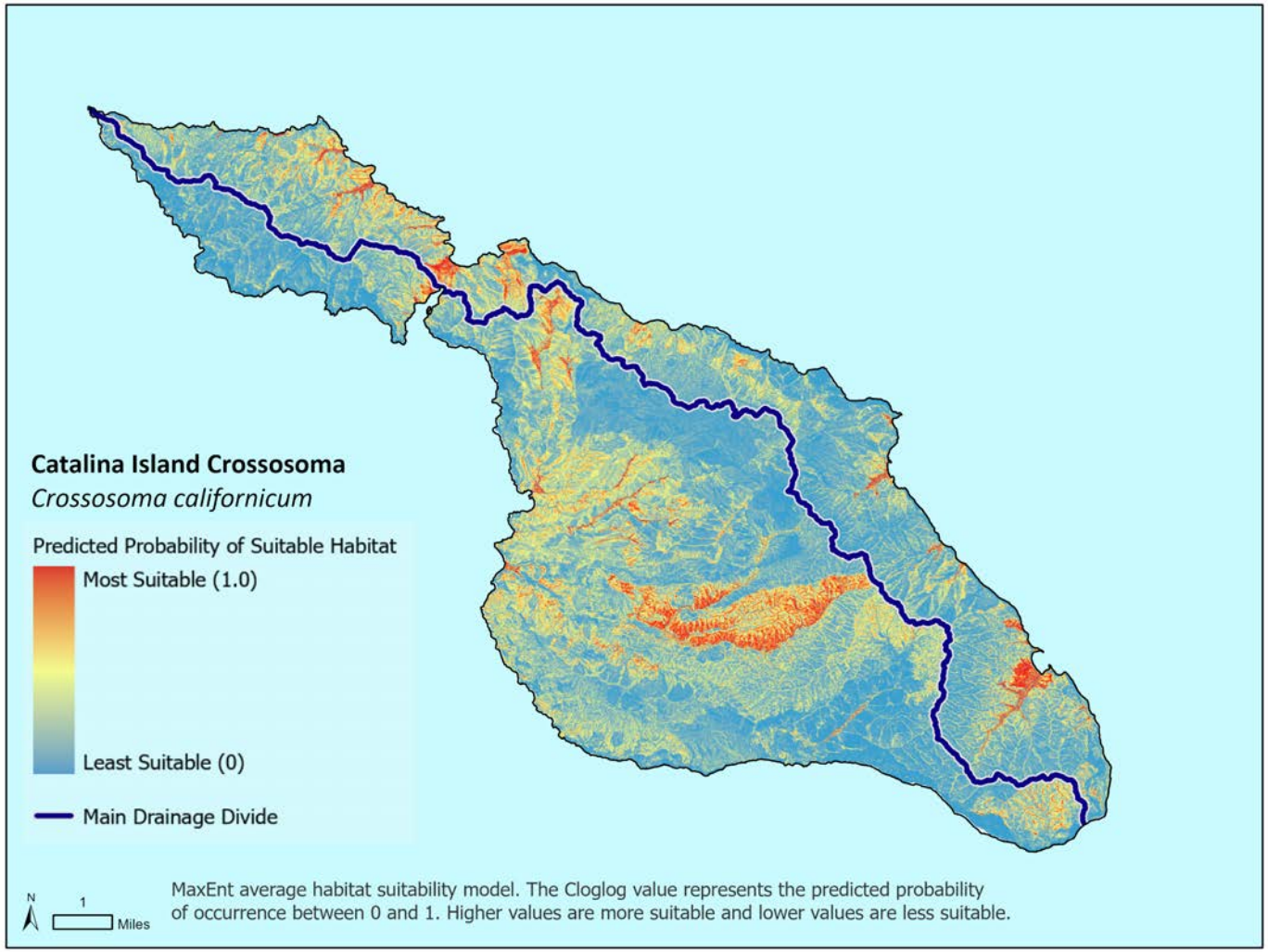

Figure 6-52 Potential Vegetation Map for Catalina Island Crossosoma (*Crossosoma californicum*), Endemic to the Channel Islands and the Palos Verdes Peninsula.

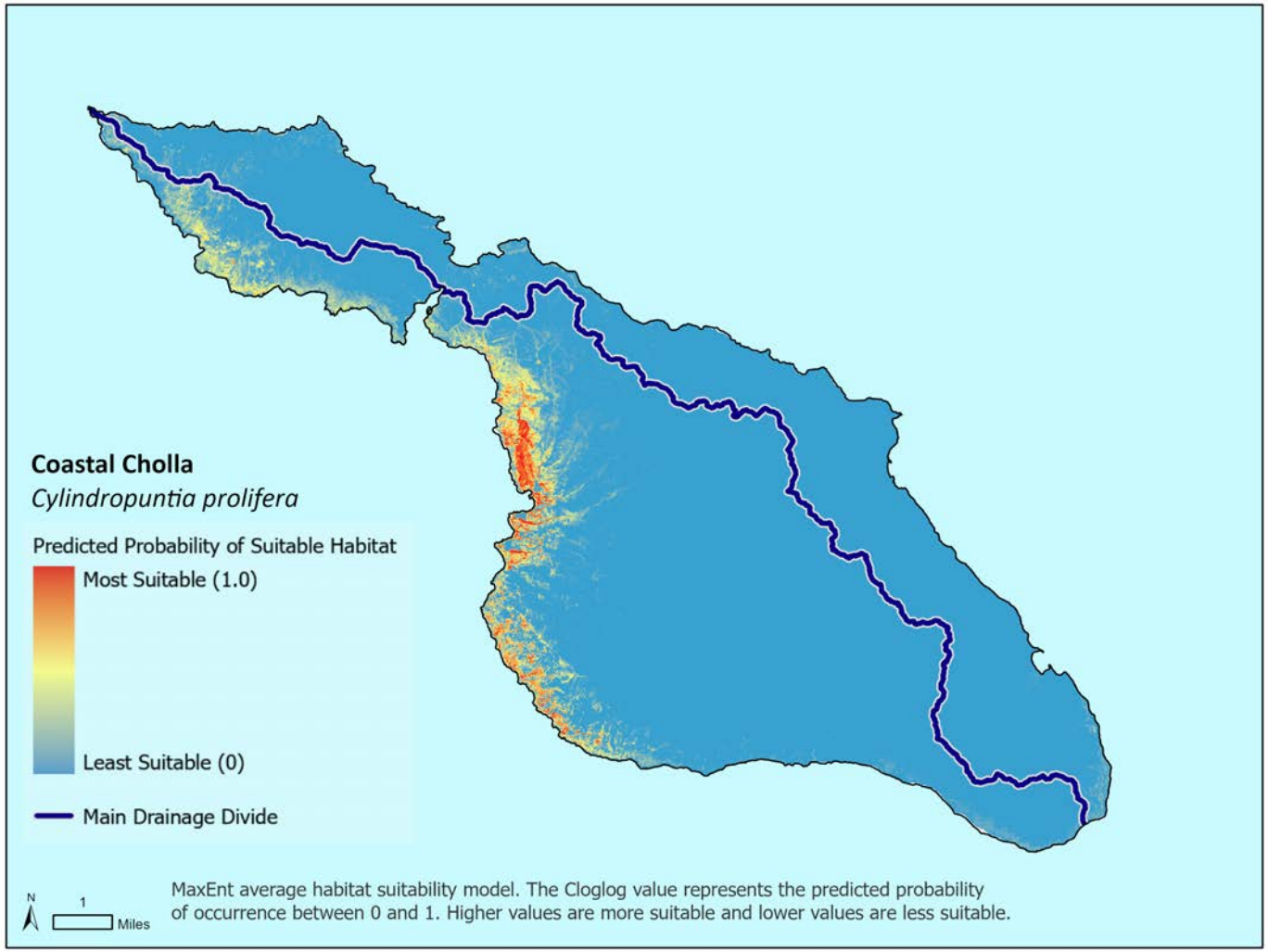

Figure 6-53 Potential Vegetation Map for Coastal Cholla (*Cylindropuntia prolifera*).

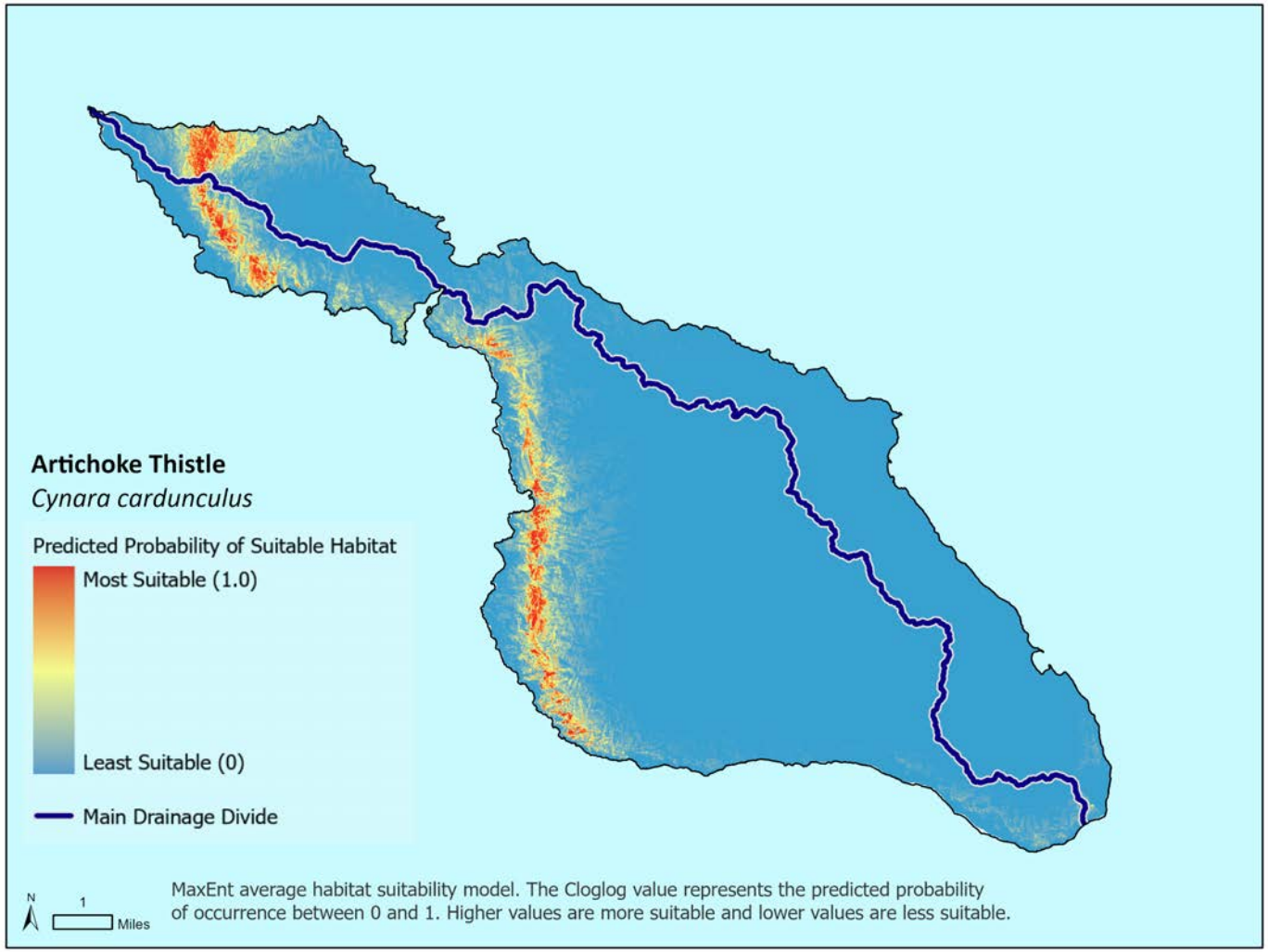

Figure 6-54 Potential Vegetation Map for Artichoke Thistle (*Cynara cardunculus*), an Invasive Plant.

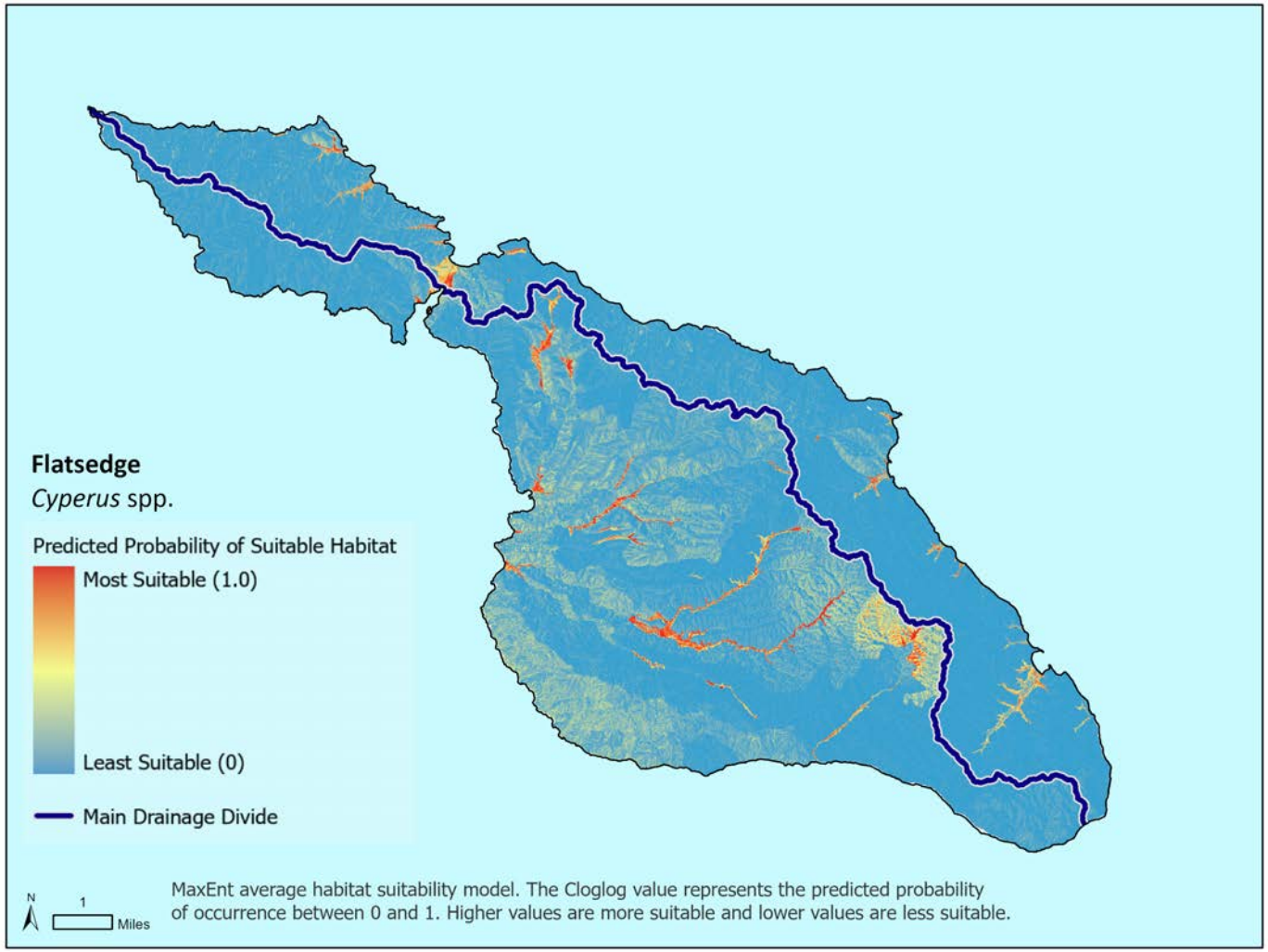

Figure 6-55 Potential Vegetation Map for Flatsedge (*Cyperus* spp.).

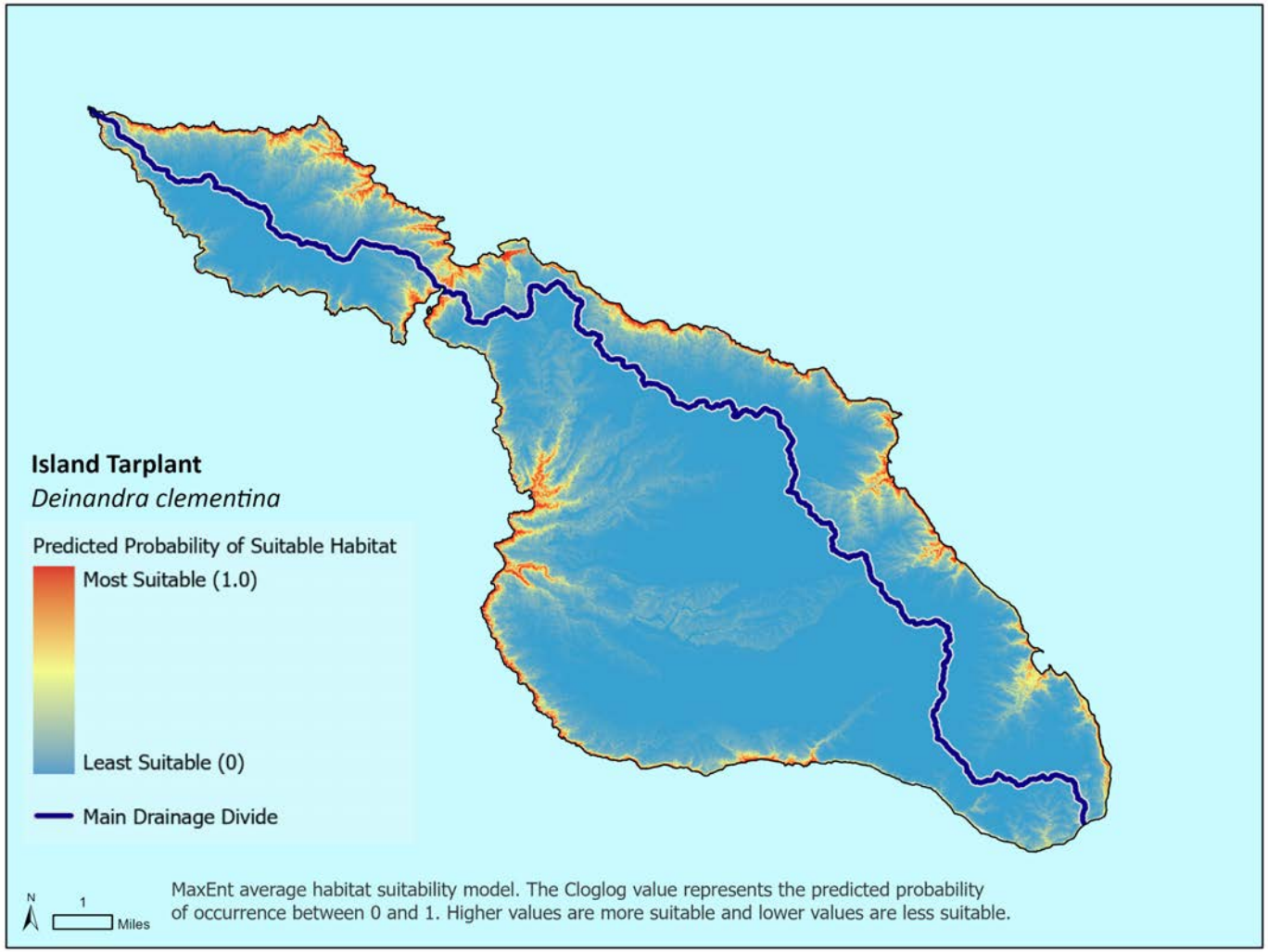

Figure 6-56 Potential Vegetation Map for Island Tarplant (*Deinandra clementina*), a Channel Island Endemic.

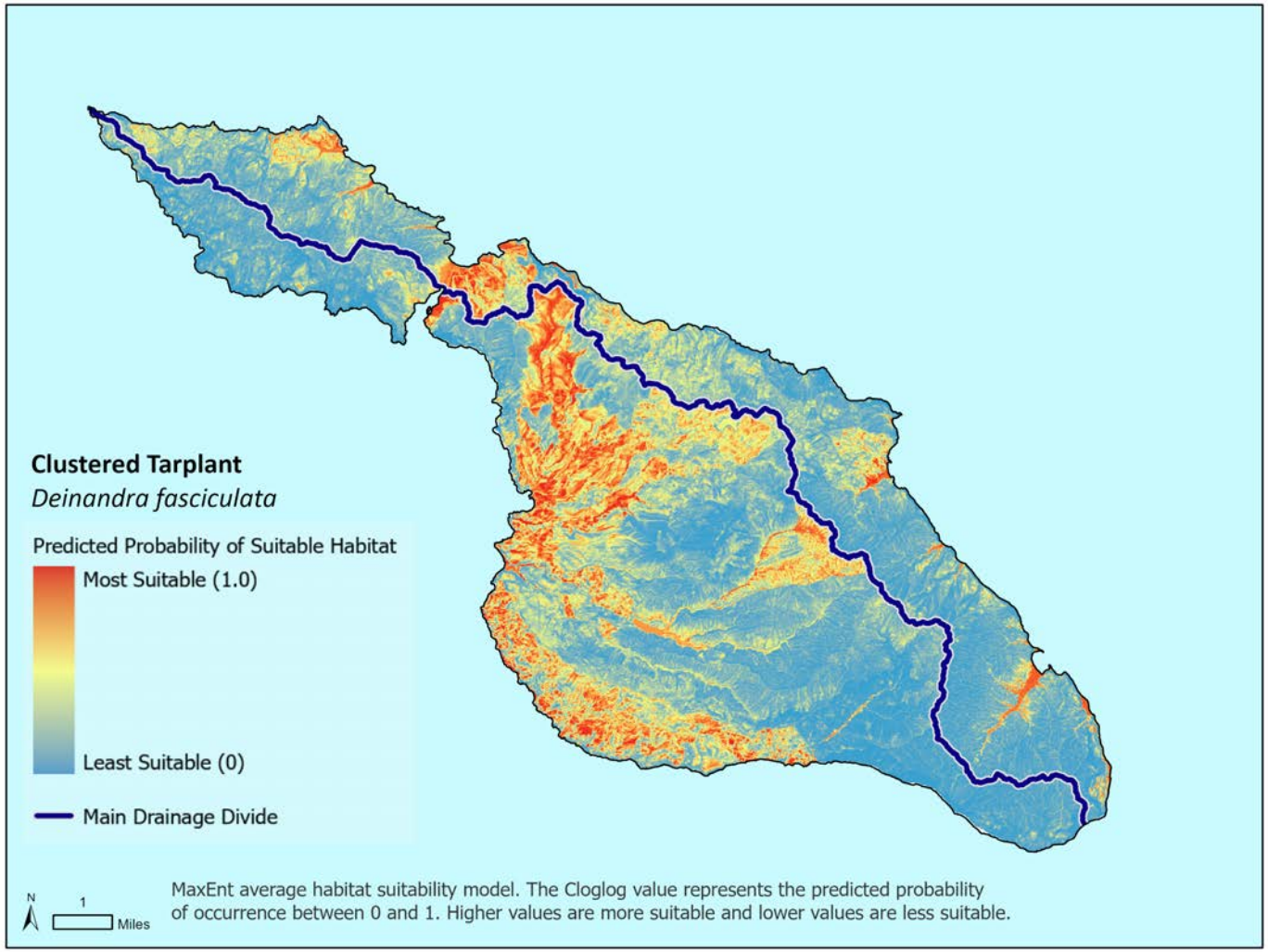

Figure 6-57 Potential Vegetation Map for Clustered Tarplant (*Deinandra fasciculata*).

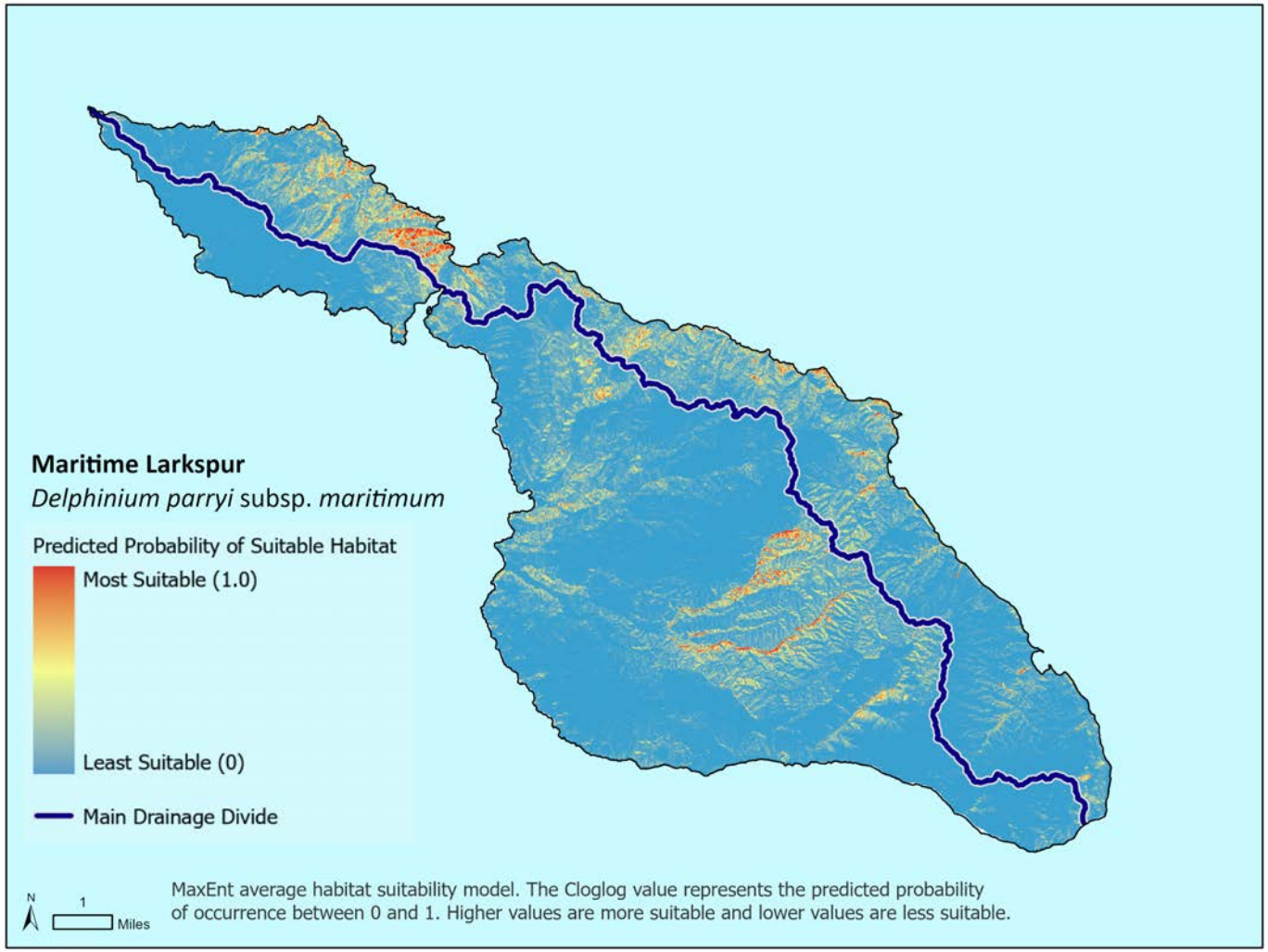

Figure 6-58 Potential Vegetation Map for Maritime Larkspur (*Delphinium parryi* subsp. *maritimum*).

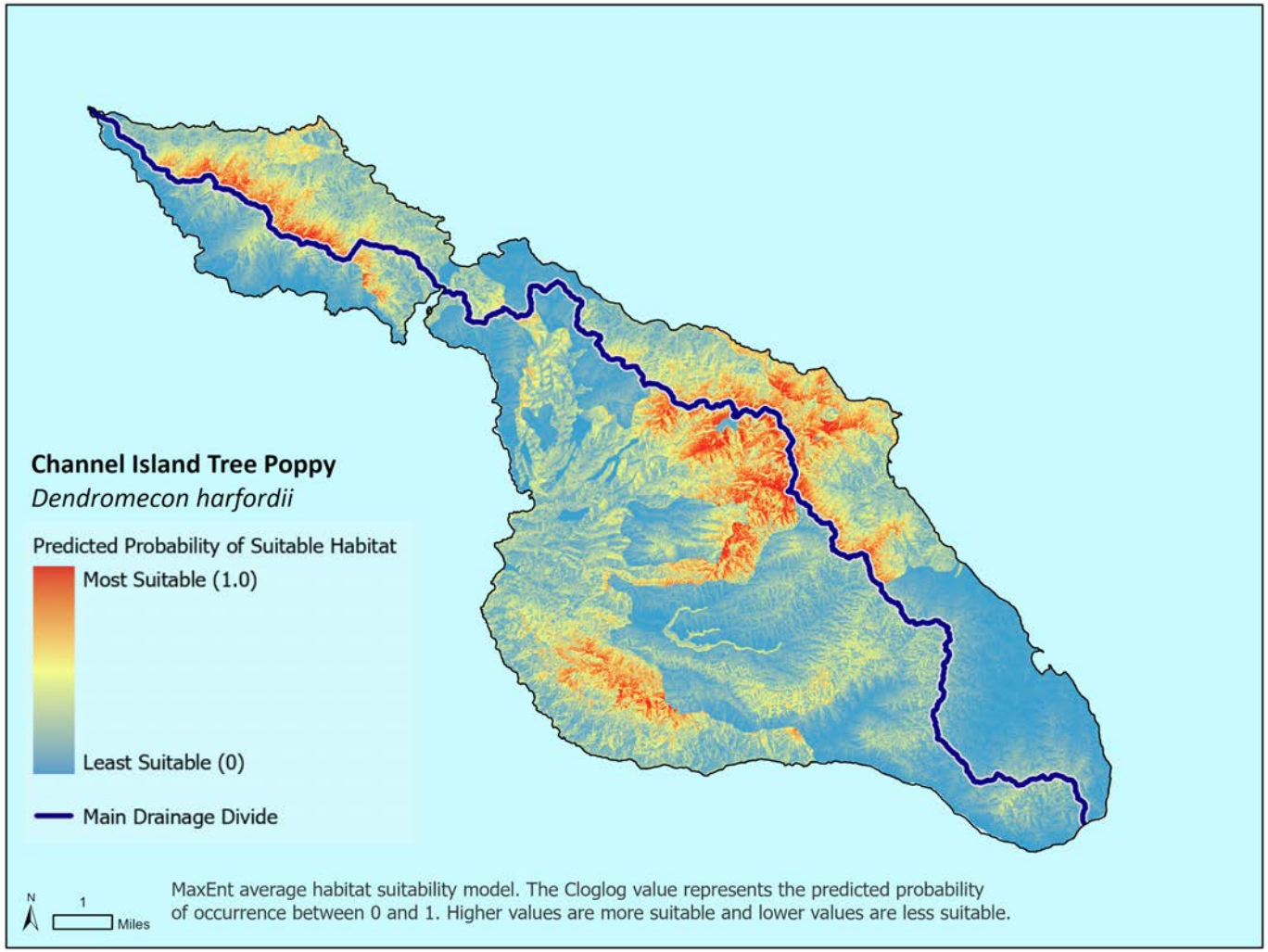

Figure 6-59 Potential Vegetation Map for Channel Island Tree Poppy (*Dendromecon harfordii*).

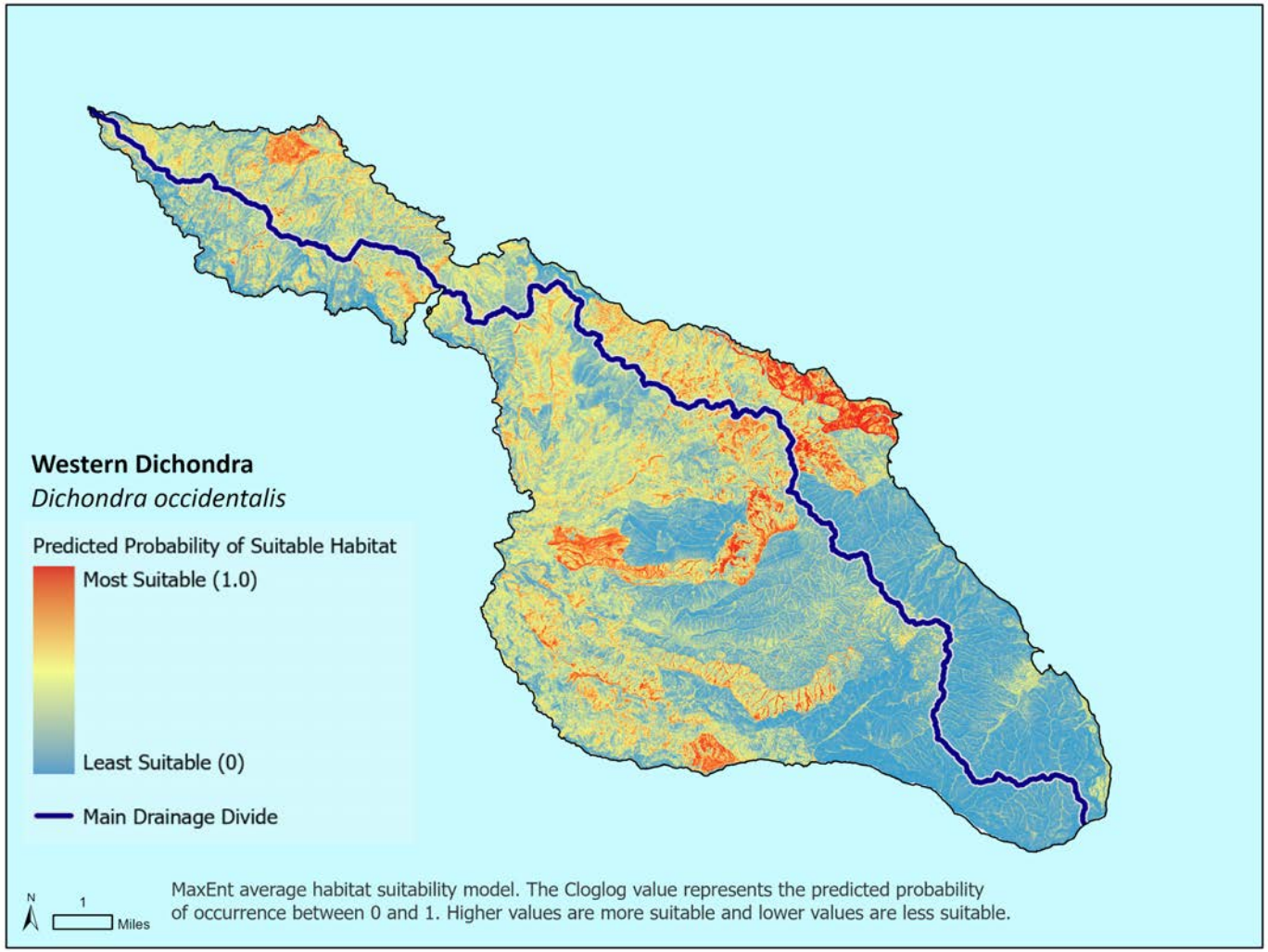

Figure 6-60 Potential Vegetation Map for Western Dichondra (*Dichondra occidentalis*).

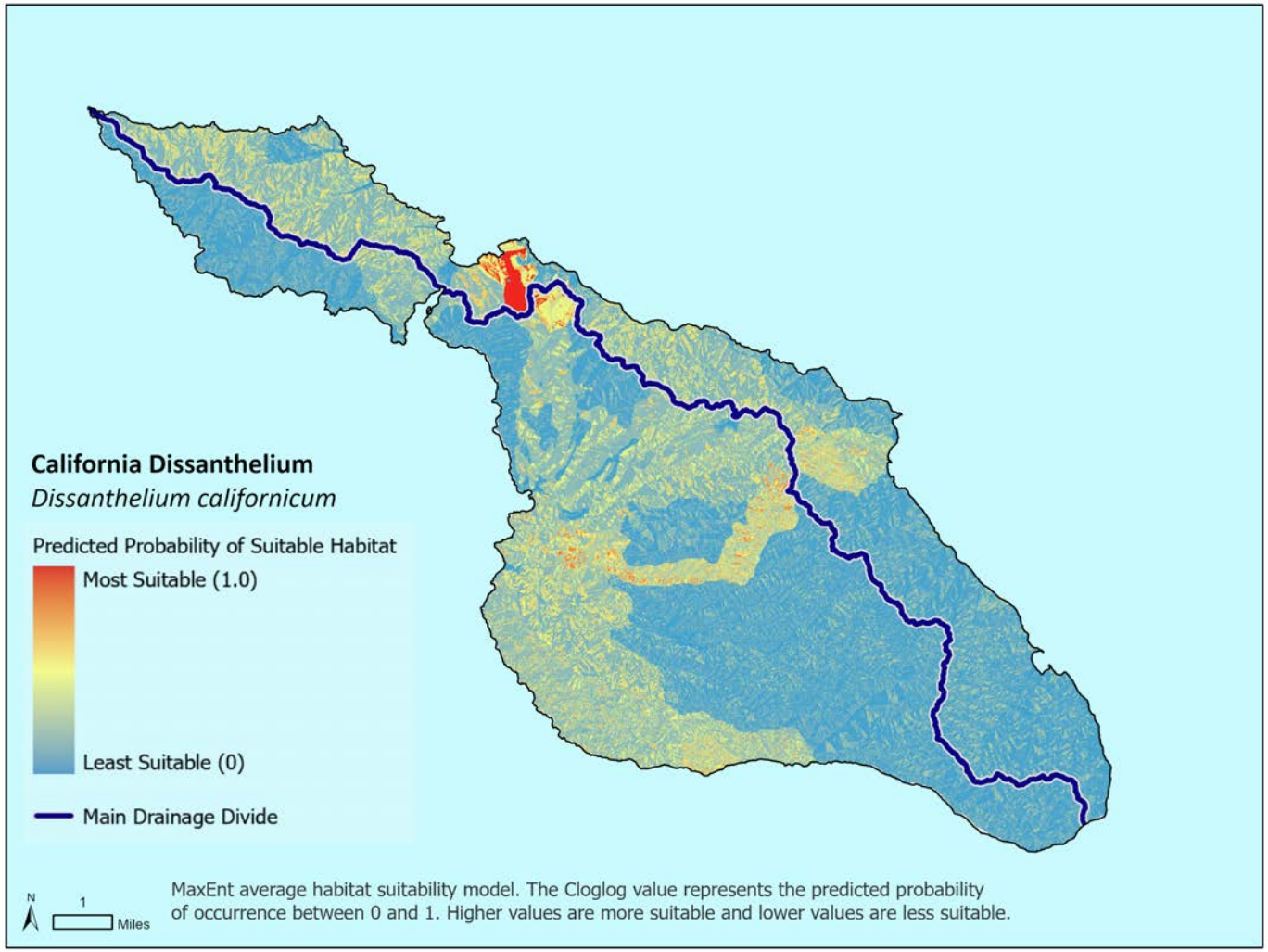

Figure 6-61 Potential Vegetation Map for California Dissanthelium (*Dissanthelium californicum*), a Channel Island Endemic.

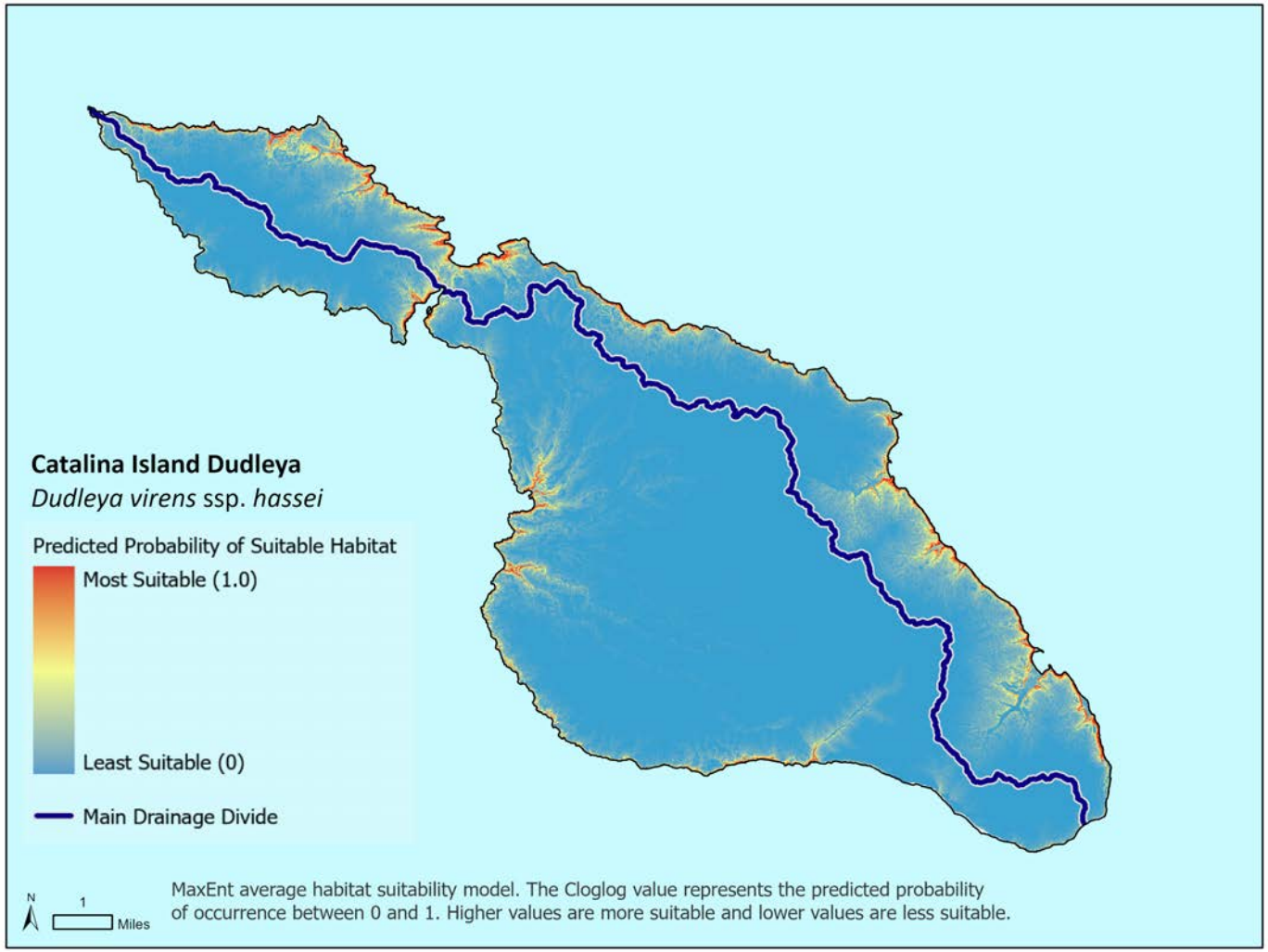

Figure 6-62 Potential Vegetation Map for Catalina Island Dudleya (*Dudleya virens* subsp. *hassei*), a Santa Catalina Island Endemic.

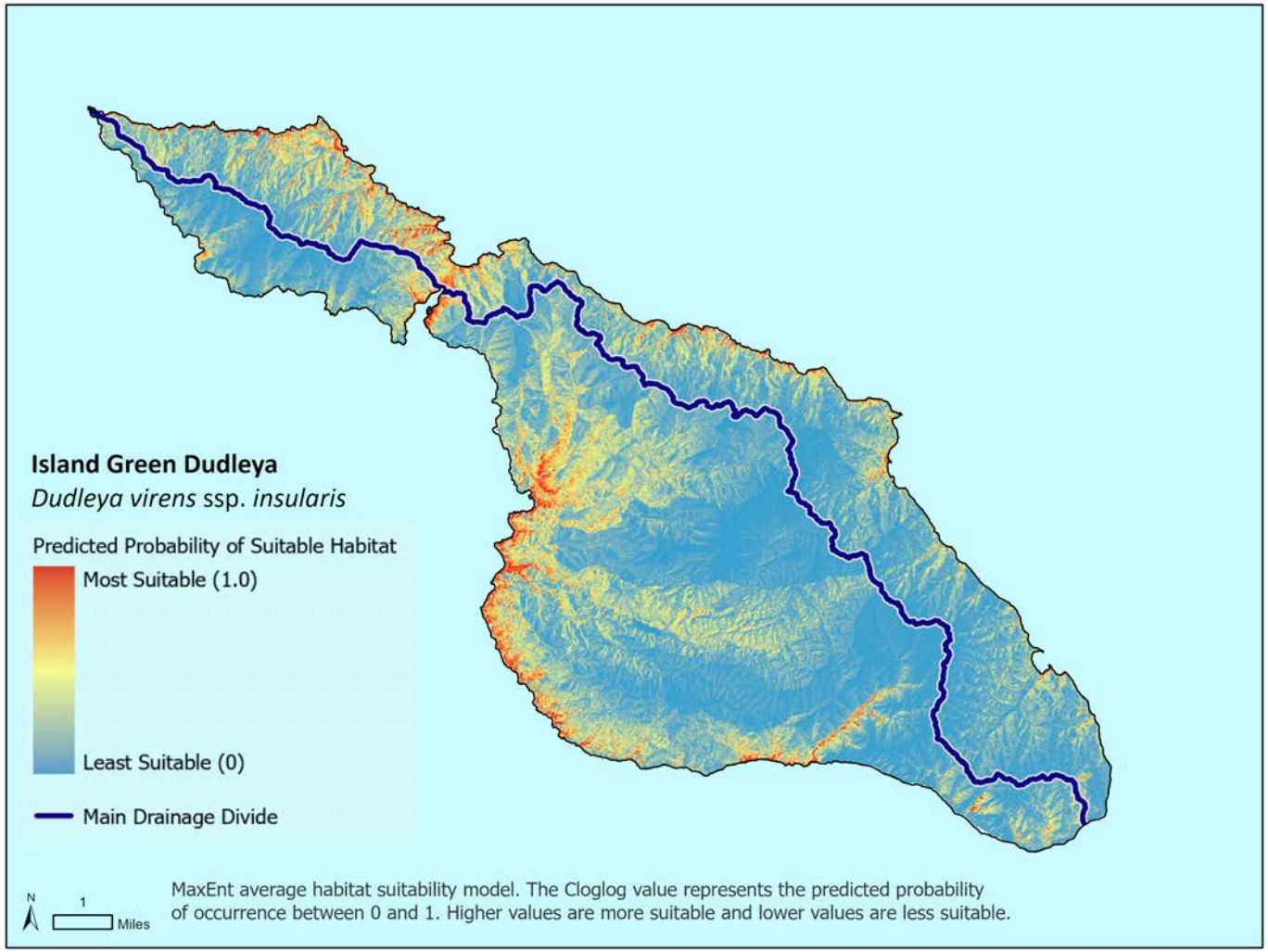

Figure 6-63 Potential Vegetation Map for Island Green Dudleya (*Dudleya virens* subsp. *insularis*).

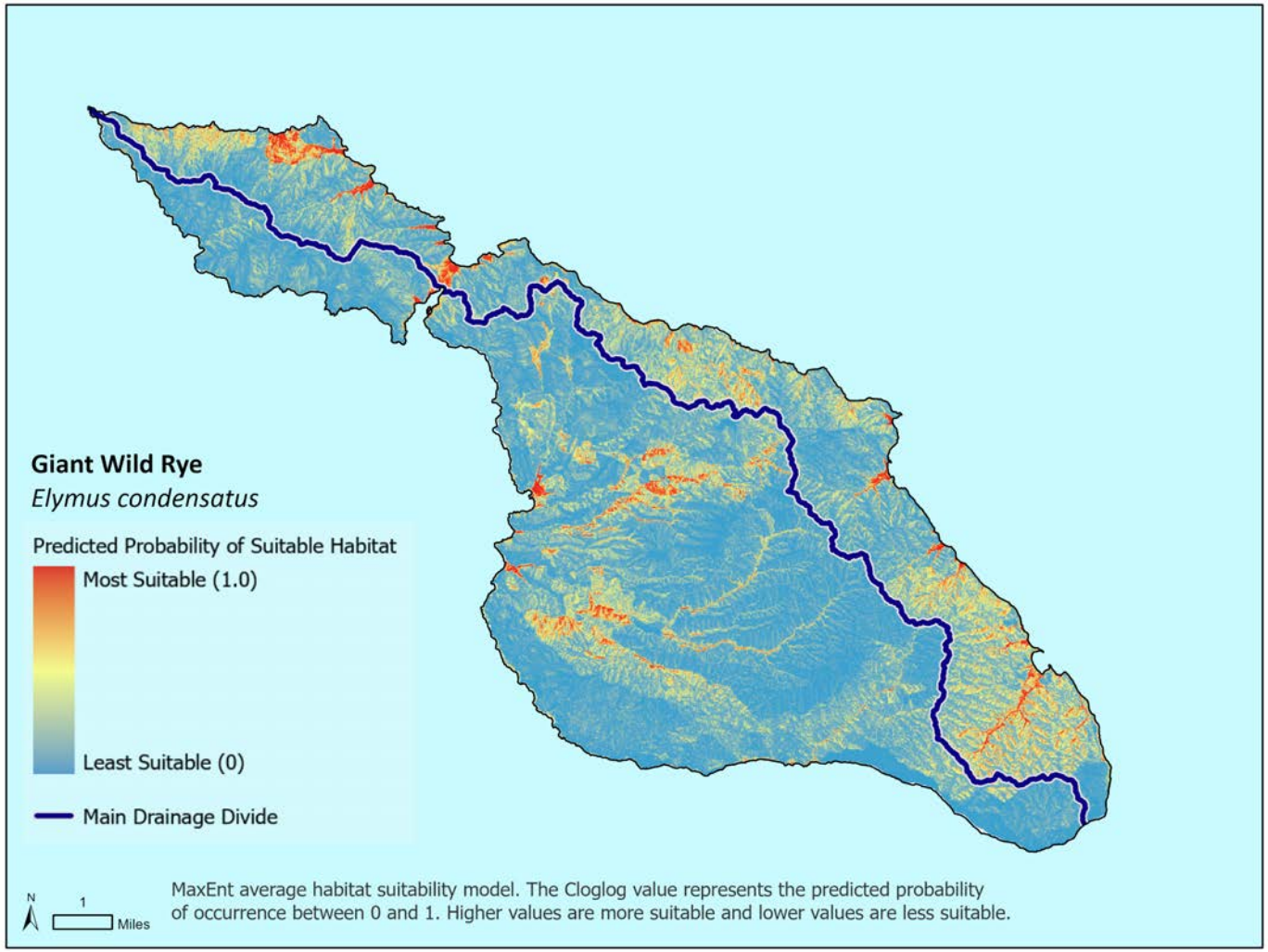

Figure 6-64 Potential Vegetation Map for Giant Wild Rye (*Elymus condensatus*).

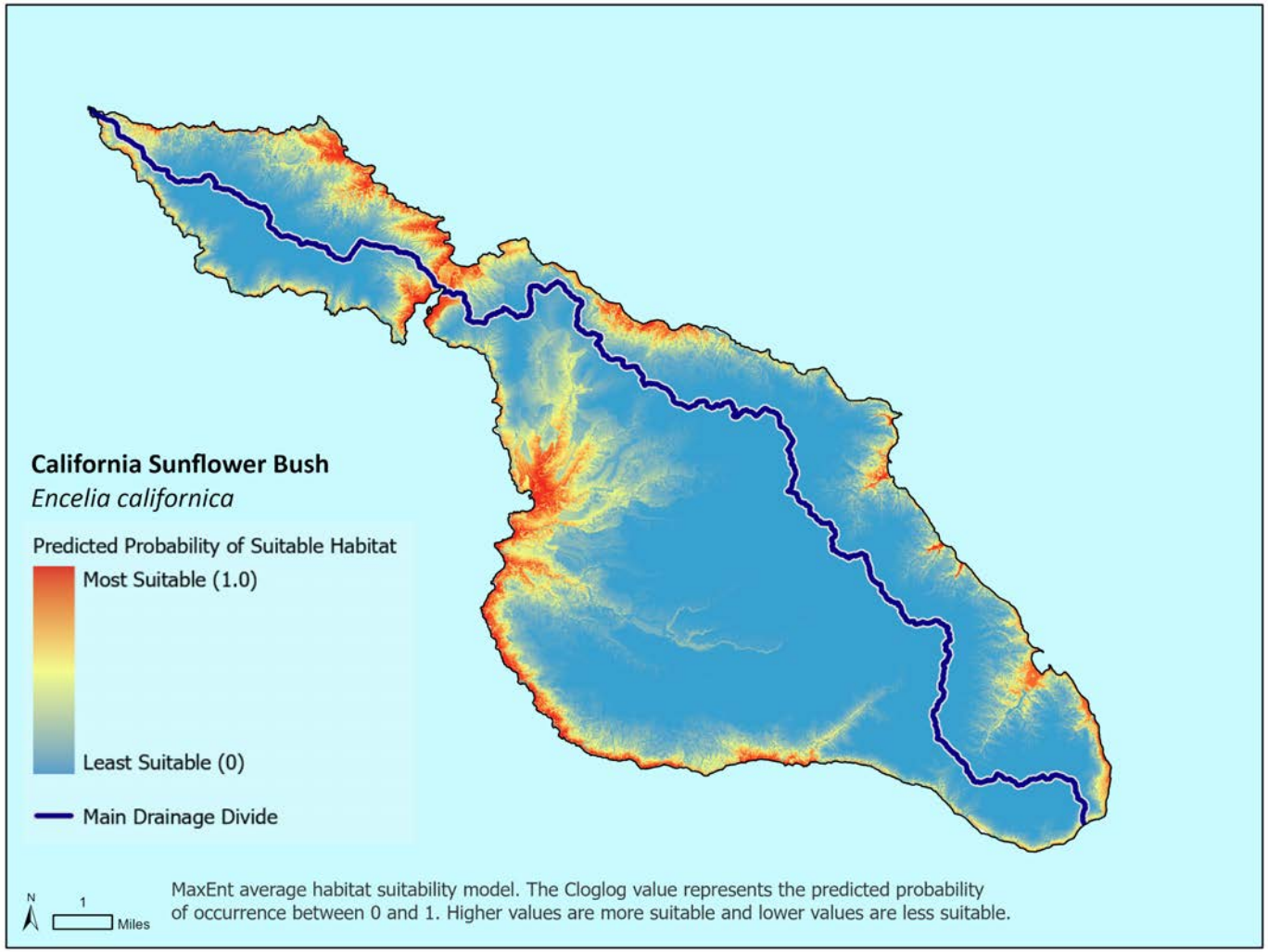

Figure 6-65 Potential Vegetation Map for California Sunflower Bush (*Encelia californica*).

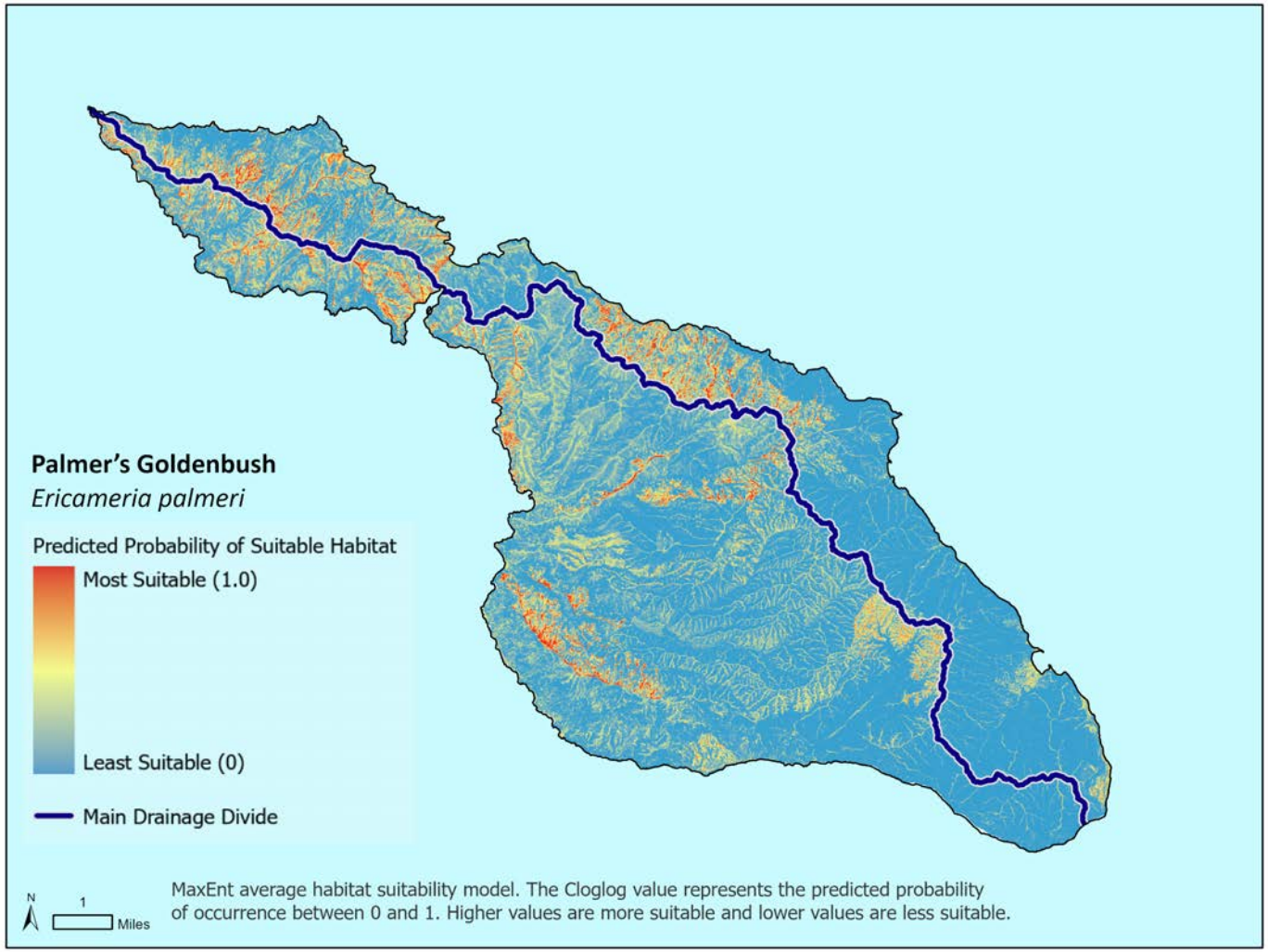

Figure 6-66 Potential Vegetation Map for Palmer's Goldenbush (*Ericameria palmeri*).

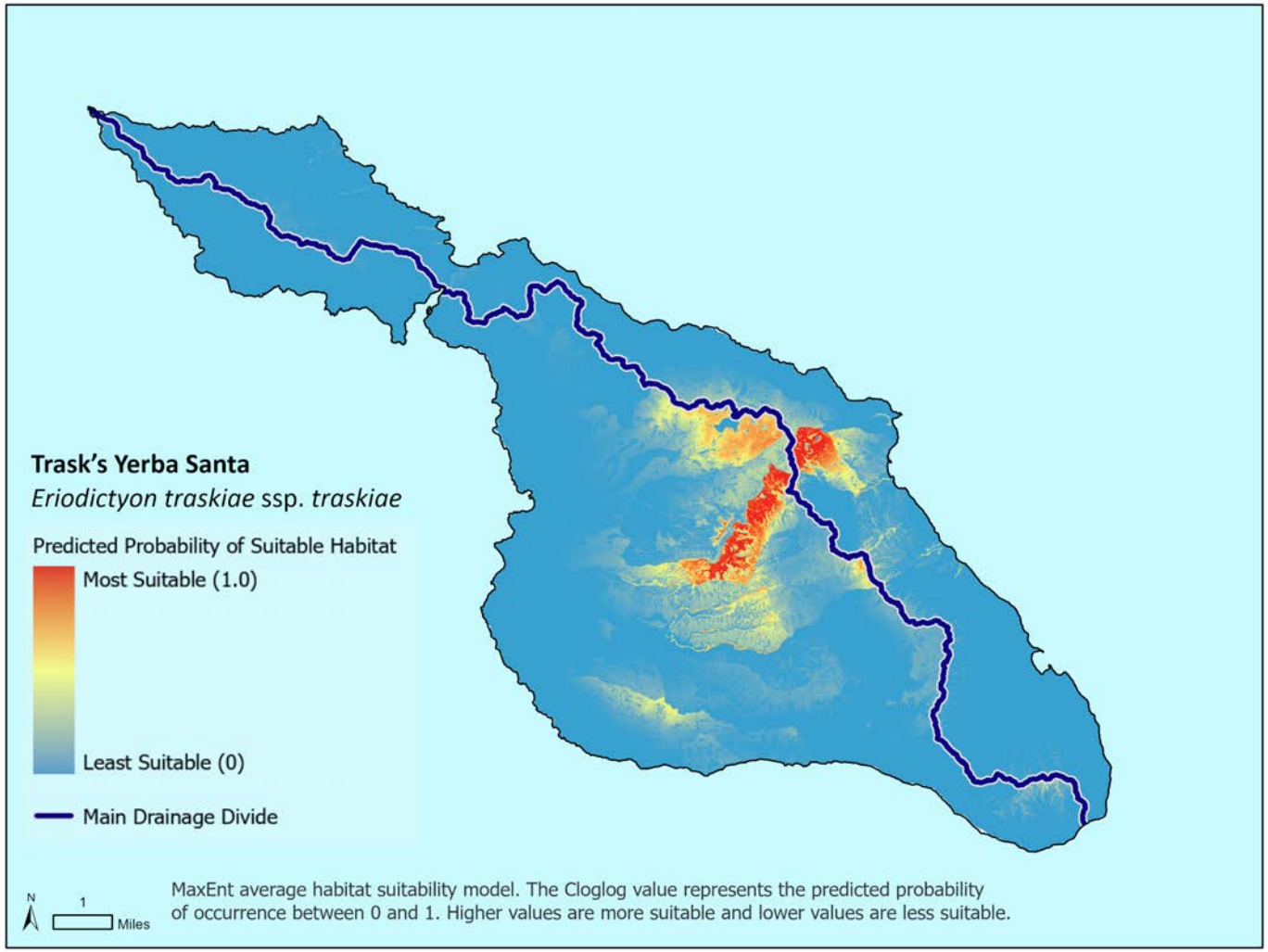

Figure 6-67 Potential Vegetation Map for Trask's Yerba Santa (*Eriodictyon traskiae* ssp. *traskiae*), a Santa Catalina Island Endemic.

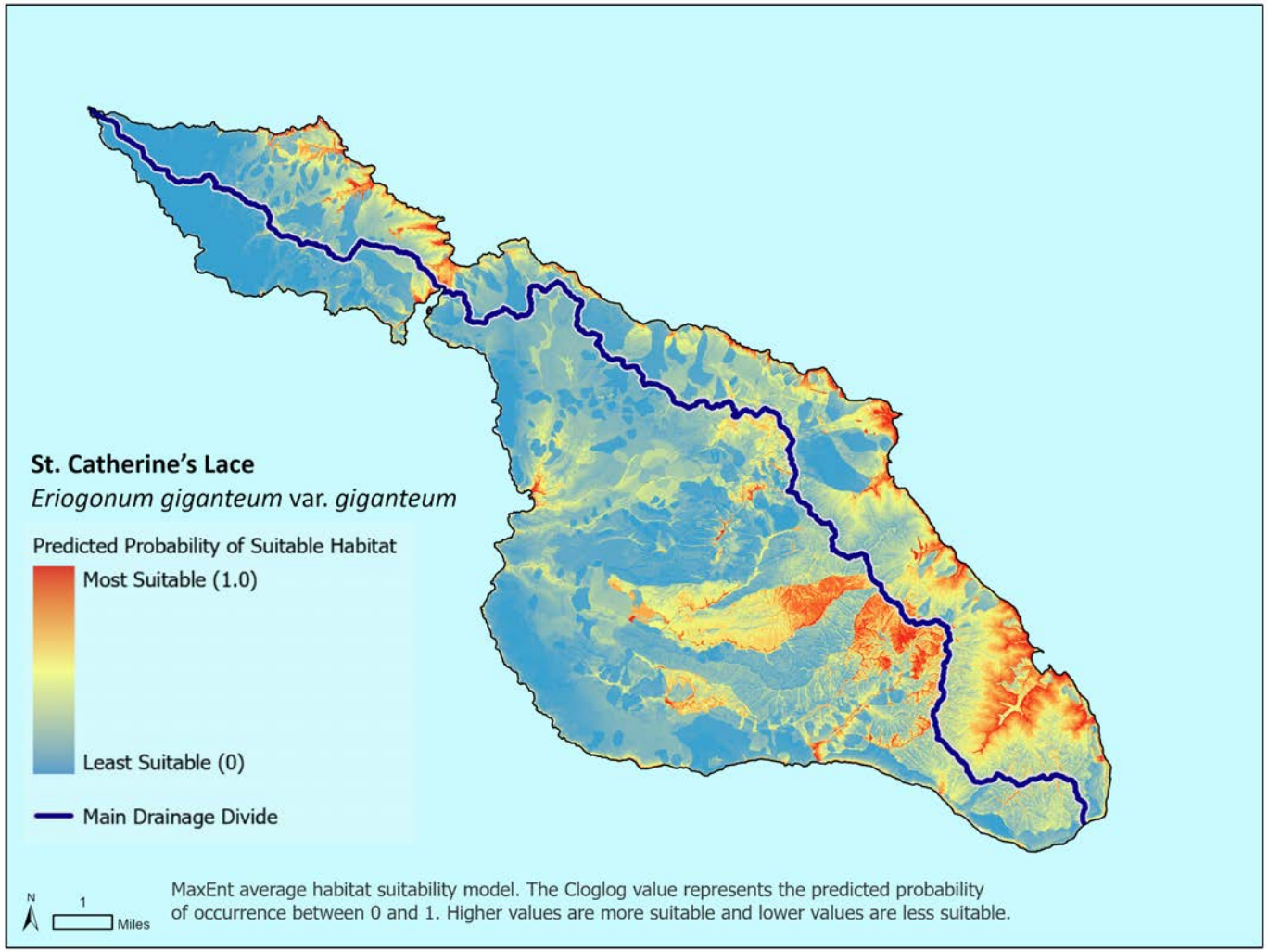

Figure 6-68 Potential Vegetation Map for St. Catherine's Lace (*Eriogonum giganteum var. giganteum*), a Santa Catalina Island Endemic.

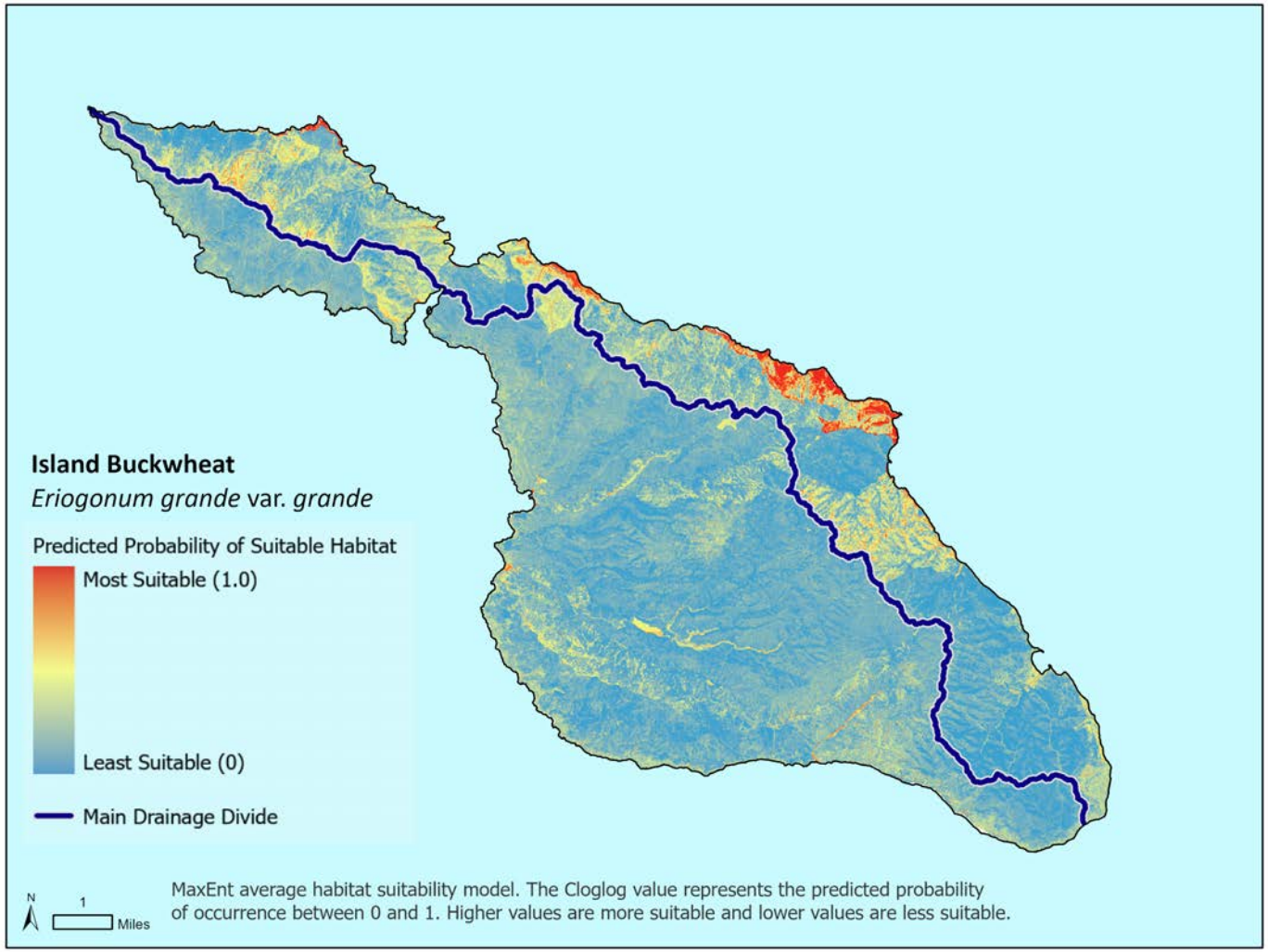

Figure 6-69 Potential Vegetation Map for Island Buckwheat (*Eriogonum grande var. grande*).

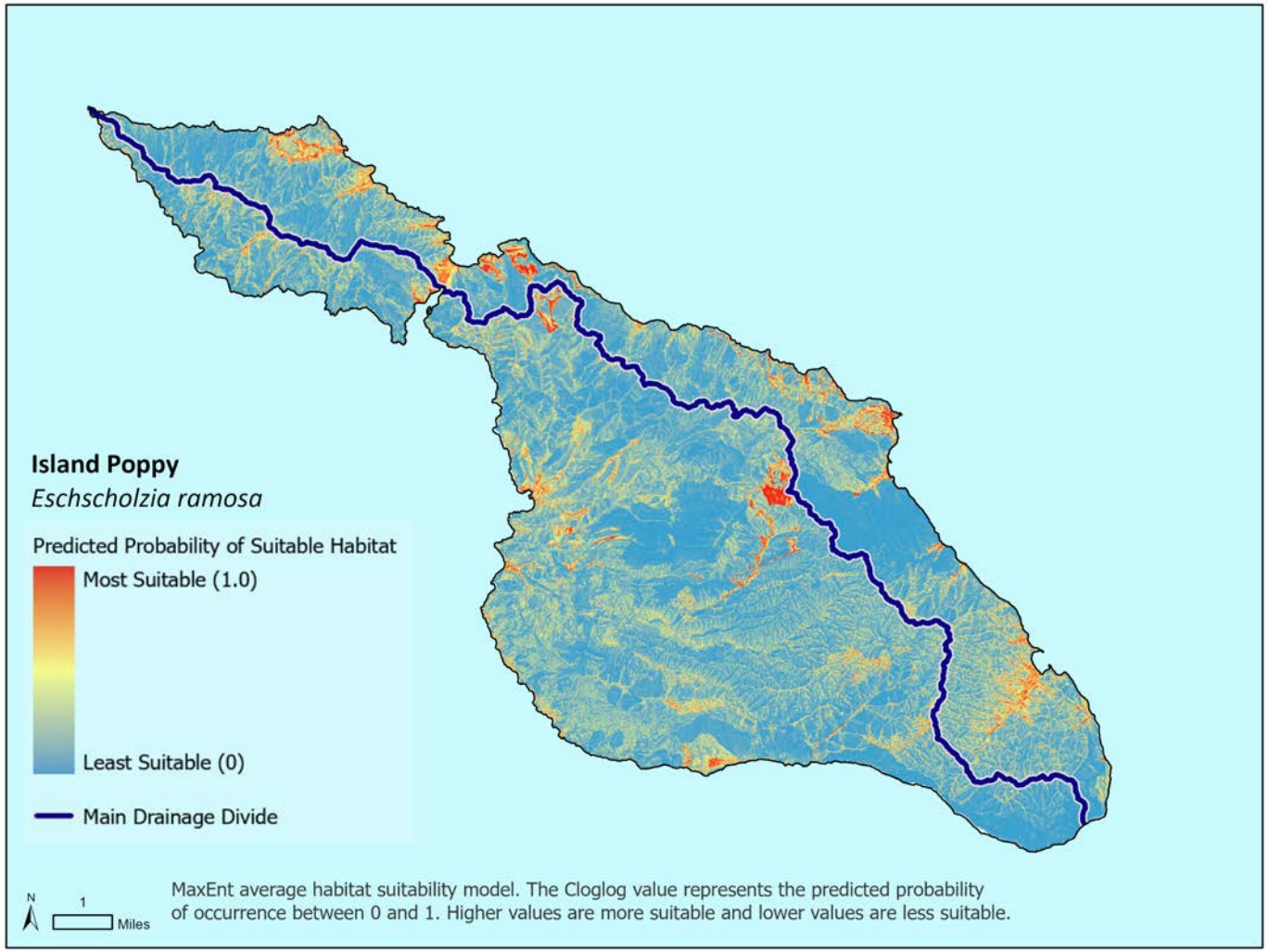

Figure 6-70 Potential Vegetation Map for Island Poppy (*Eschscholzia ramosa*), a Channel Island Endemic.

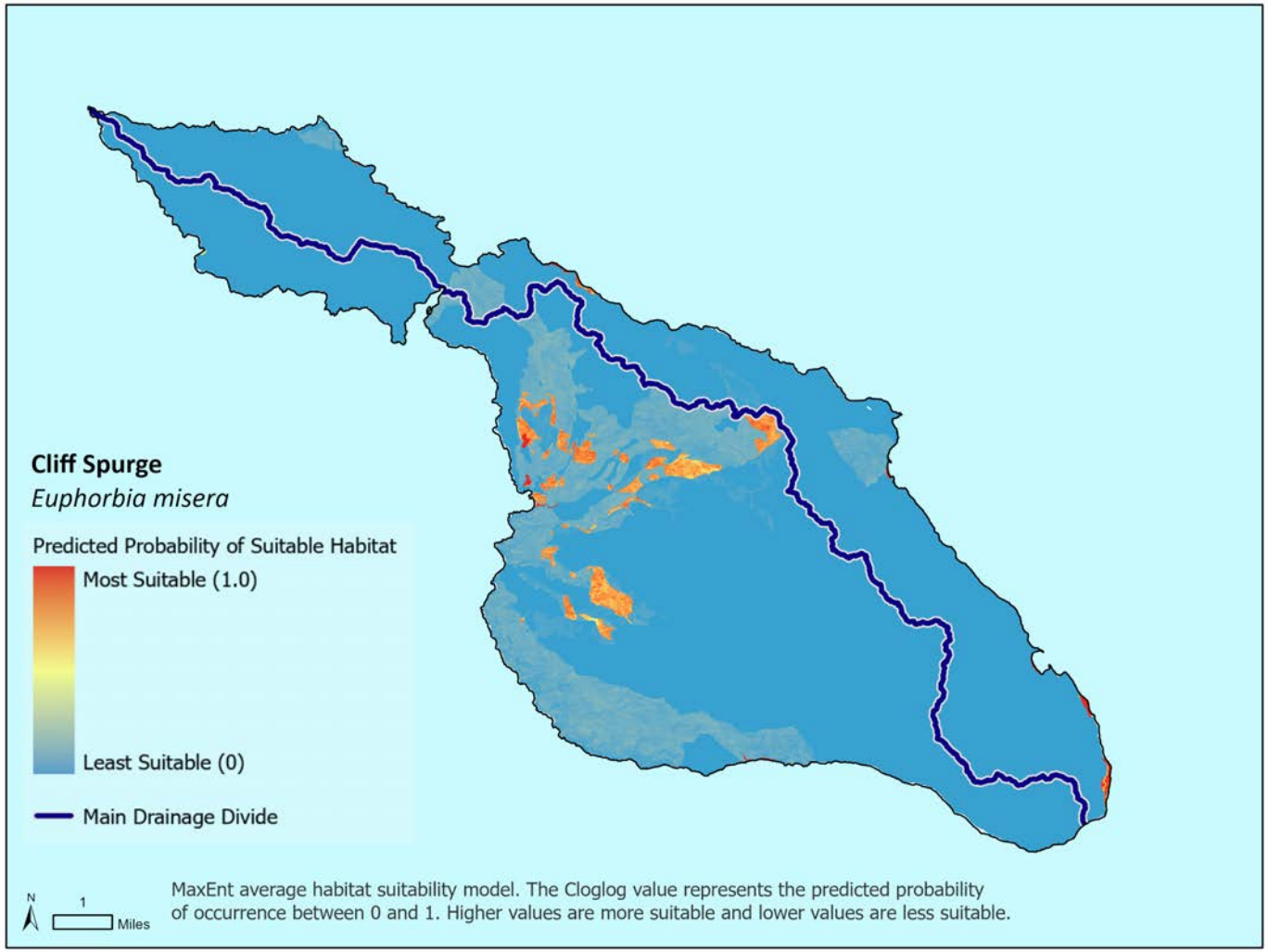

Figure 6-71 Potential Vegetation Map for Cliff Spurge (*Euphorbia misera*), a Channel Island Endemic.

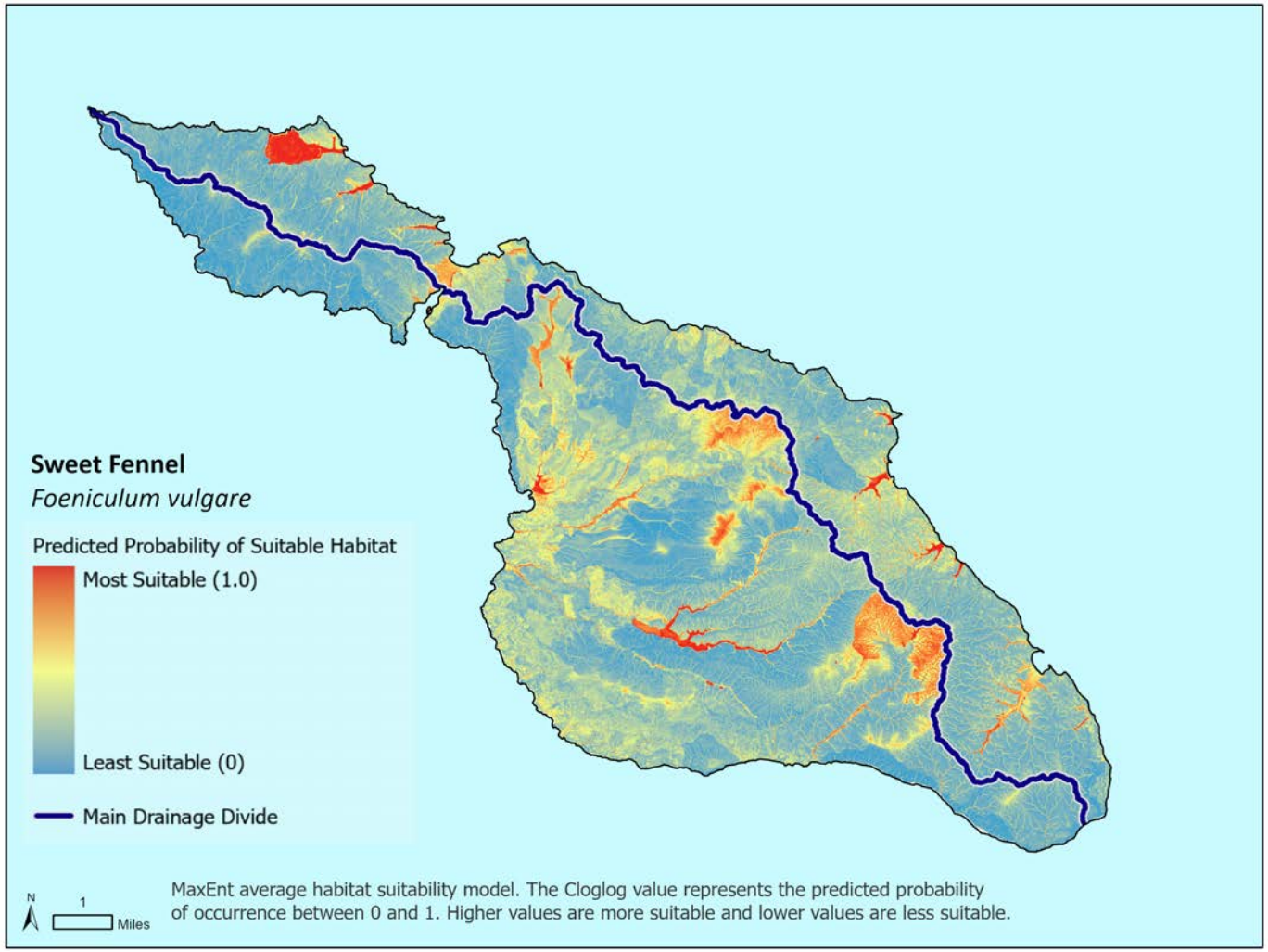

Figure 6-72 Potential Vegetation Map for Sweet Fennel (*Foeniculum vulgare*), an Invasive Plant.

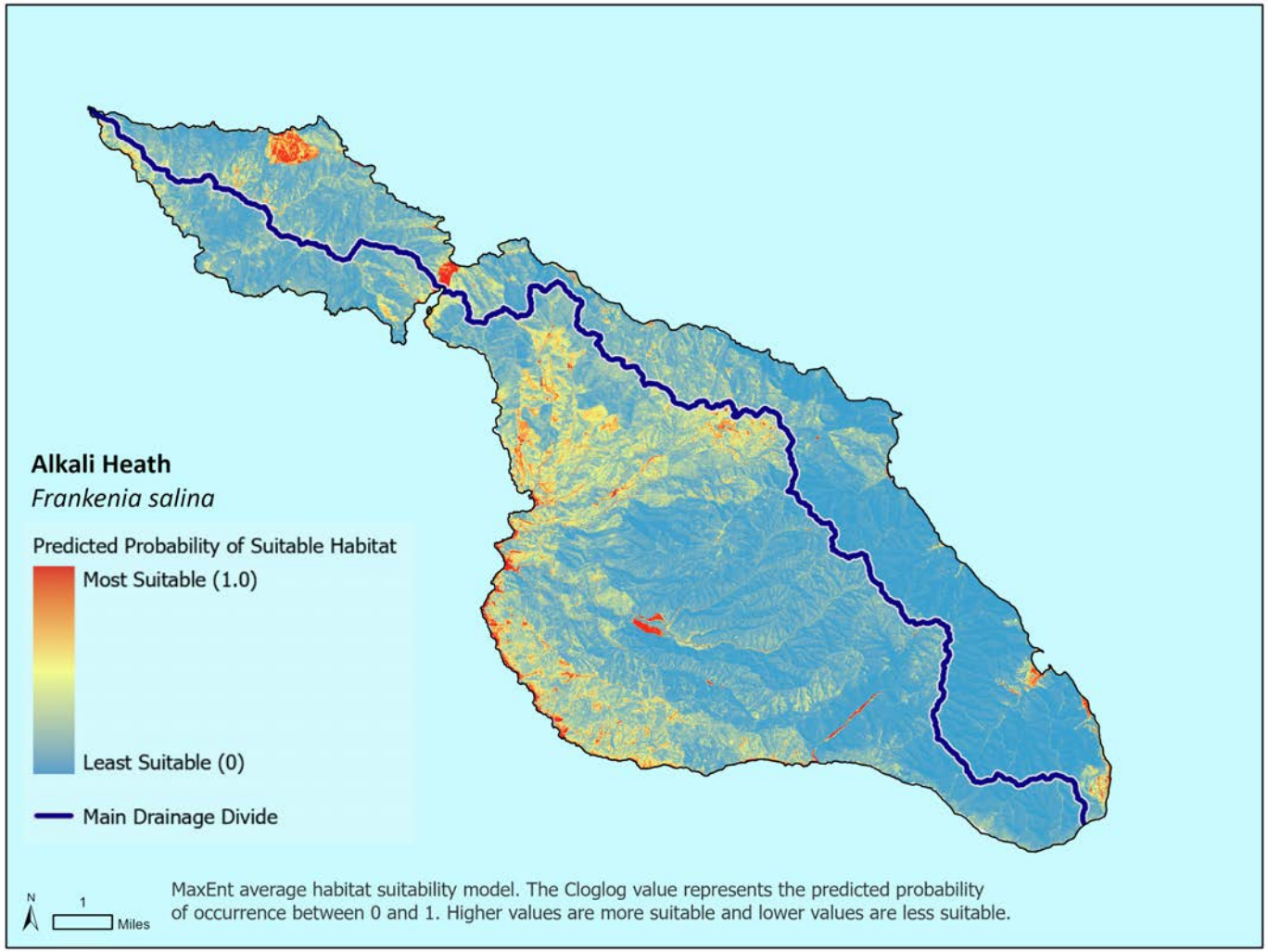

Figure 6-73 Potential Vegetation Map for Alkali Heath (*Frankenia salina*).

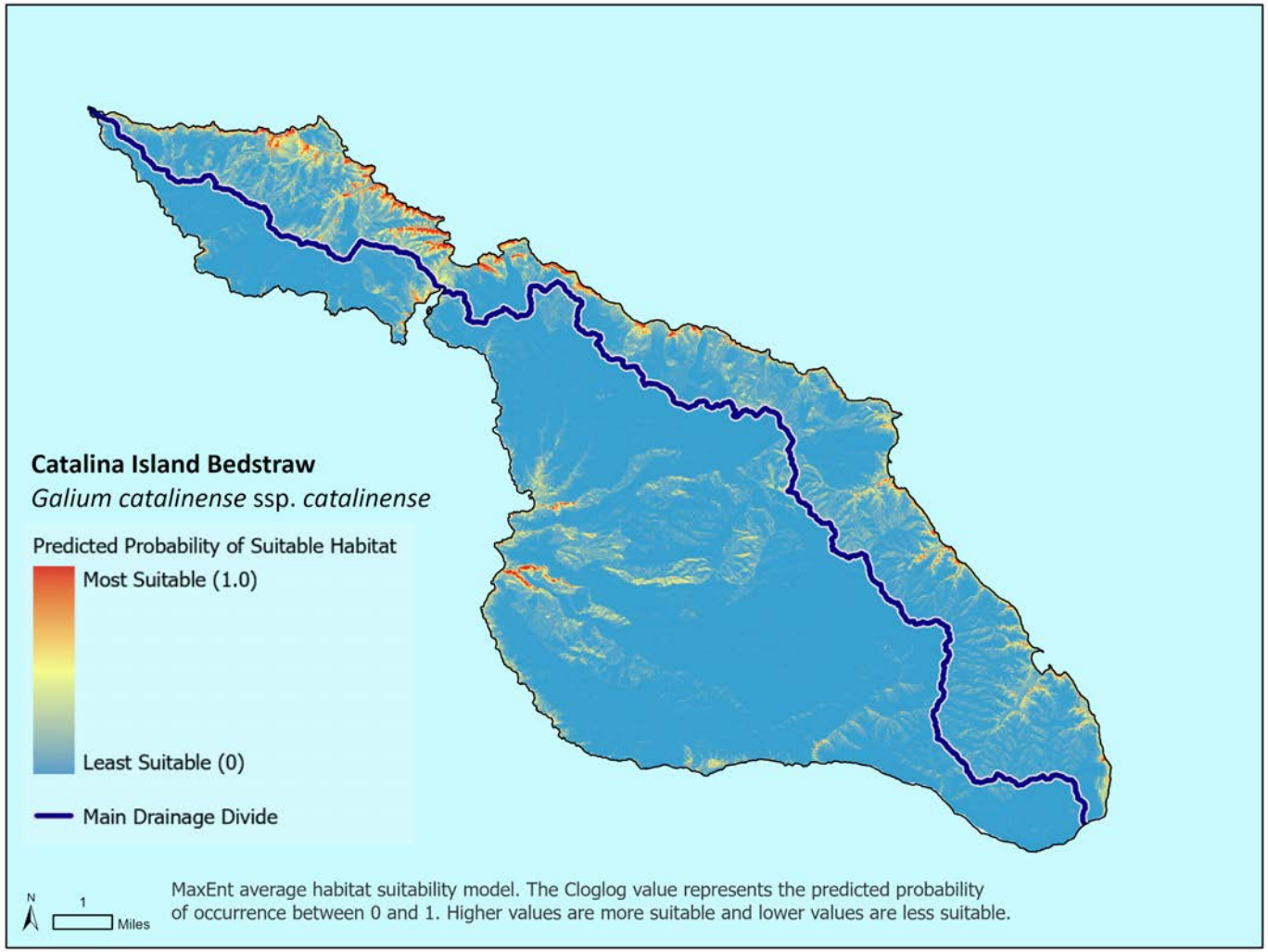

Figure 6-74 Potential Vegetation Map for Catalina Island Bedstraw (*Galium catalinense* subsp. *catalinense*), a Santa Catalina Island Endemic.

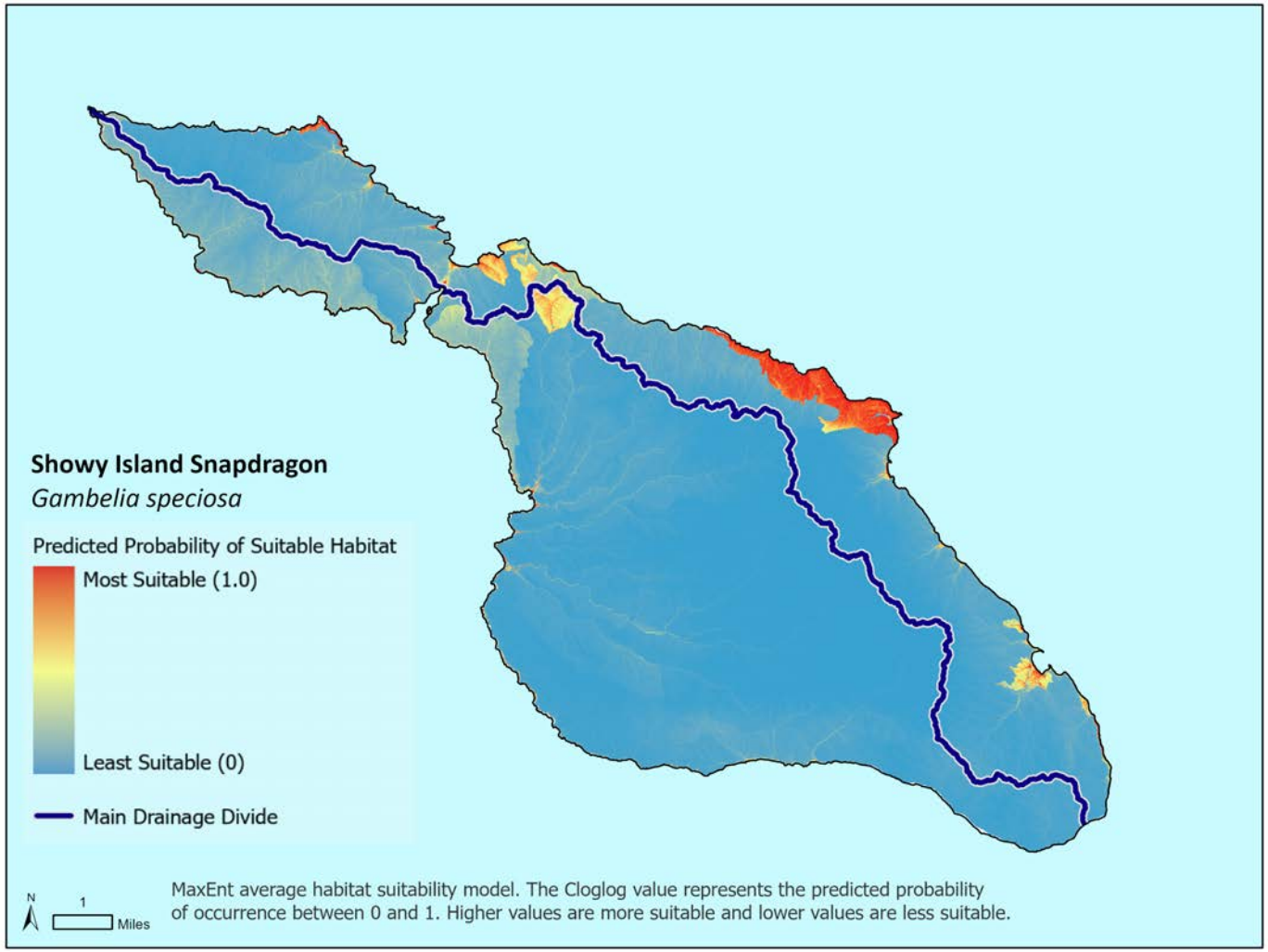

Figure 6-75 Potential Vegetation Map for Showy Island Snapdragon (*Gambelia speciosa*).

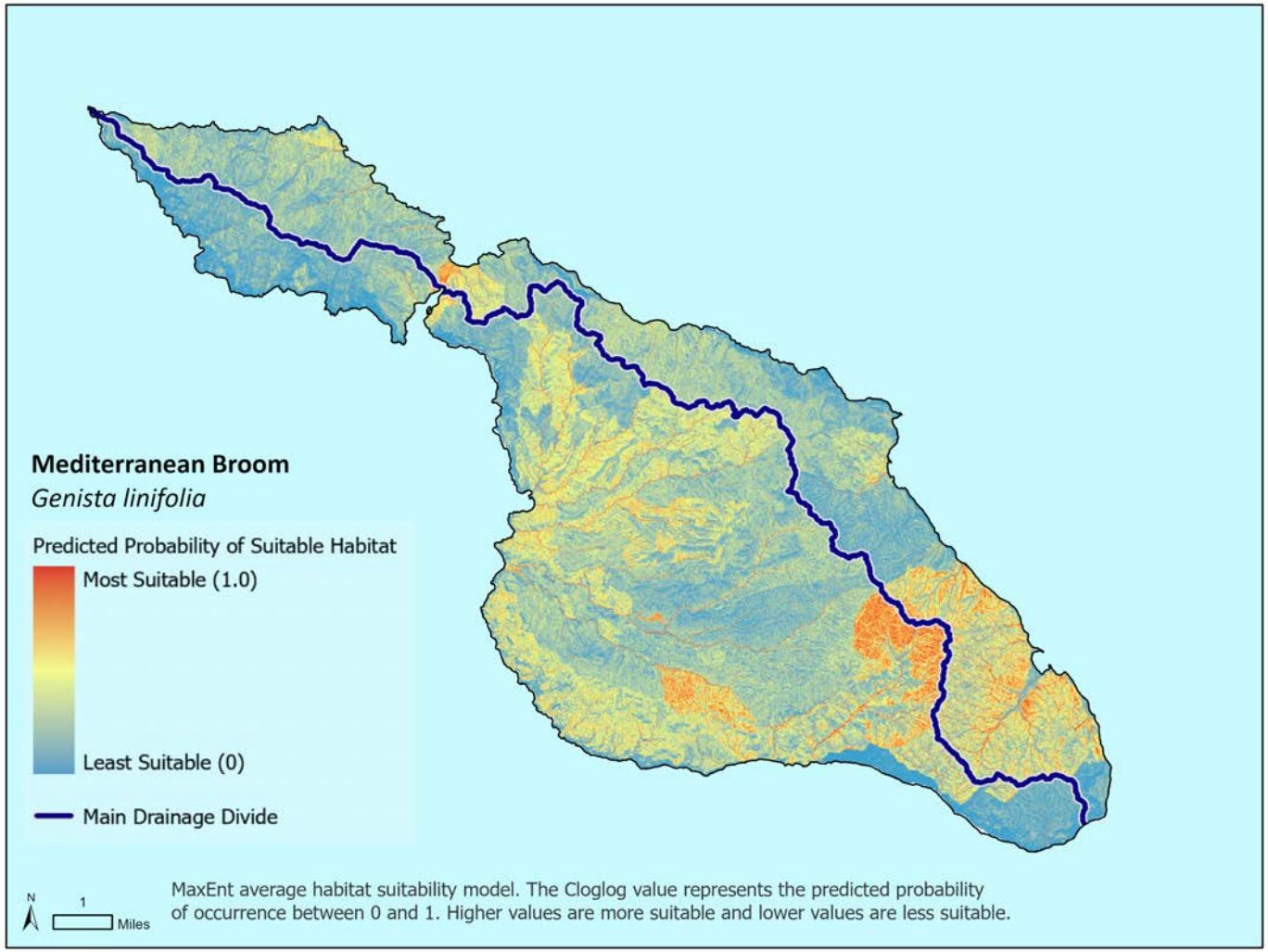

Figure 6-76 Potential Vegetation Map for Mediterranean Broom (*Genista linifolia*), an Invasive Plant.

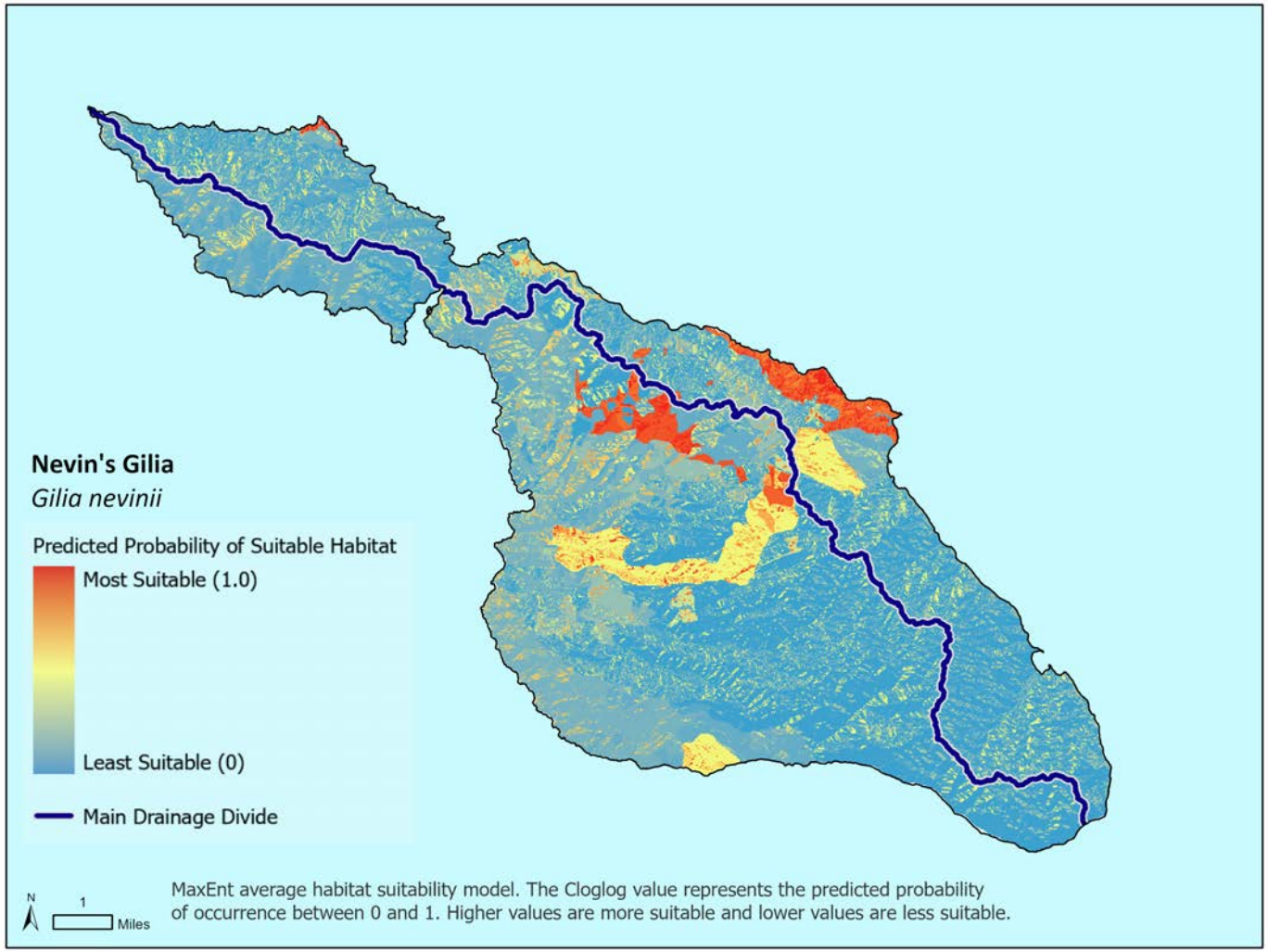

Figure 6-77 Potential Vegetation Map for Nevin's Gilia (*Gilia nevinii*), a Channel Island Endemic.

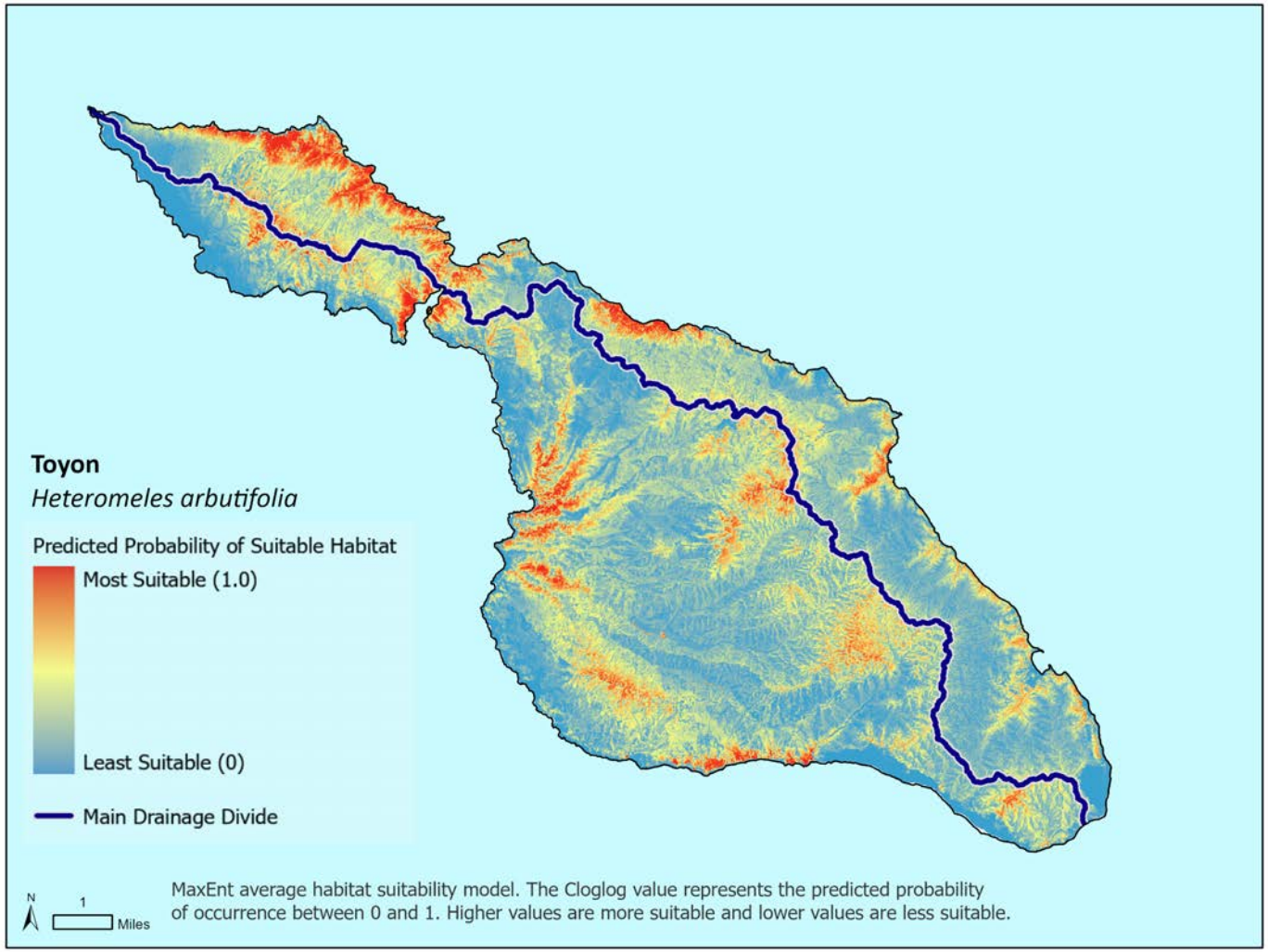

Figure 6-78 Potential Vegetation Map for Toyon (*Heteromeles arbutifolia*).

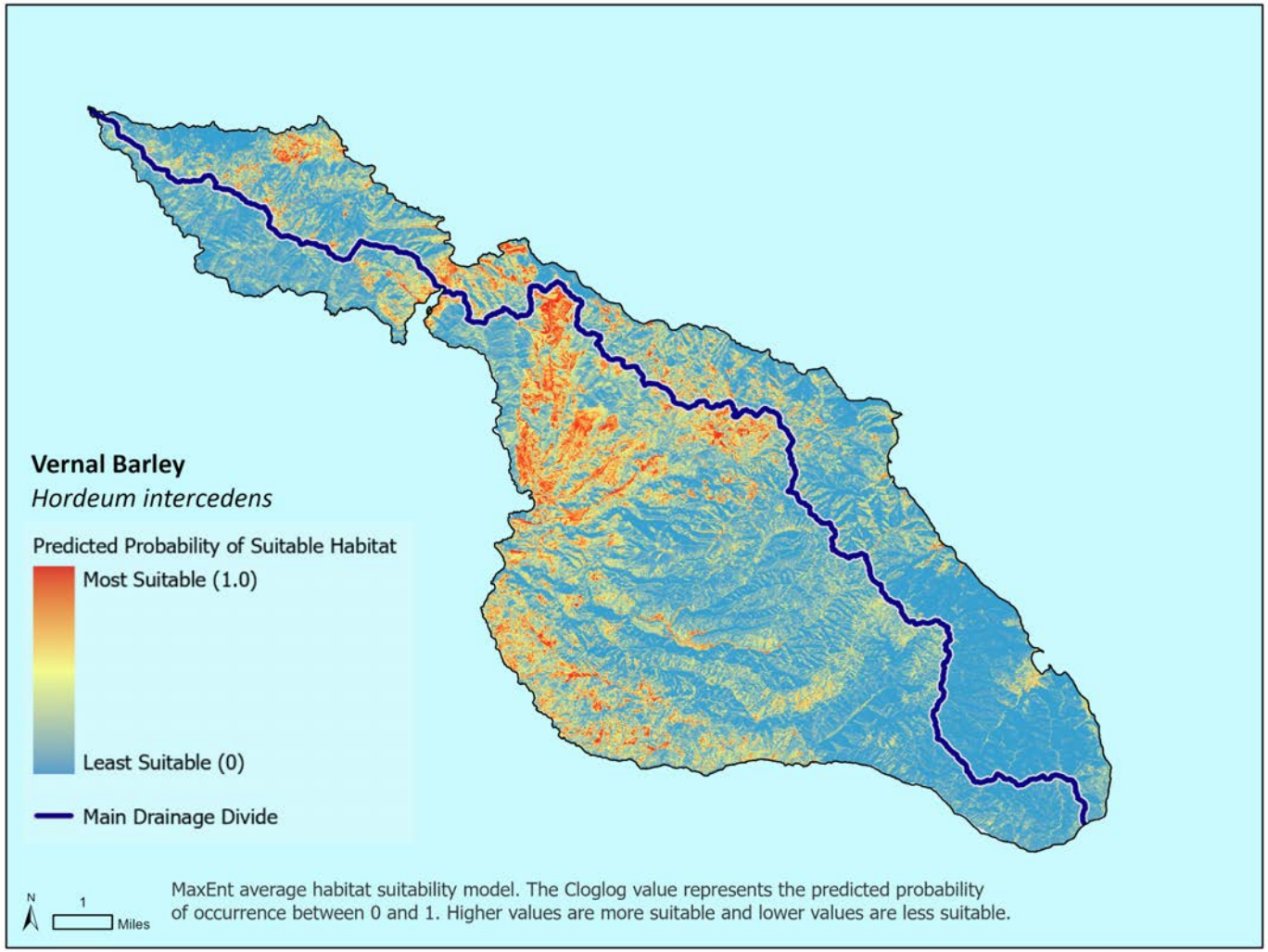

Figure 6-79 Potential Vegetation Map for Vernal Barley (*Hordeum intercedens*).

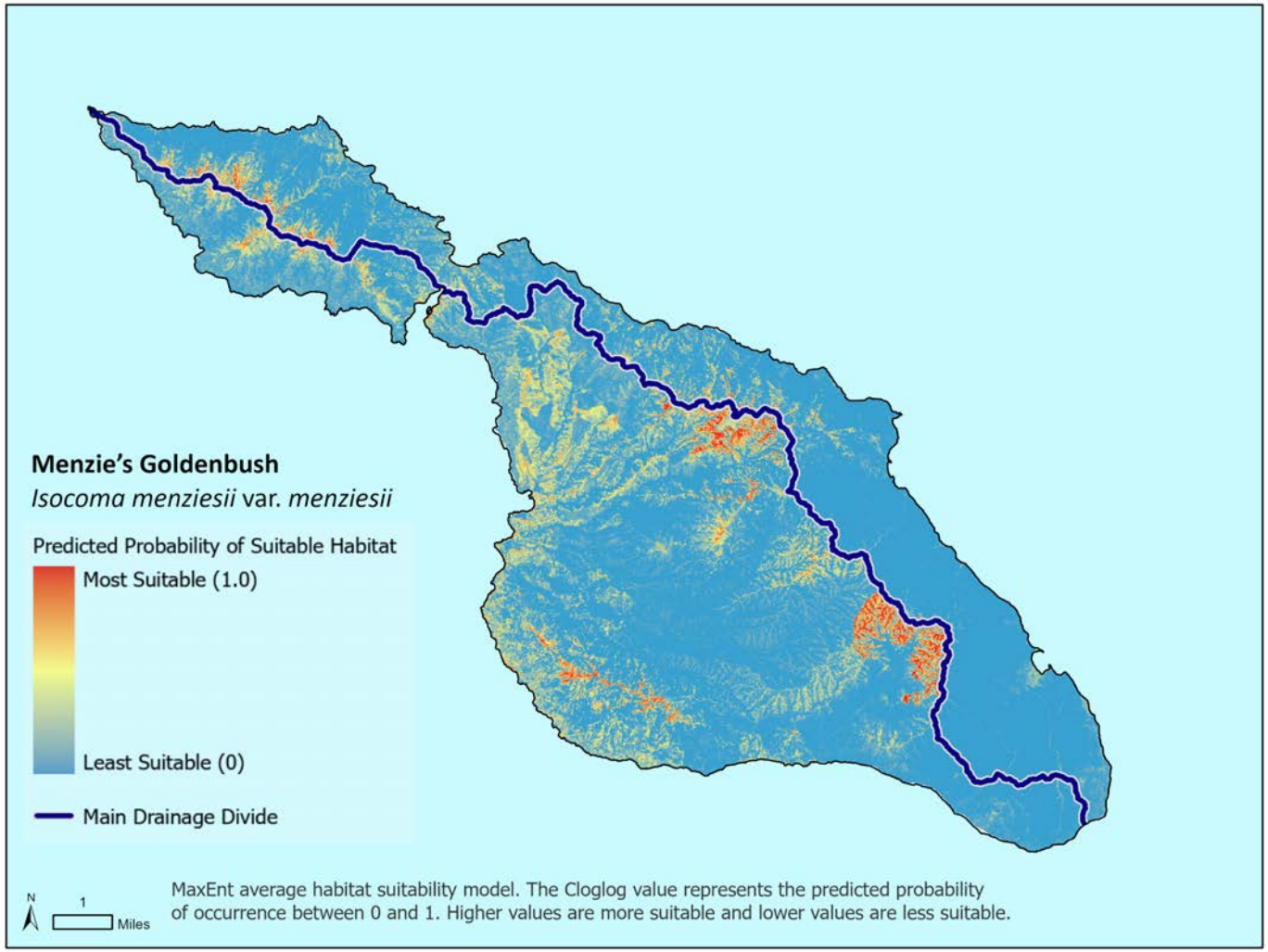

Figure 6-80 Potential Vegetation Map for Menzie's Goldenbush (*Isocoma menziesii* var. *menziesii*).

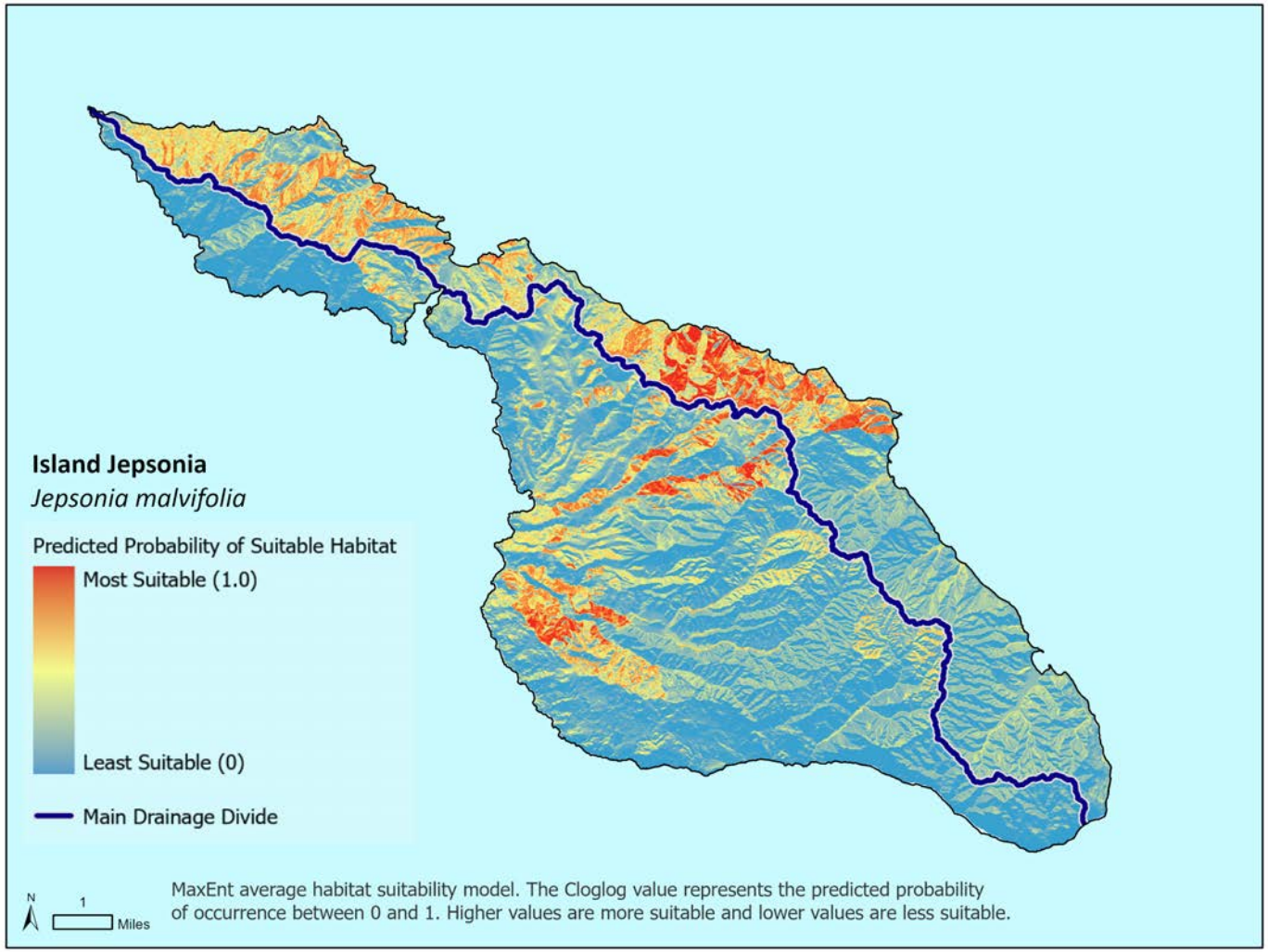

Figure 6-81 Potential Vegetation Map for Island Jepsonia (*Jepsonia malvifolia*), a Channel Island Endemic.

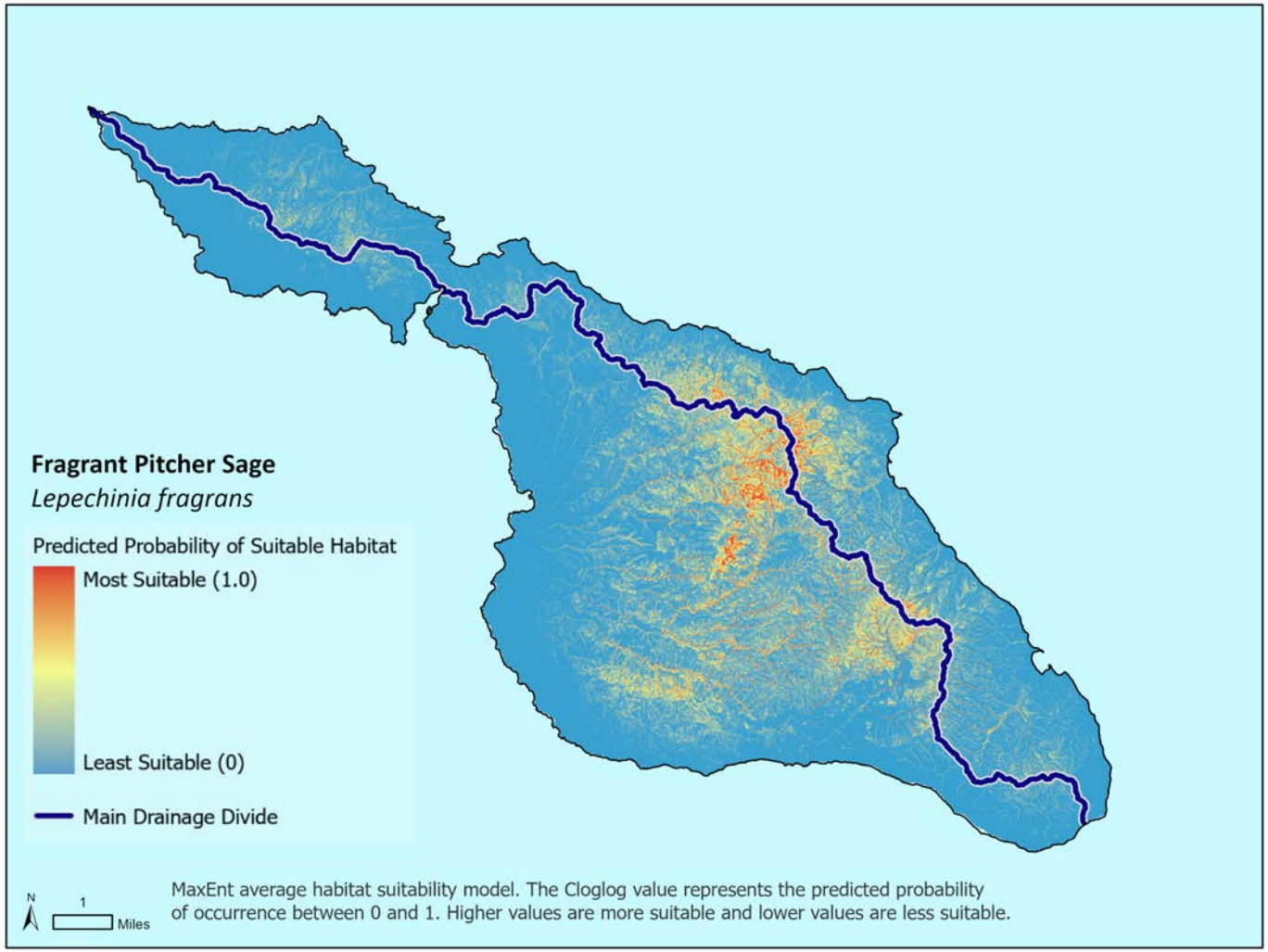

Figure 6-82 Potential Vegetation Map for Fragrant Pitcher Sage (*Lepechinia fragrans*).

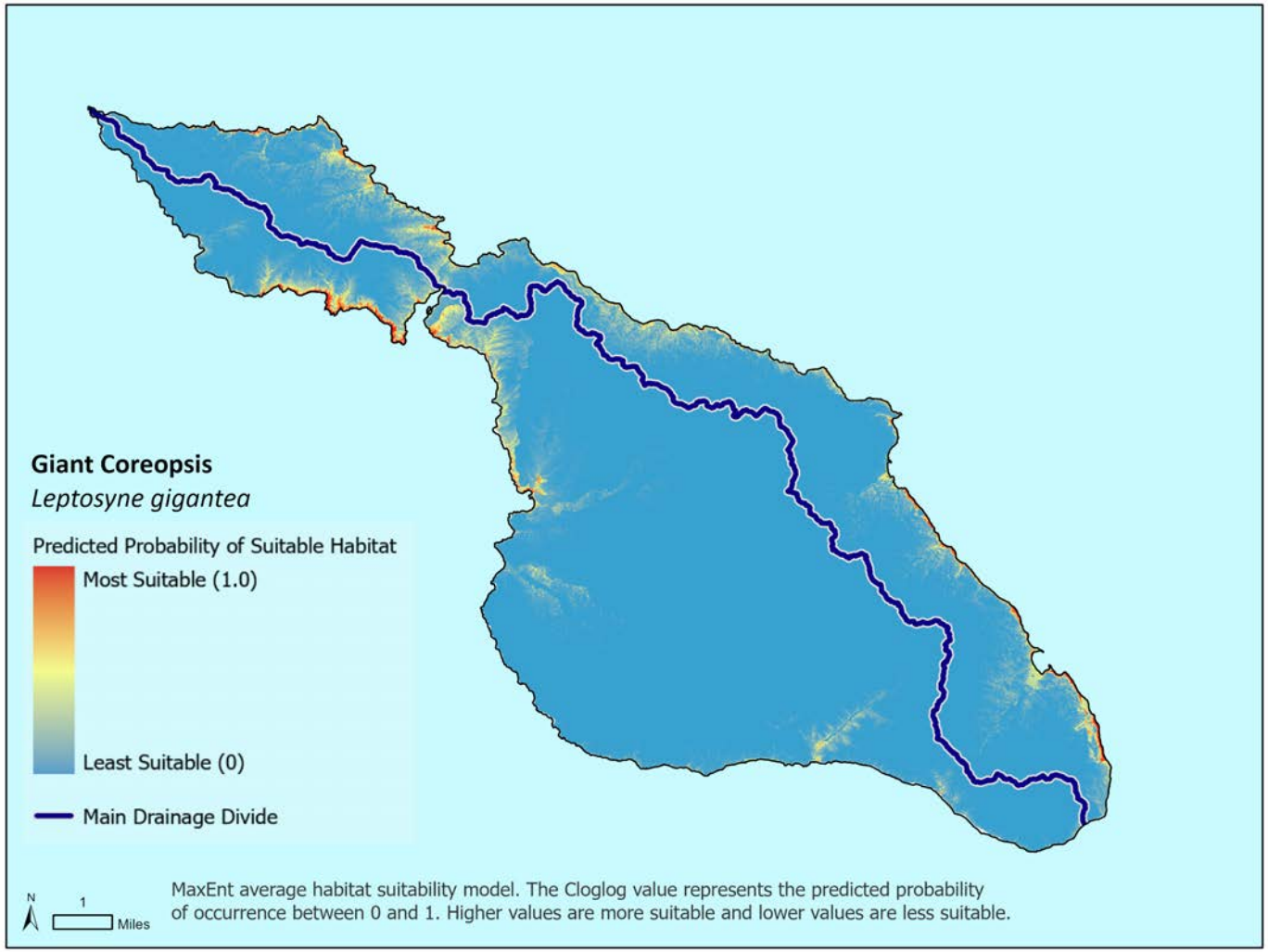

Figure 6-83 Potential Vegetation Map for Giant Coreopsis (*Leptosyne gigantea*).

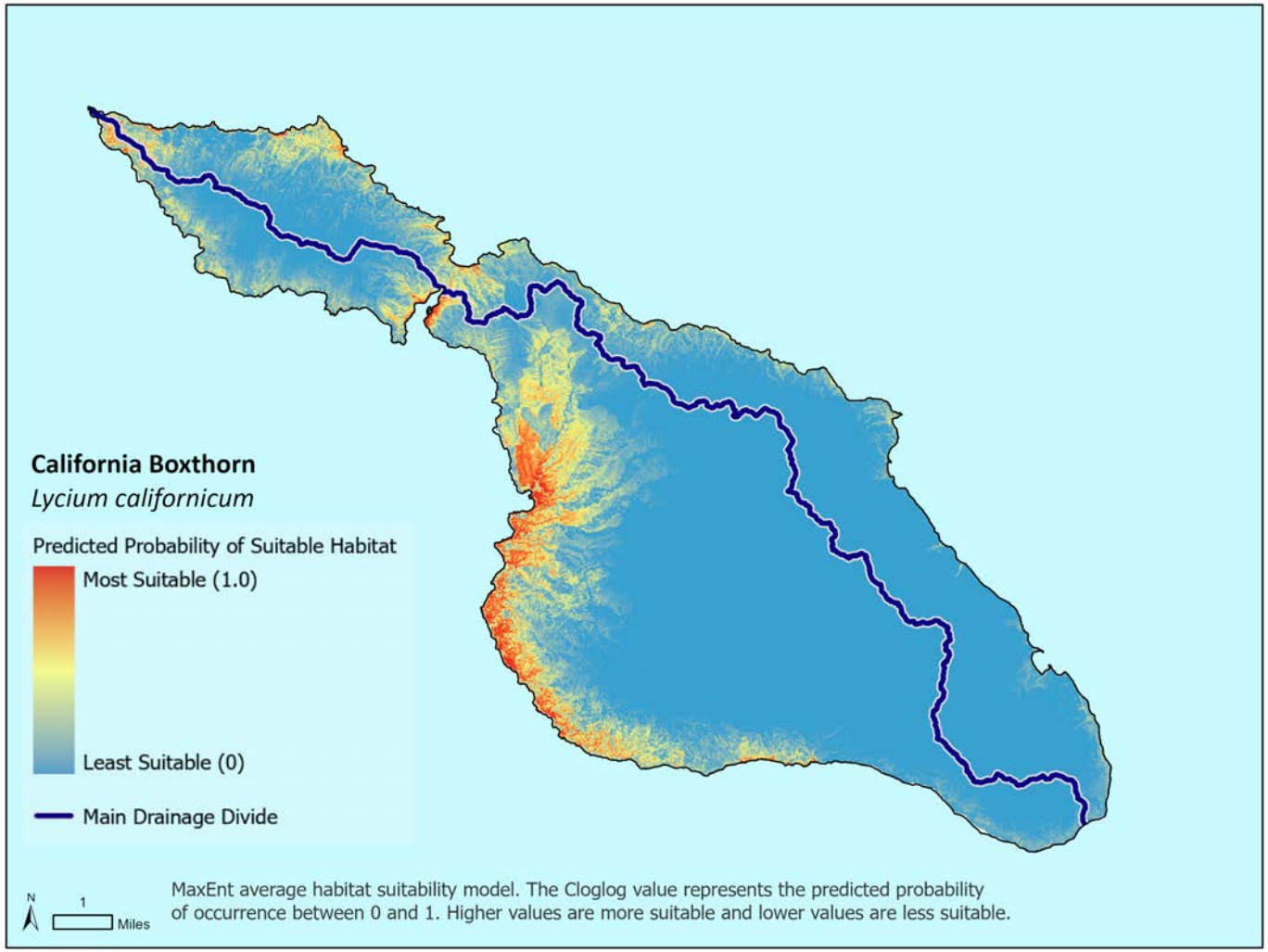

Figure 6-84 Potential Vegetation Map for California Boxthorn (*Lycium californicum*).

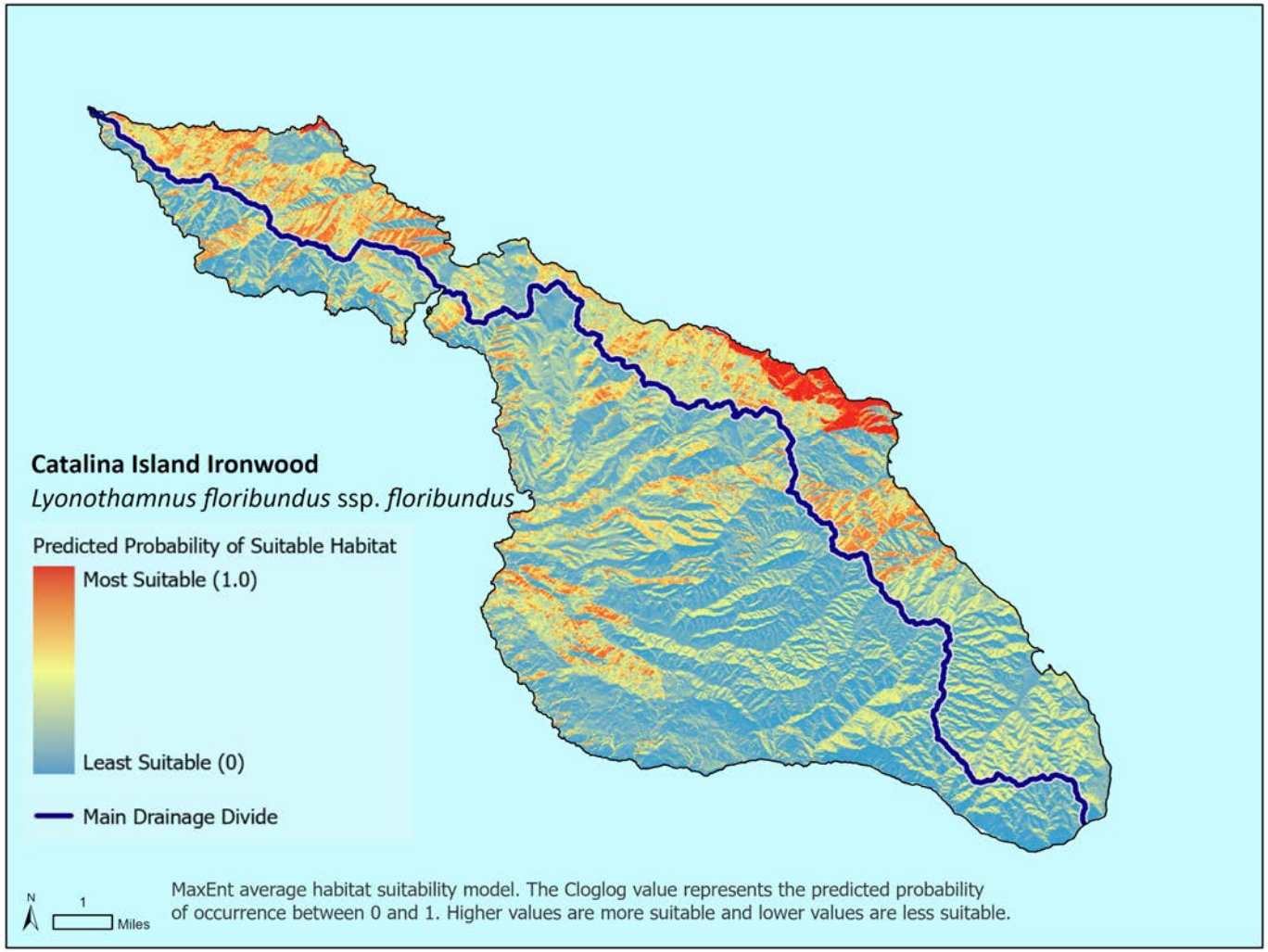

Figure 6-85 Potential Vegetation Map for Catalina Island Ironwood (*Lyonothamnus floribundus* subsp. *floribundus*), a Santa Catalina Island Endemic.

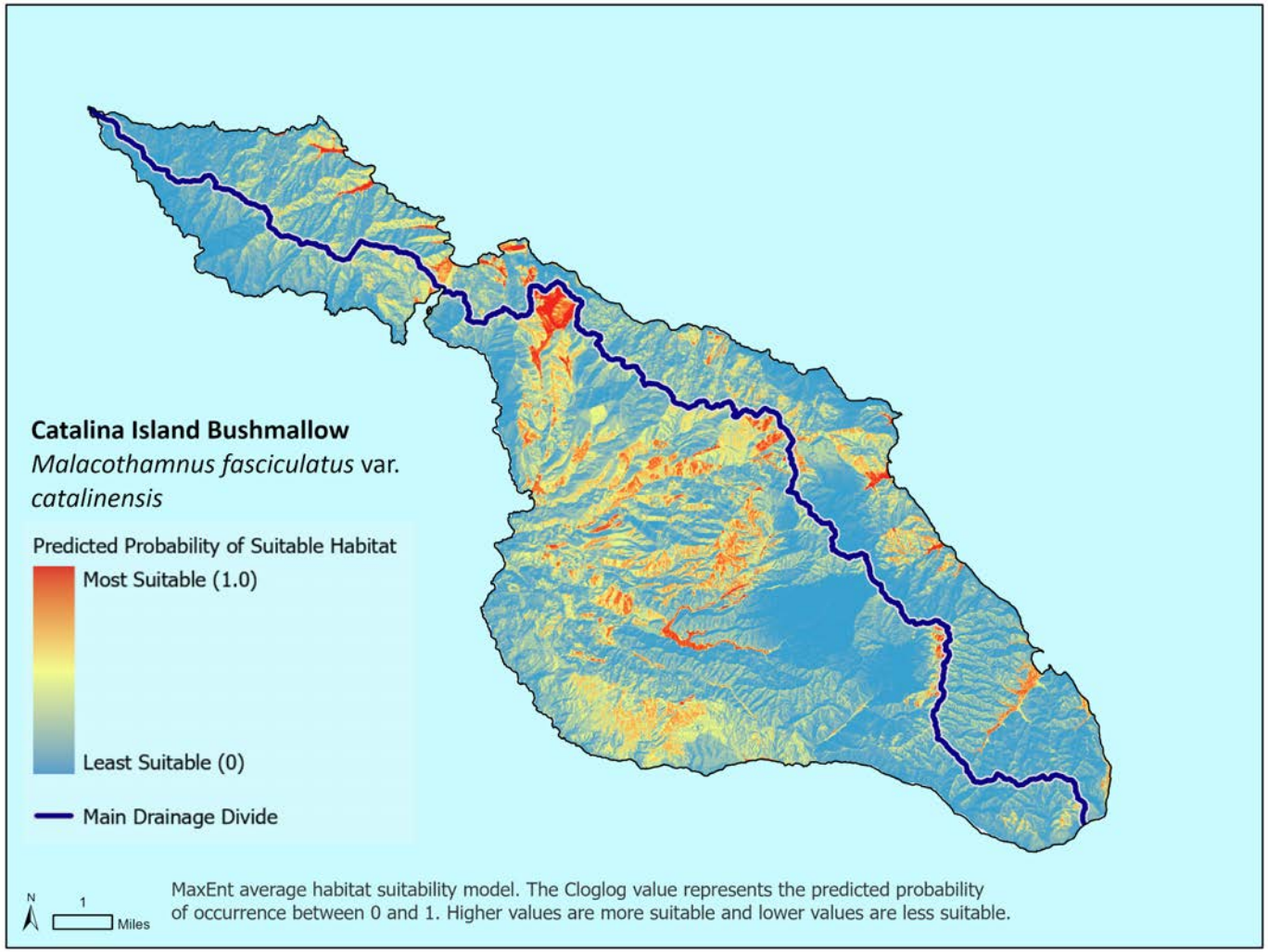

Figure 6-86 Potential Vegetation Map for Catalina Island Bushmallow (*Malacothamnus fasciculatus* var. *catalinensis*), a Santa Catalina Island Endemic.

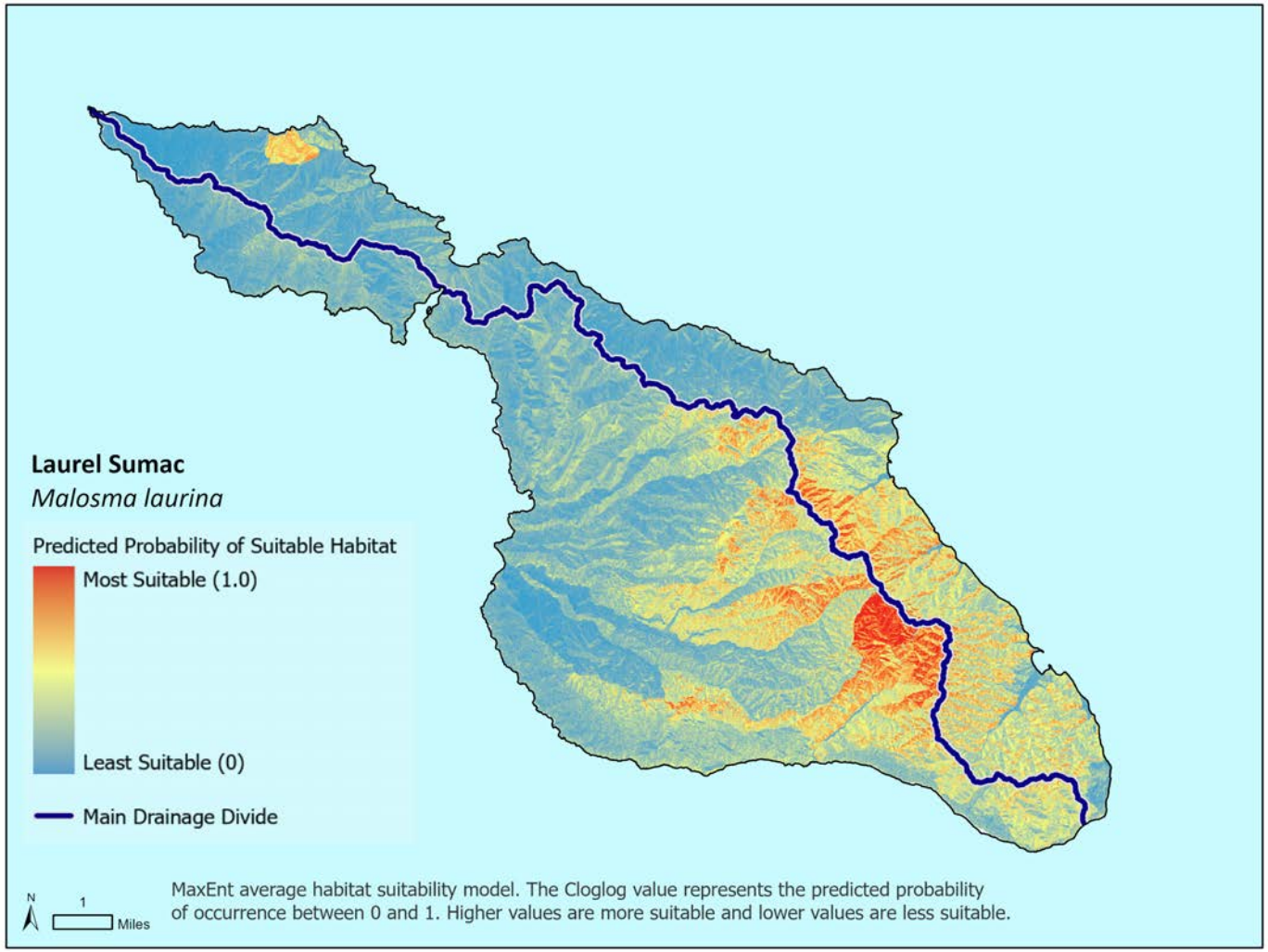

Figure 6-87 Potential Vegetation Map for Laurel Sumac (*Malosma laurina*).

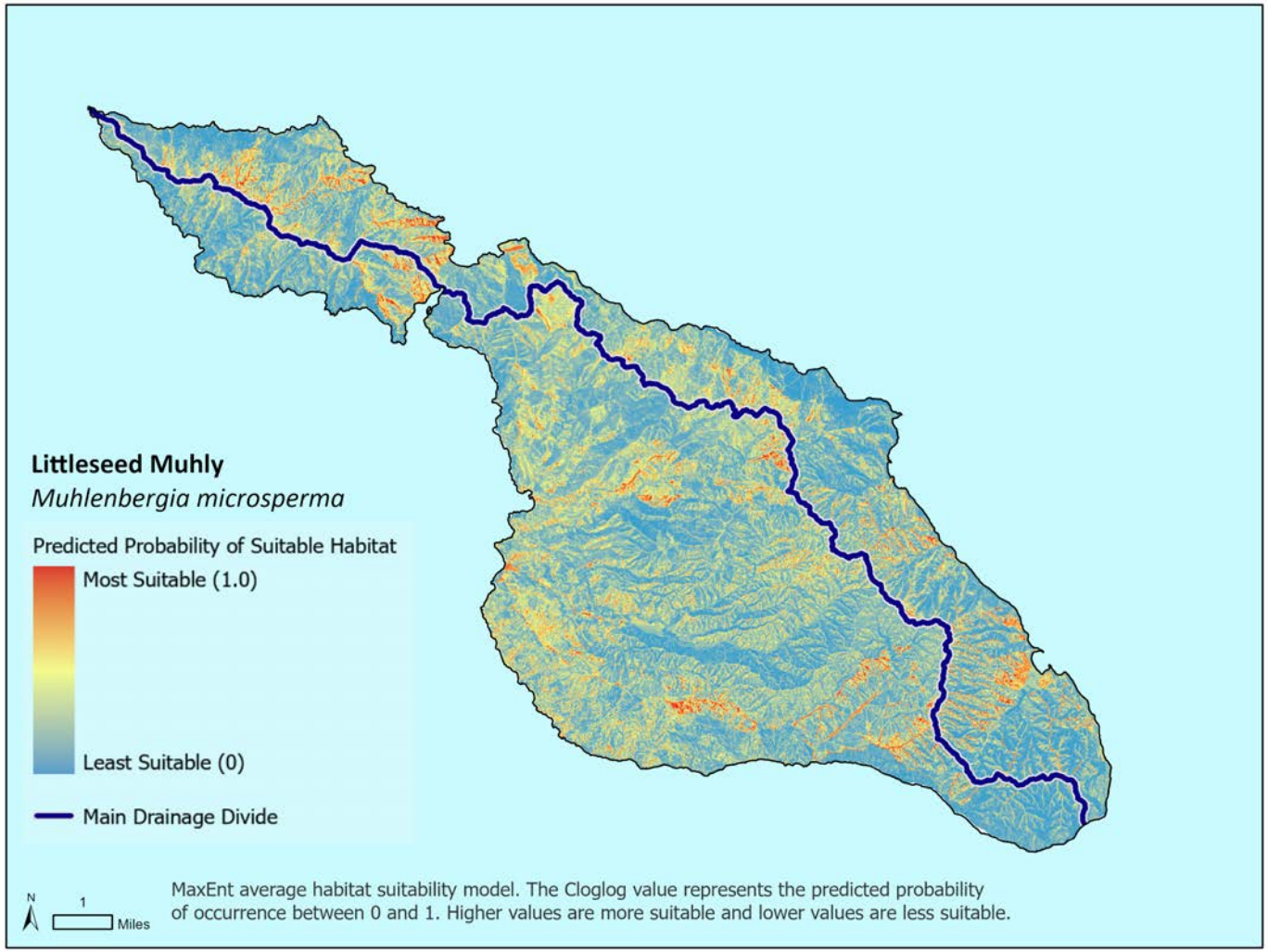

Figure 6-88 Potential Vegetation Map for Littleseed Muhly (*Muhlenbergia microsperma*).

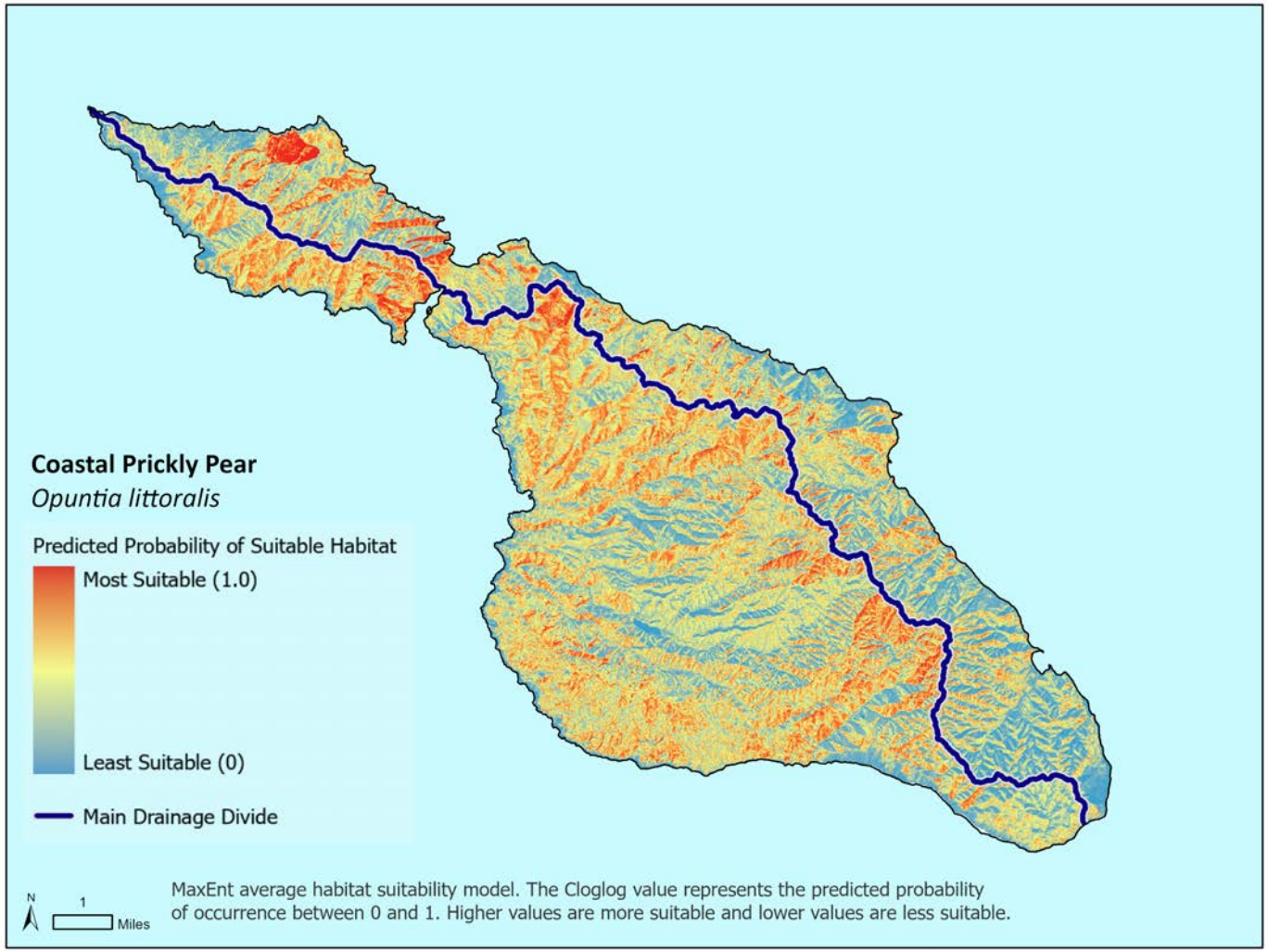

Figure 6-89 Potential Vegetation Map for Coastal Prickly Pear (*Opuntia littoralis*).

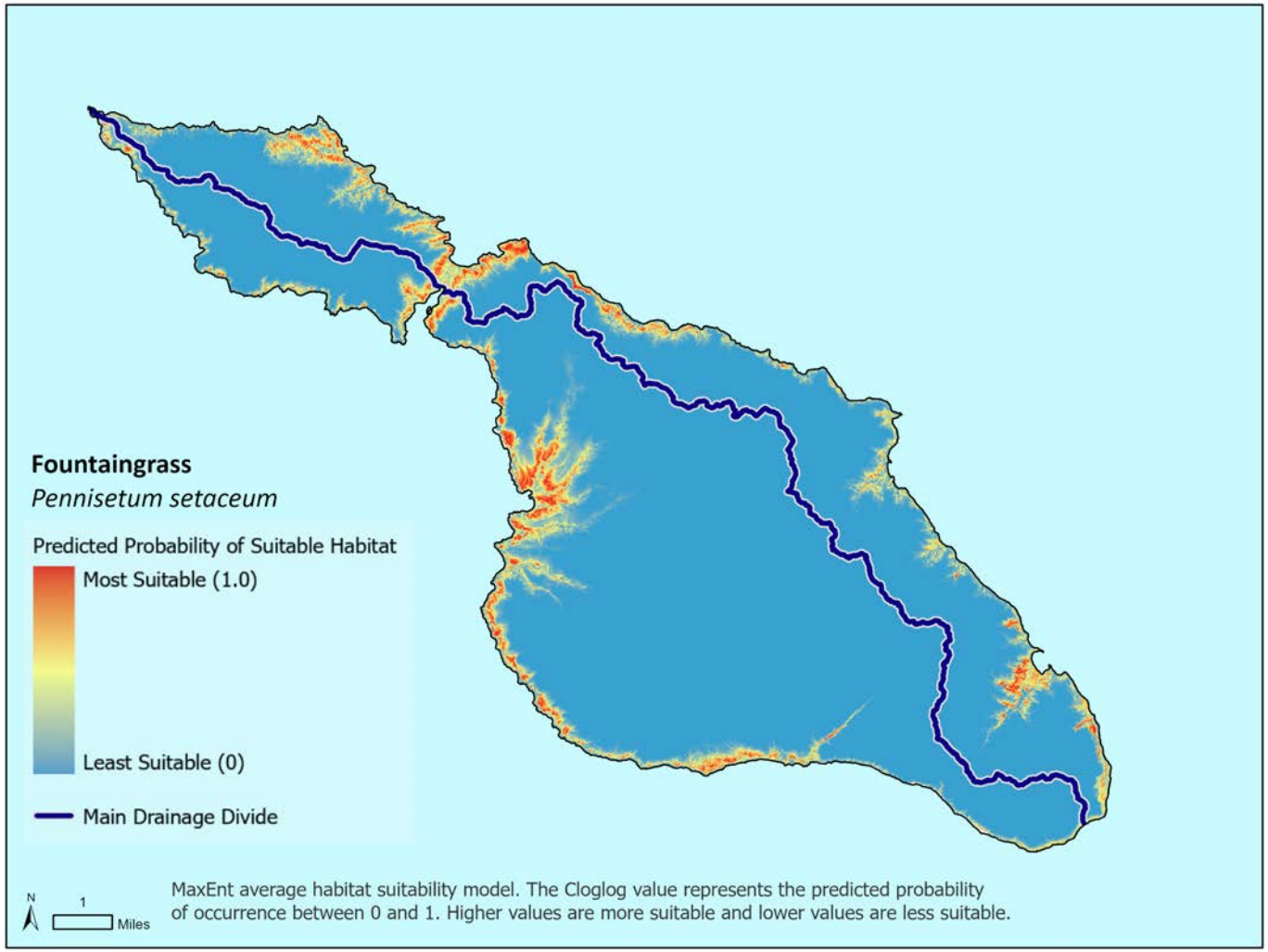

Figure 6-90 Potential Vegetation Map for Fountaingrass (*Pennisetum setaceum*), an Invasive Plant.

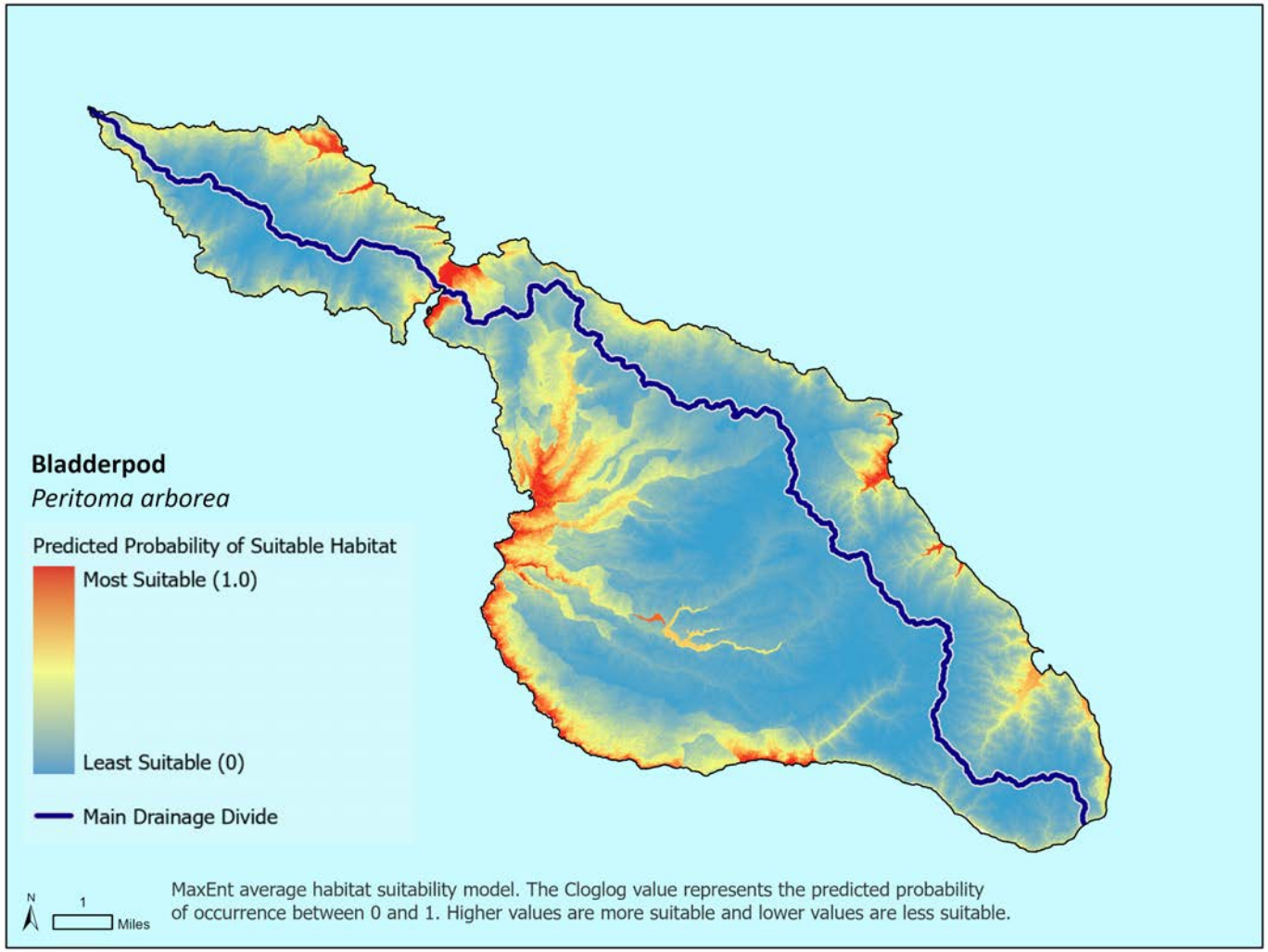

Figure 6-91 Potential Vegetation Map for Bladderpod (*Peritoma arborea*).

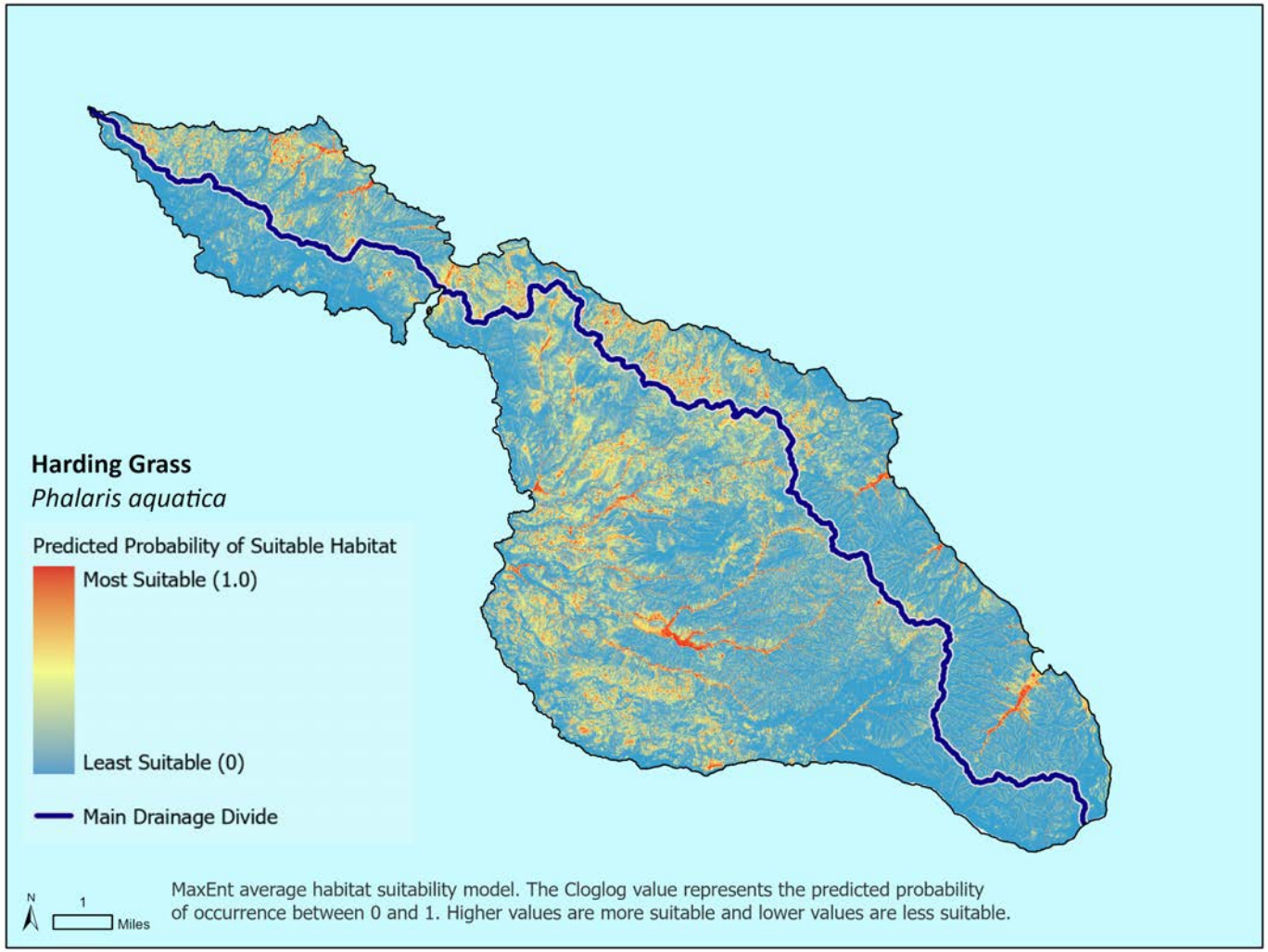

Figure 6-92 Potential Vegetation Map for Harding Grass (*Phalaris aquatica*), an Invasive Plant.

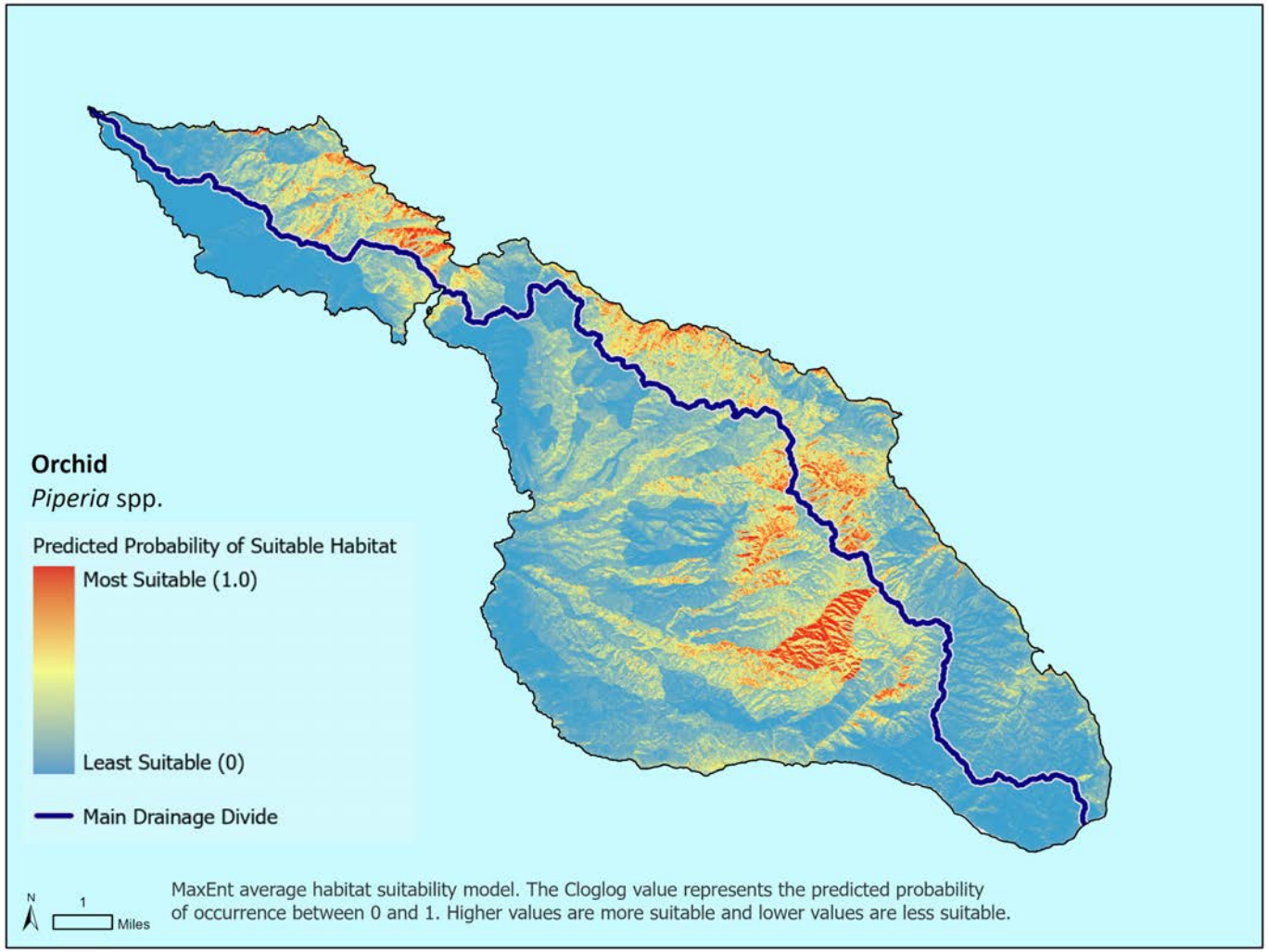

Figure 6-93 Potential Vegetation Map for Orchid (*Piperia* spp.).

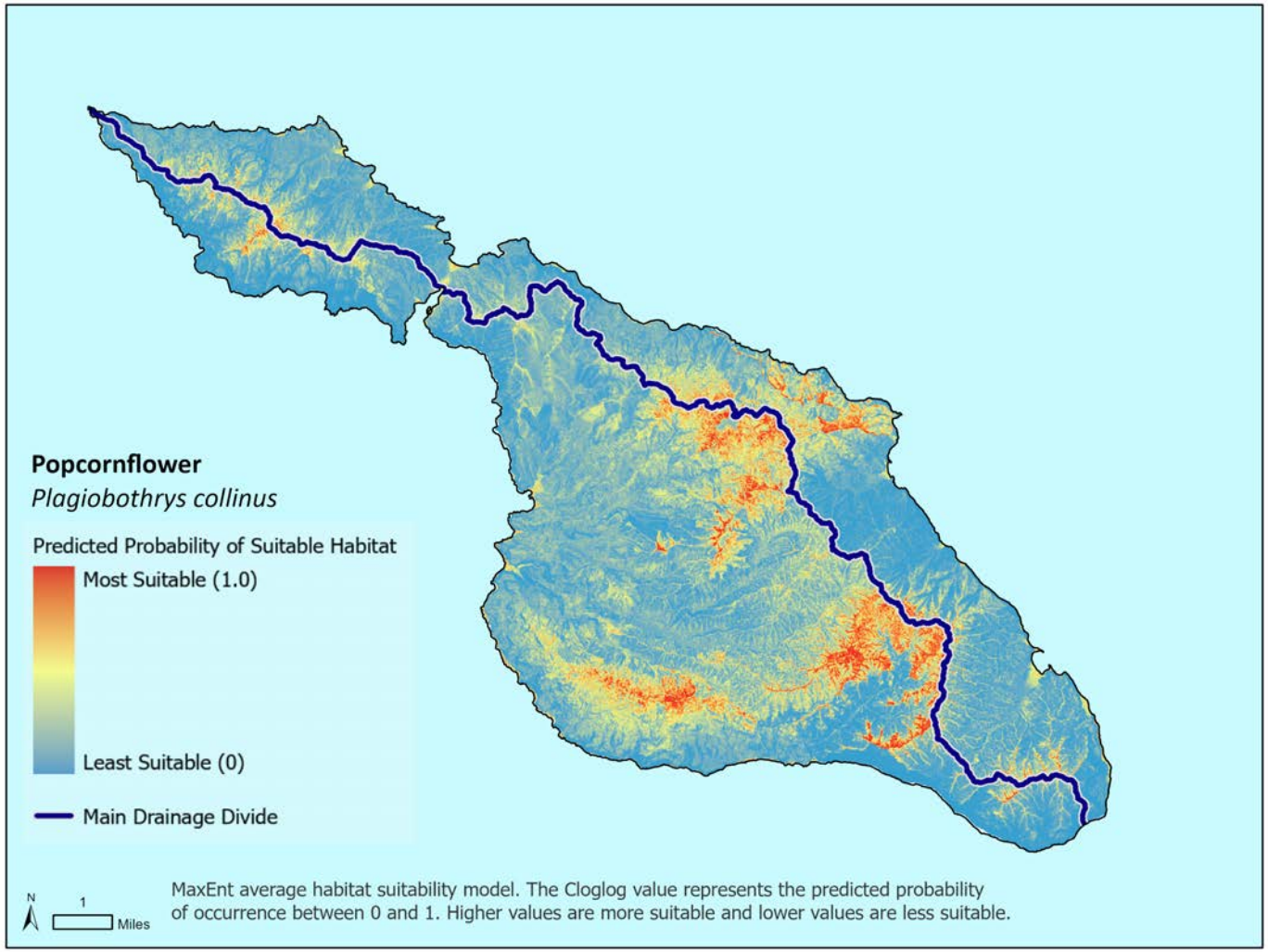

Figure 6-94 Potential Vegetation Map for Popcornflower (*Plagiobothrys collinus*).

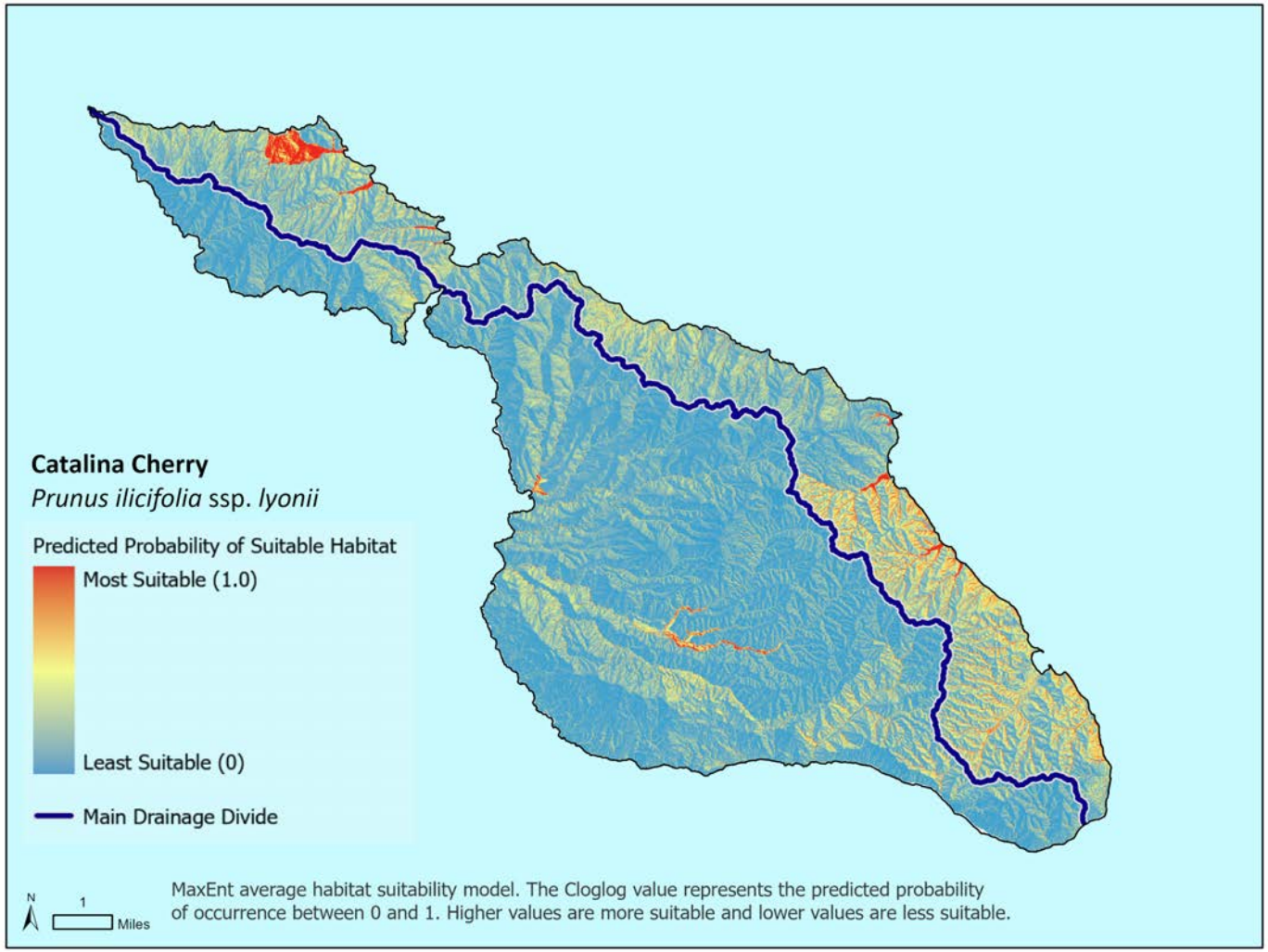

Figure 6-95 Potential Vegetation Map for Catalina Cherry (*Prunus ilicifolia* ssp. *lyonii*), a Channel Island Endemic.

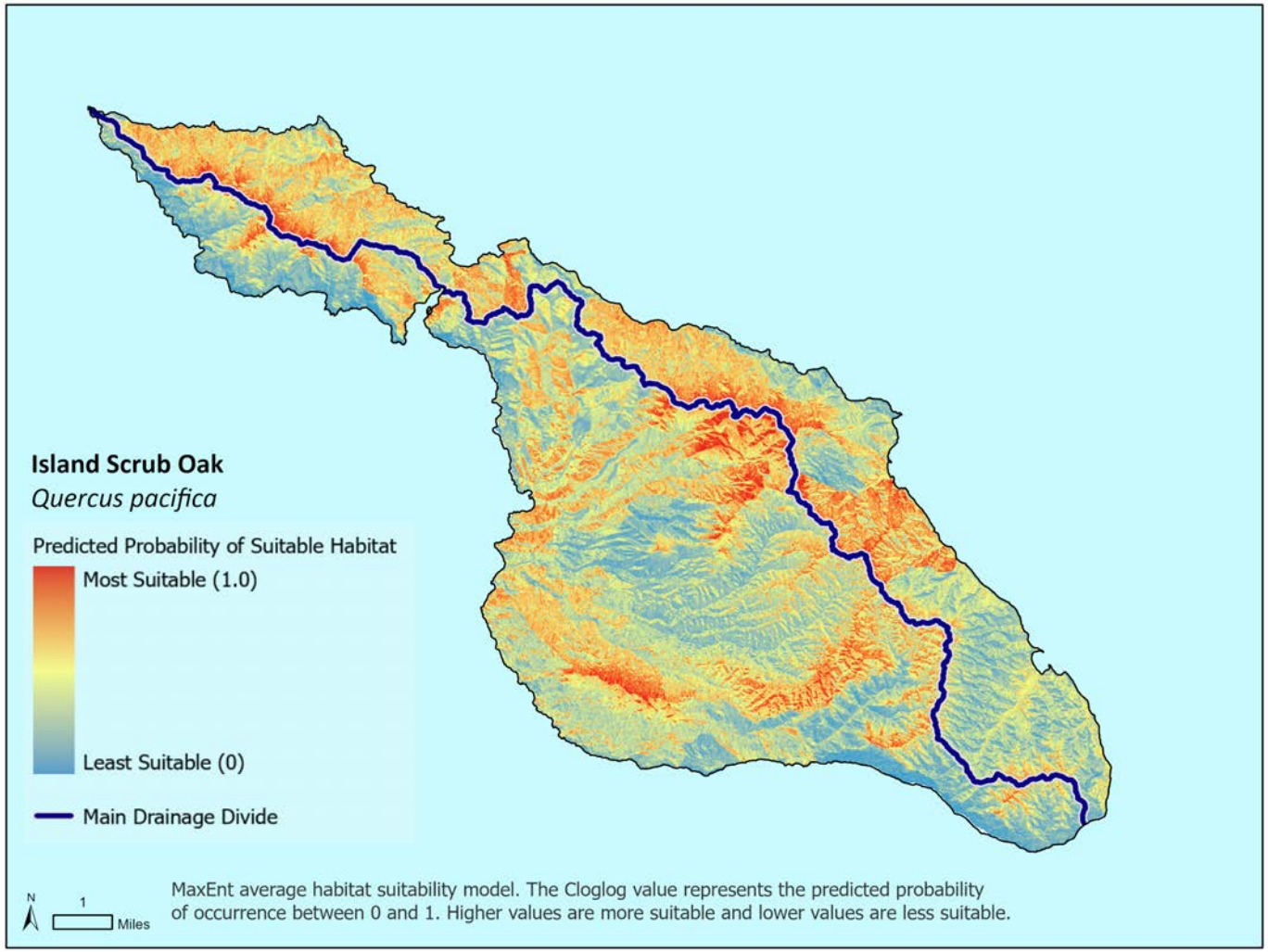

Figure 6-96 Potential Vegetation Map for Island Scrub Oak (*Quercus pacifica*), a Channel Island Endemic.

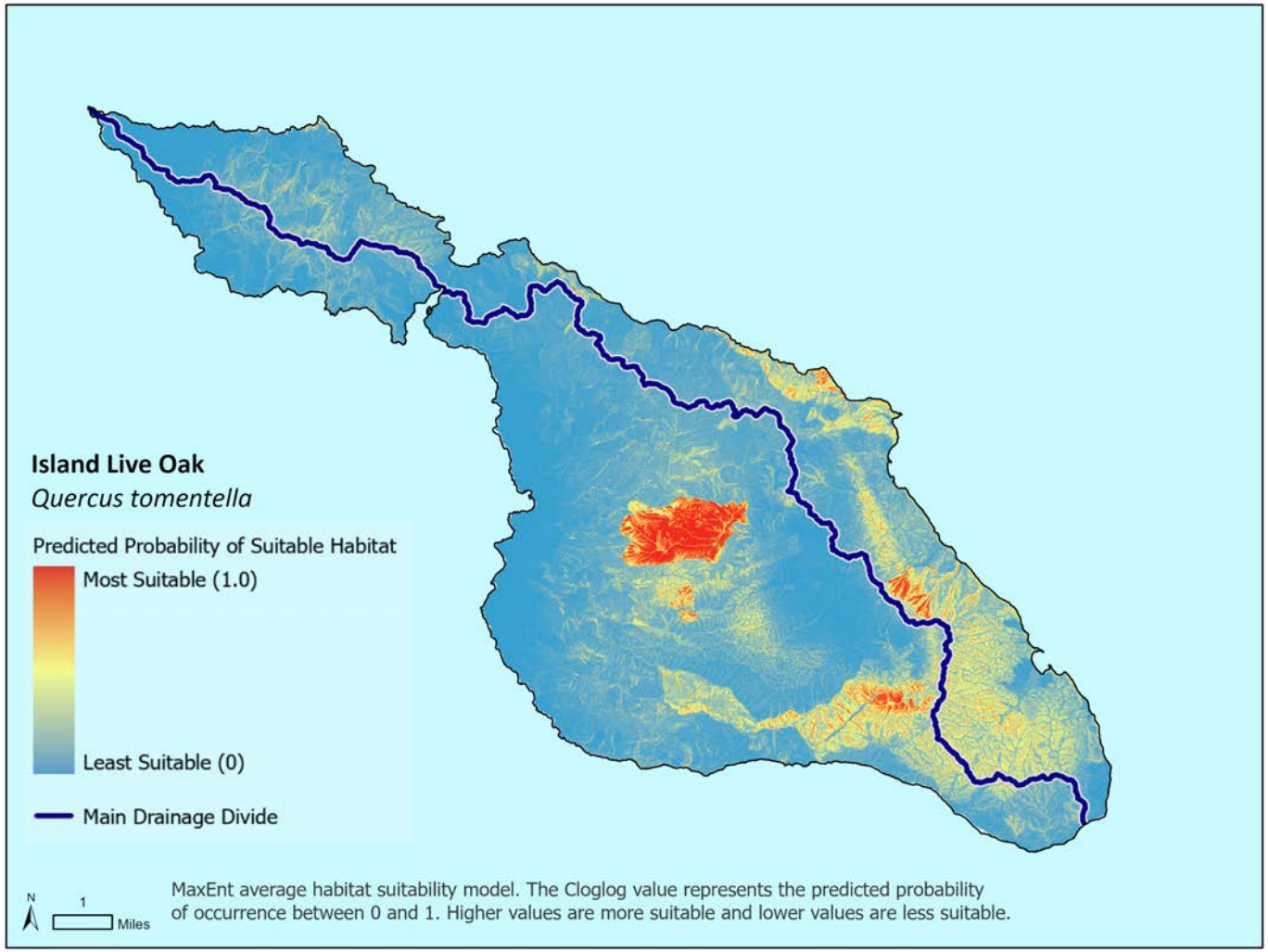

Figure 6-97 Potential Vegetation Map for Island Live Oak (*Quercus tomentella*), a Channel Island Endemic.

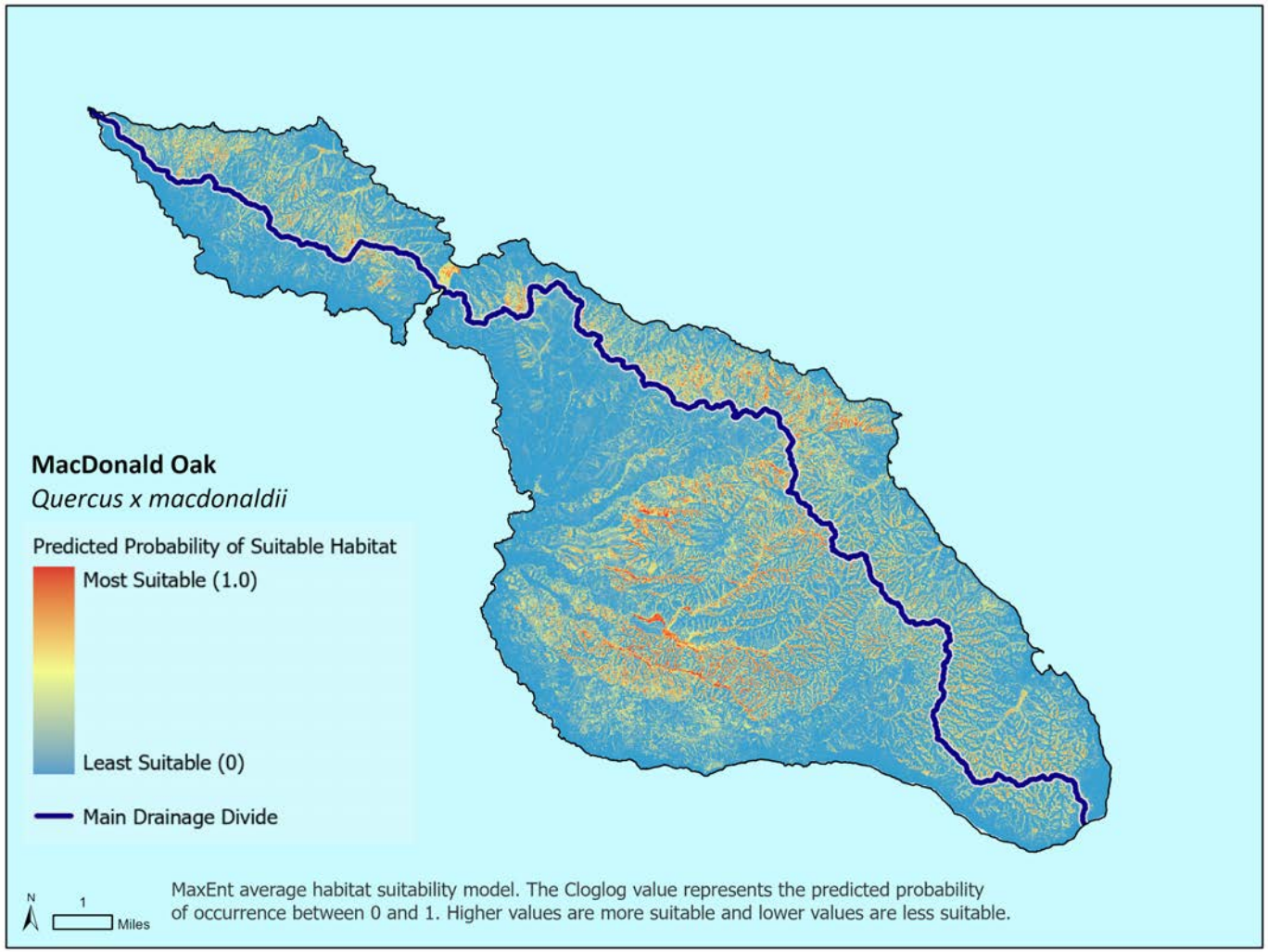

Figure 6-98 Potential Vegetation Map for MacDonald Oak (*Quercus* x *macdonaldii*), a Channel Island Endemic and a naturally occurring hybrid of *Q. pacifica* and *Q. lobata.*

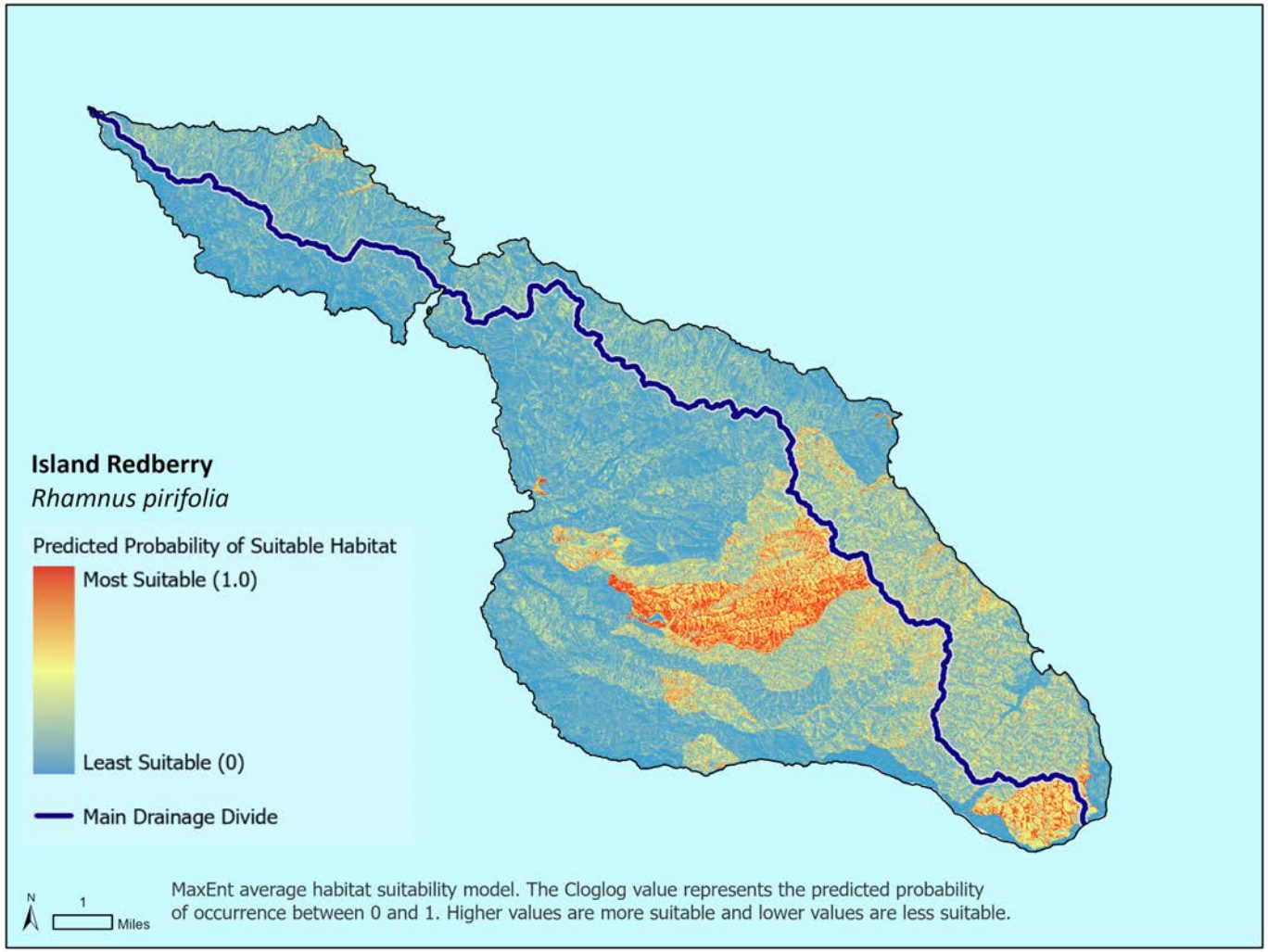

Figure 6-99 Potential Vegetation Map for Island Redberry (*Rhamnus pirifolia*), a Channel Island Endemic.

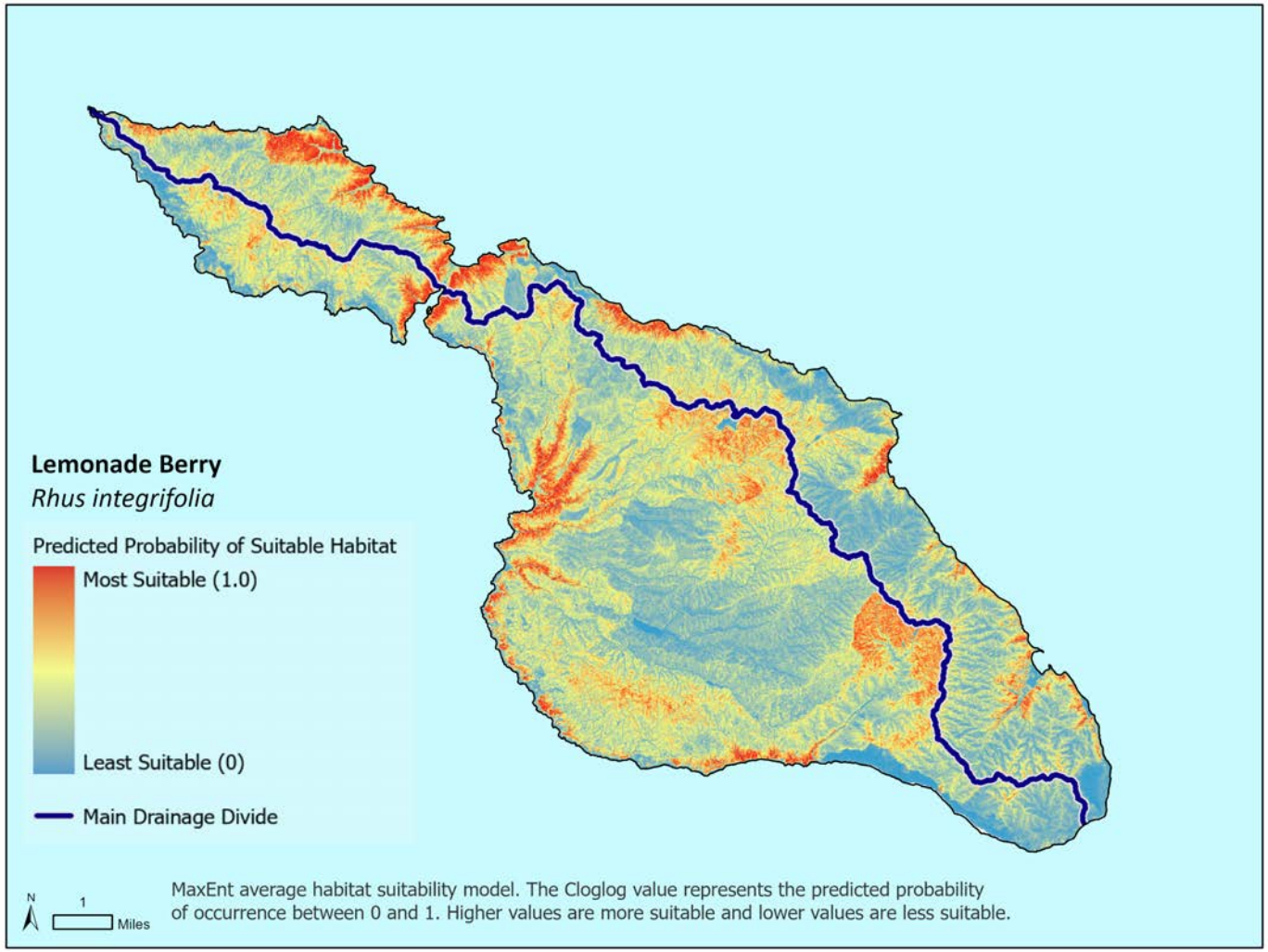

Figure 6-100 Potential Vegetation Map for Lemonade Berry (*Rhus integrifolia*).

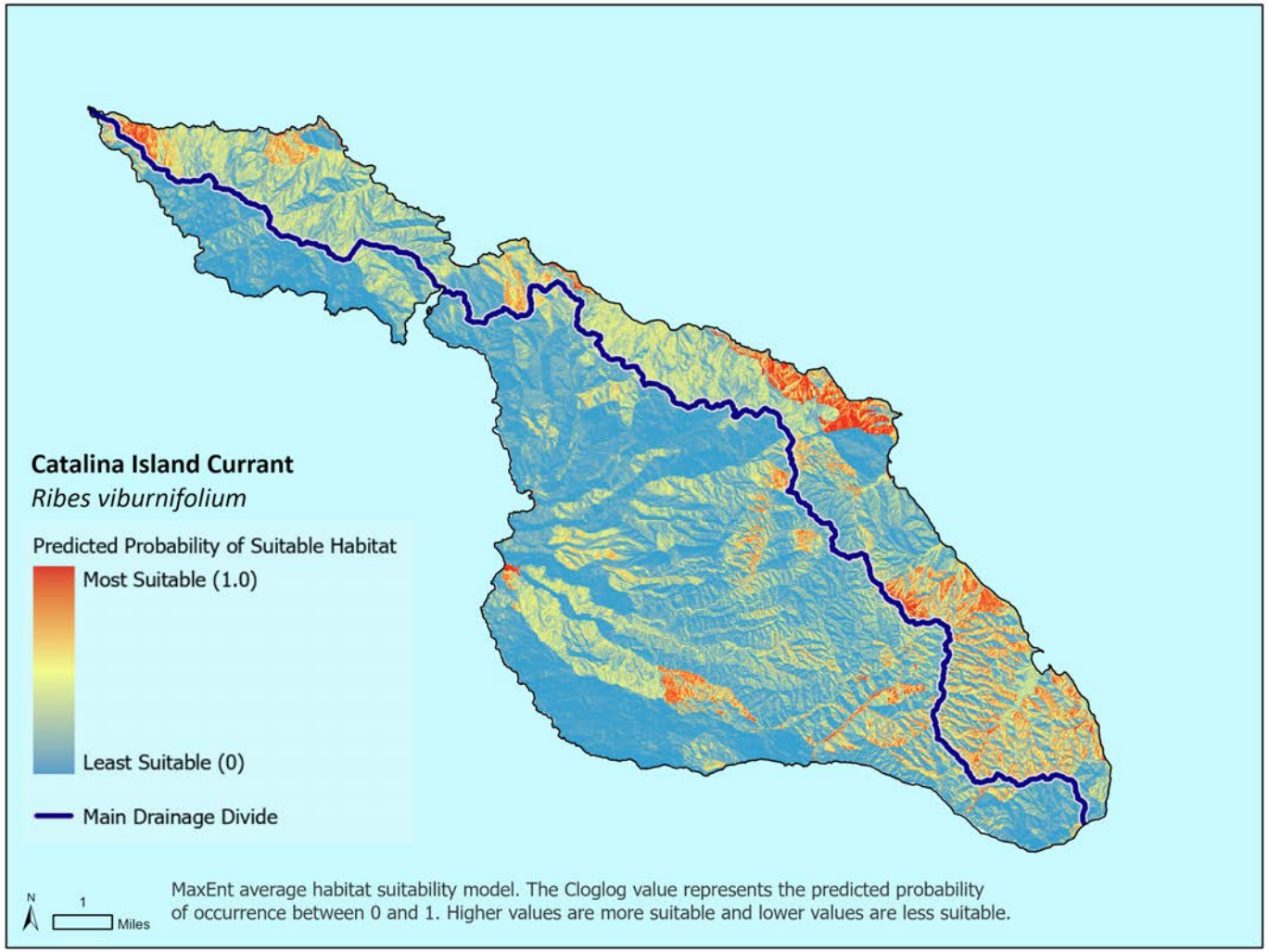

Figure 6-101 Potential Vegetation Map for Catalina Island Currant (*Ribes viburnifolium*), a Channel Island Endemic.

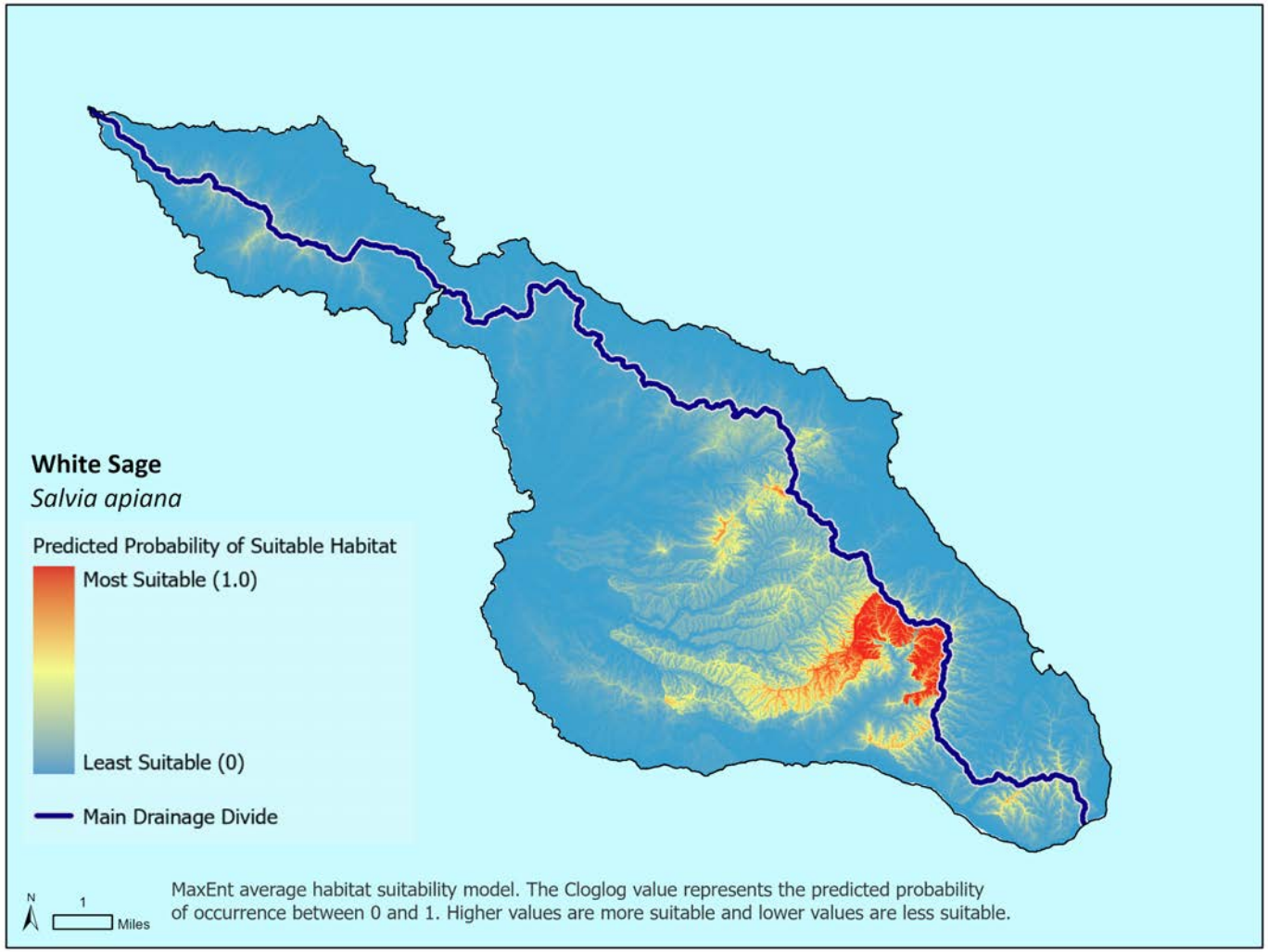

Figure 6-102 Potential Vegetation Map for White Sage (*Salvia apiana*).

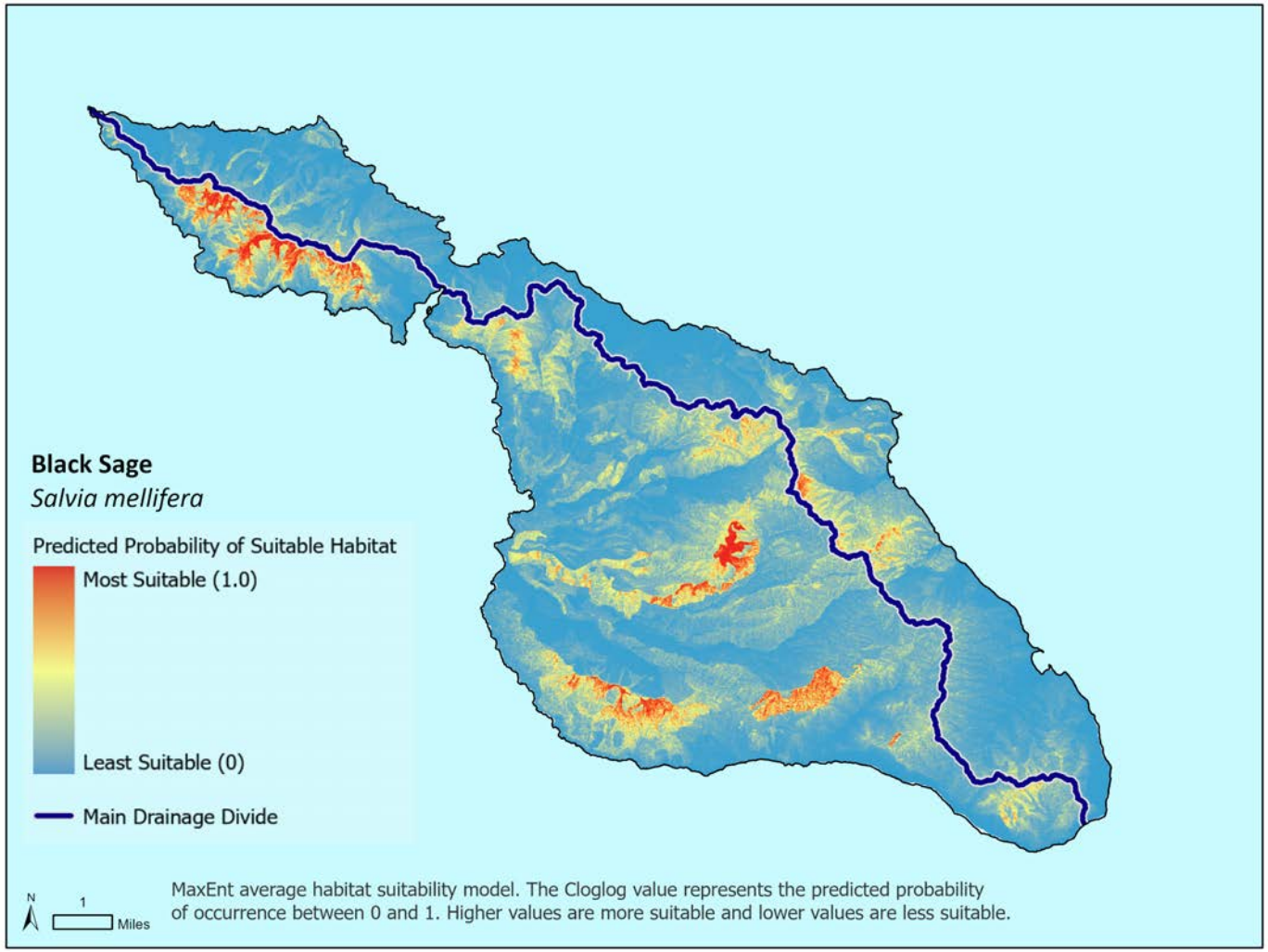

Figure 6-103 Potential Vegetation Map for Black Sage (*Salvia mellifera*).

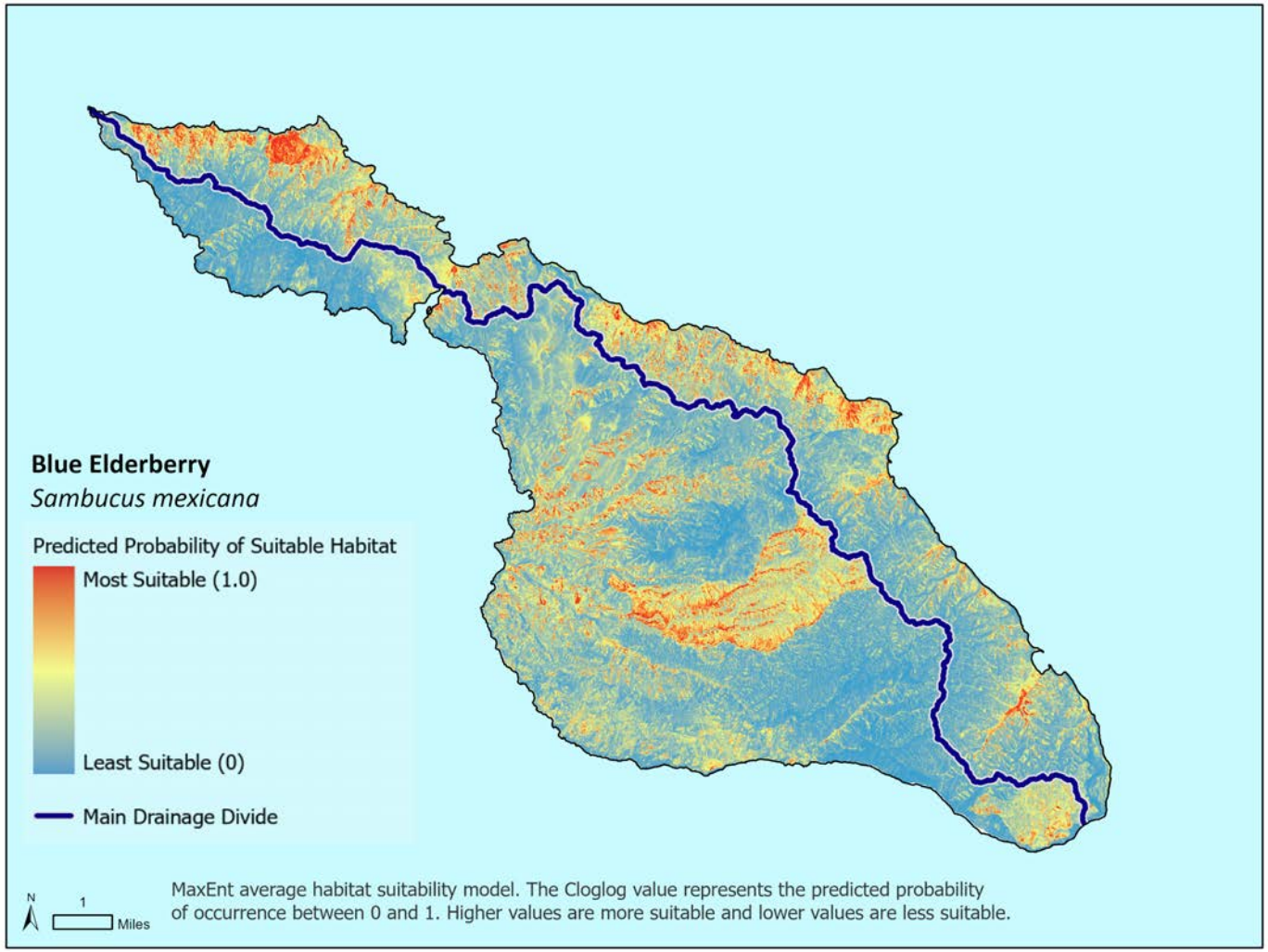

Figure 6-104 Potential Vegetation Map for Blue Elderberry (*Sambucus mexicana*).

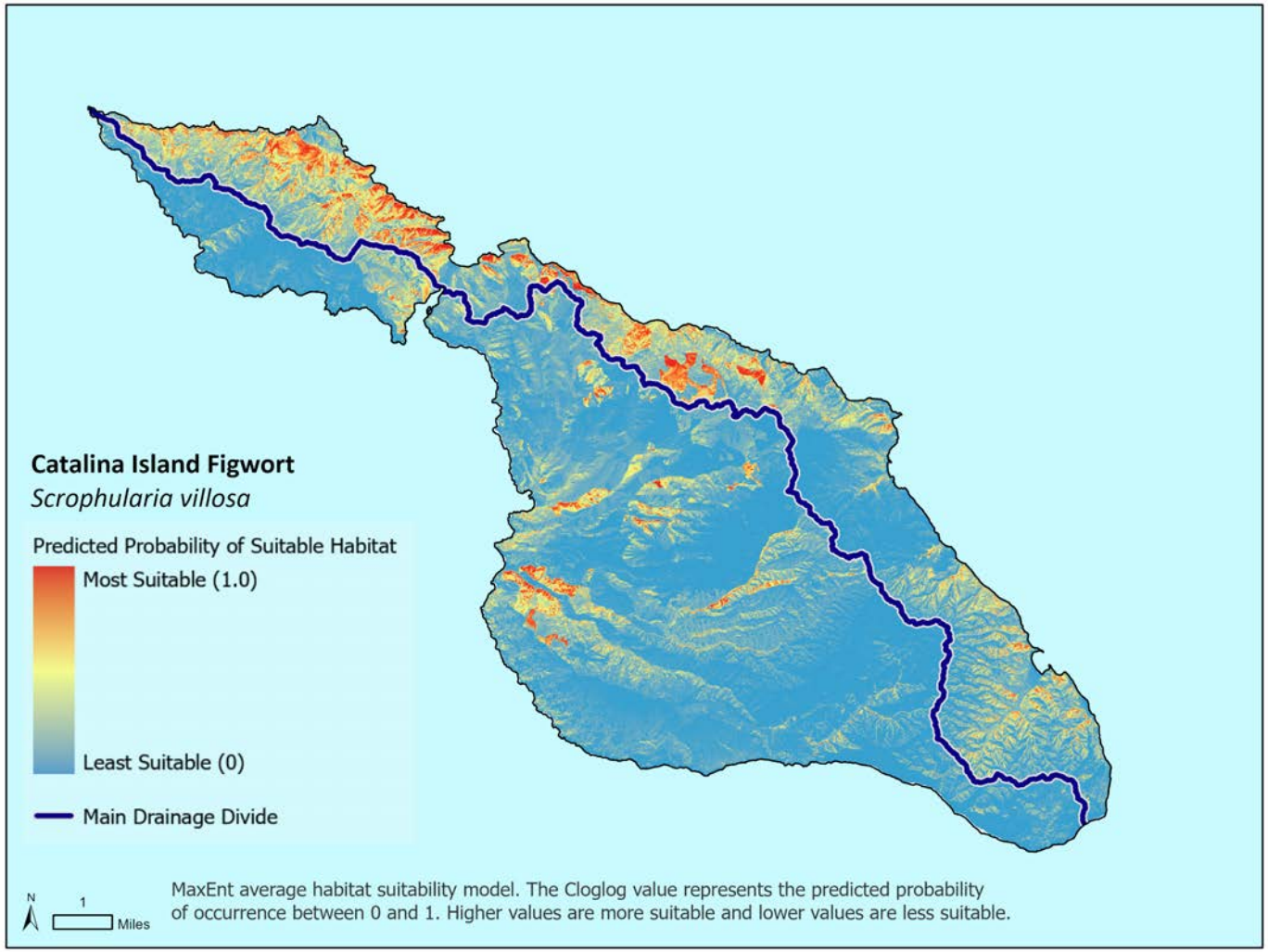

Figure 6-105 Potential Vegetation Map for Catalina Island Figwort (*Scrophularia villosa*), a Channel Island Endemic.

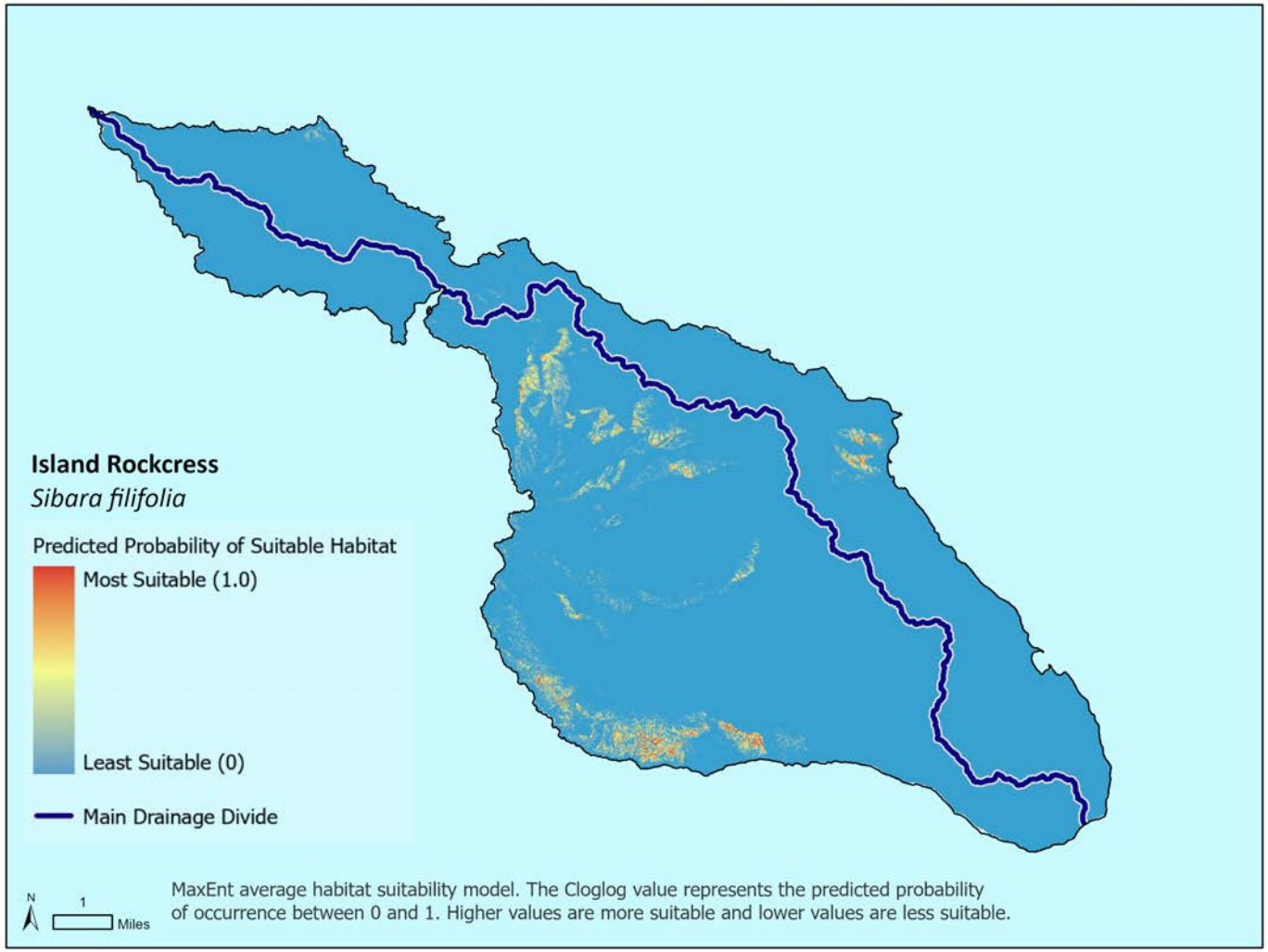

Figure 6-106 Potential Vegetation Map for Island Rockcress (*Sibara filifolia*), a Channel Island Endemic and Federally Endangered Plant.

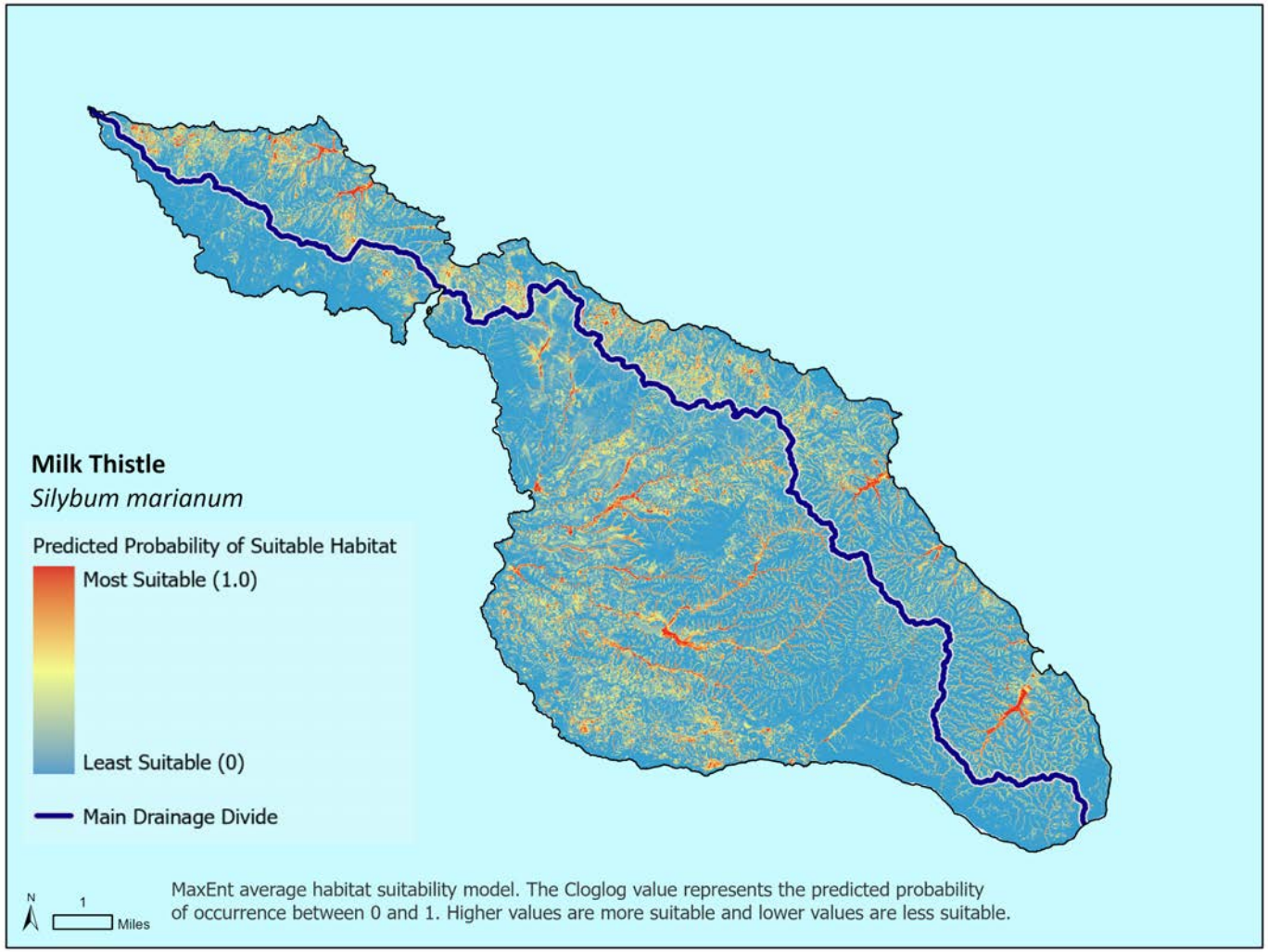

Figure 6-107 Potential Vegetation Map for Milk Thistle (*Silybum marianum*), an Invasive Plant.

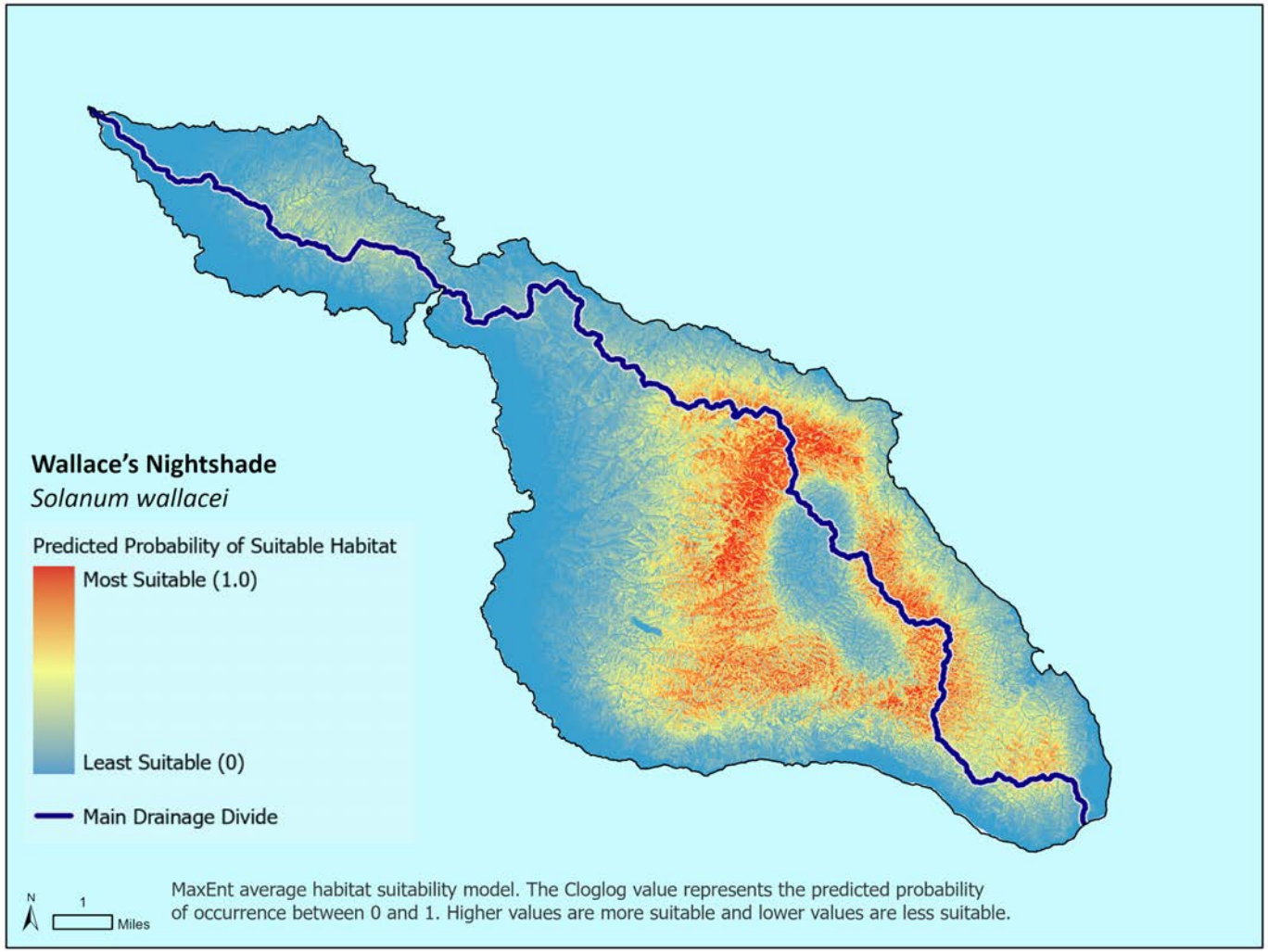

Figure 6-108 Potential Vegetation Map for Wallace's Nightshade (*Solanum wallacei*), a Channel Island Endemic.

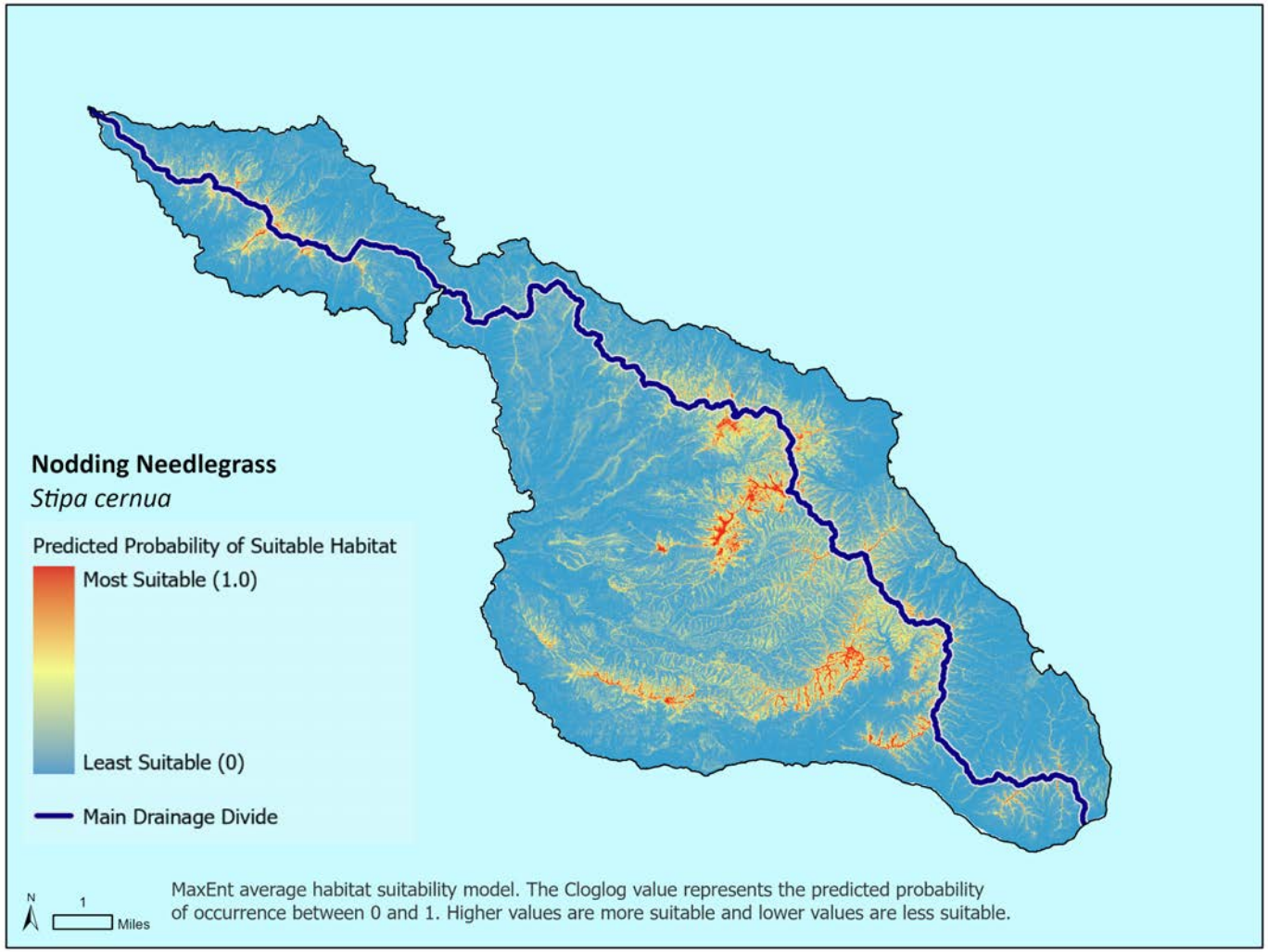

Figure 6-109 Potential Vegetation Map for Nodding Needlegrass (*Stipa cernua*).

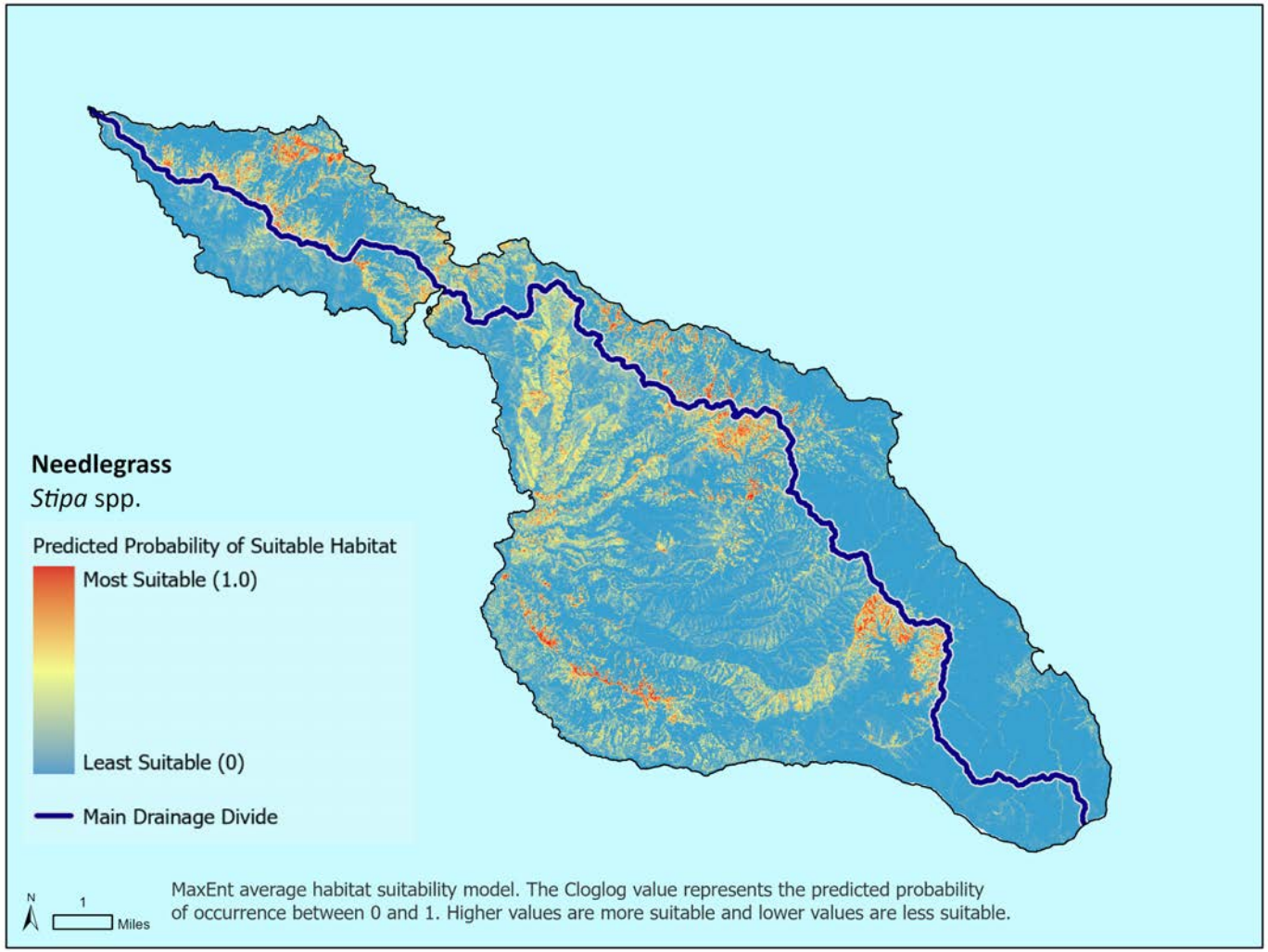

Figure 6-110 Potential Vegetation Map for Needlegrass (*Stipa* spp.).

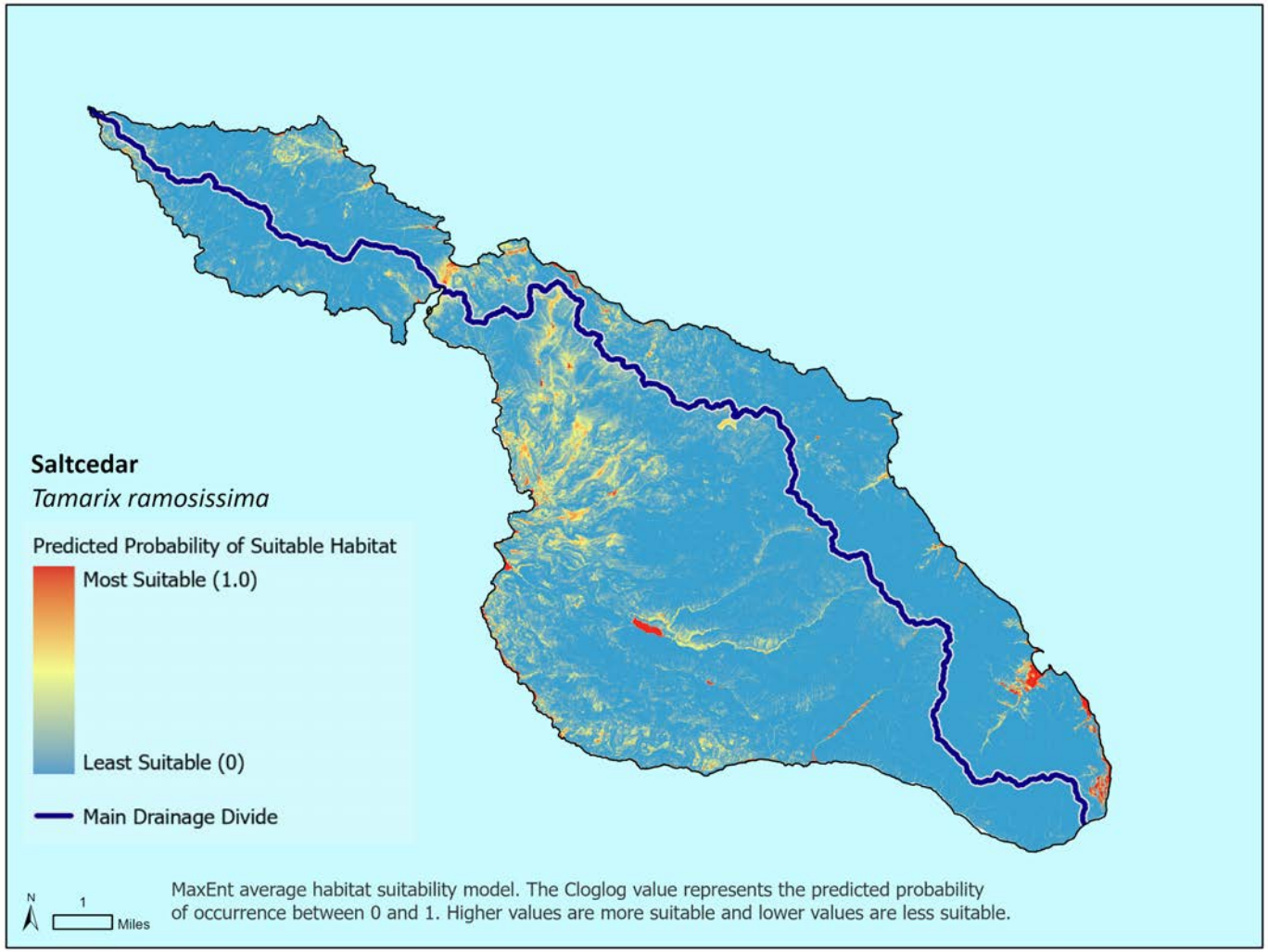

Figure 6-111 Potential Vegetation Map for Saltcedar (*Tamarix ramosissima*), an Invasive Plant.

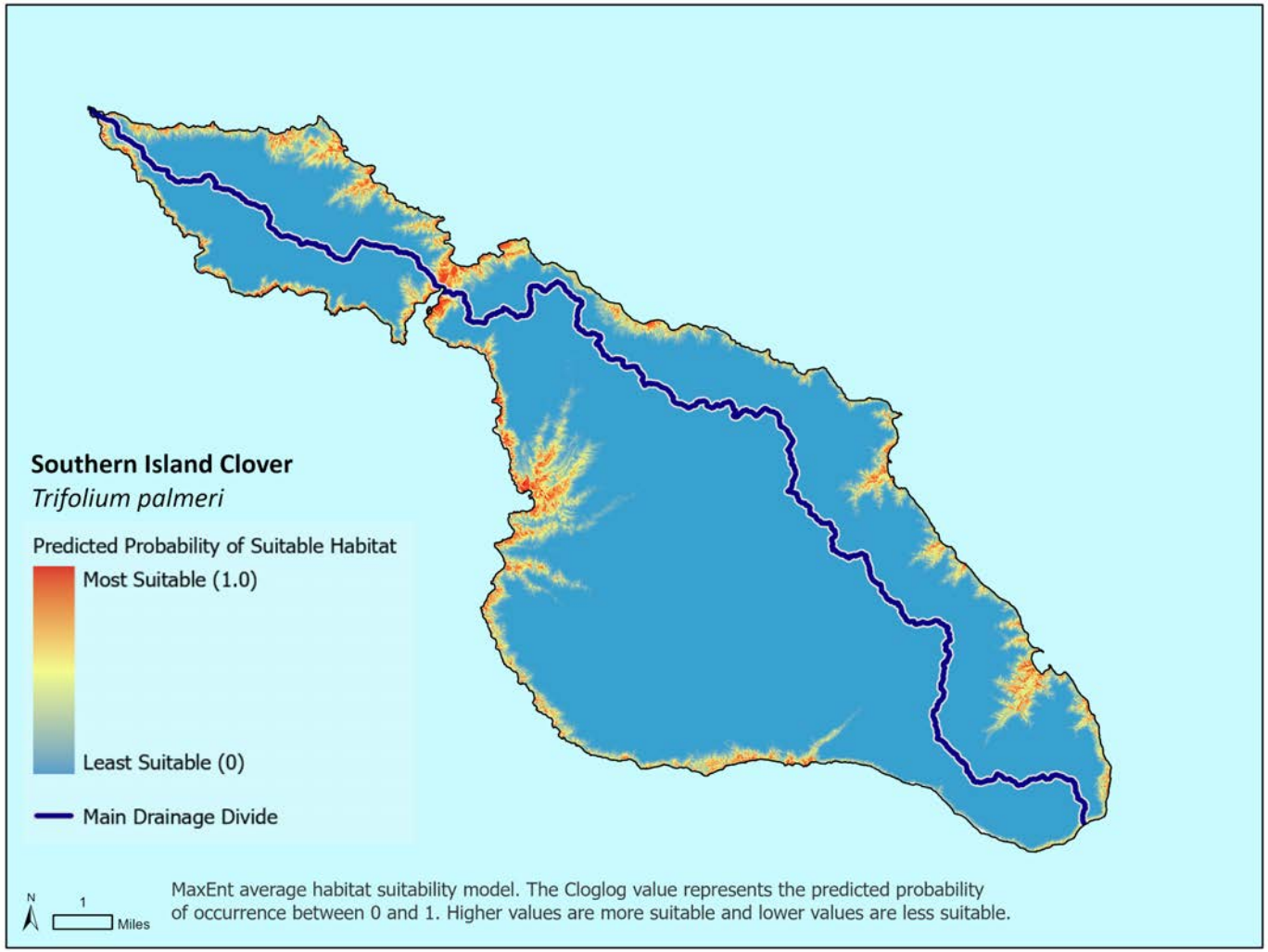

Figure 6-112 Potential Vegetation Map for Southern Island Clover (*Trifolium palmeri*), a Channel Island Endemic.

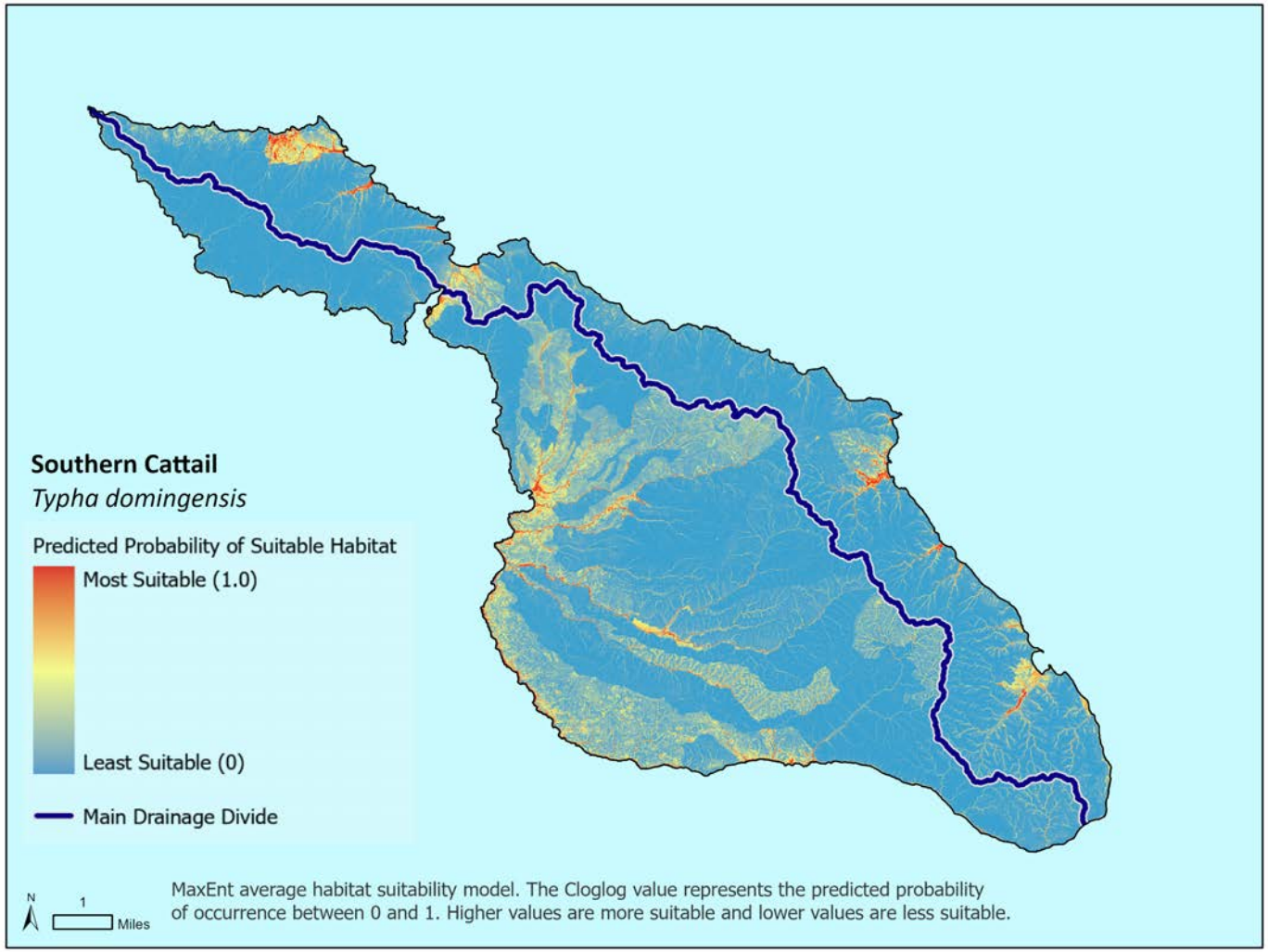

Figure 6-113 Potential Vegetation Map for Southern Cattail (*Typha domingensis*).

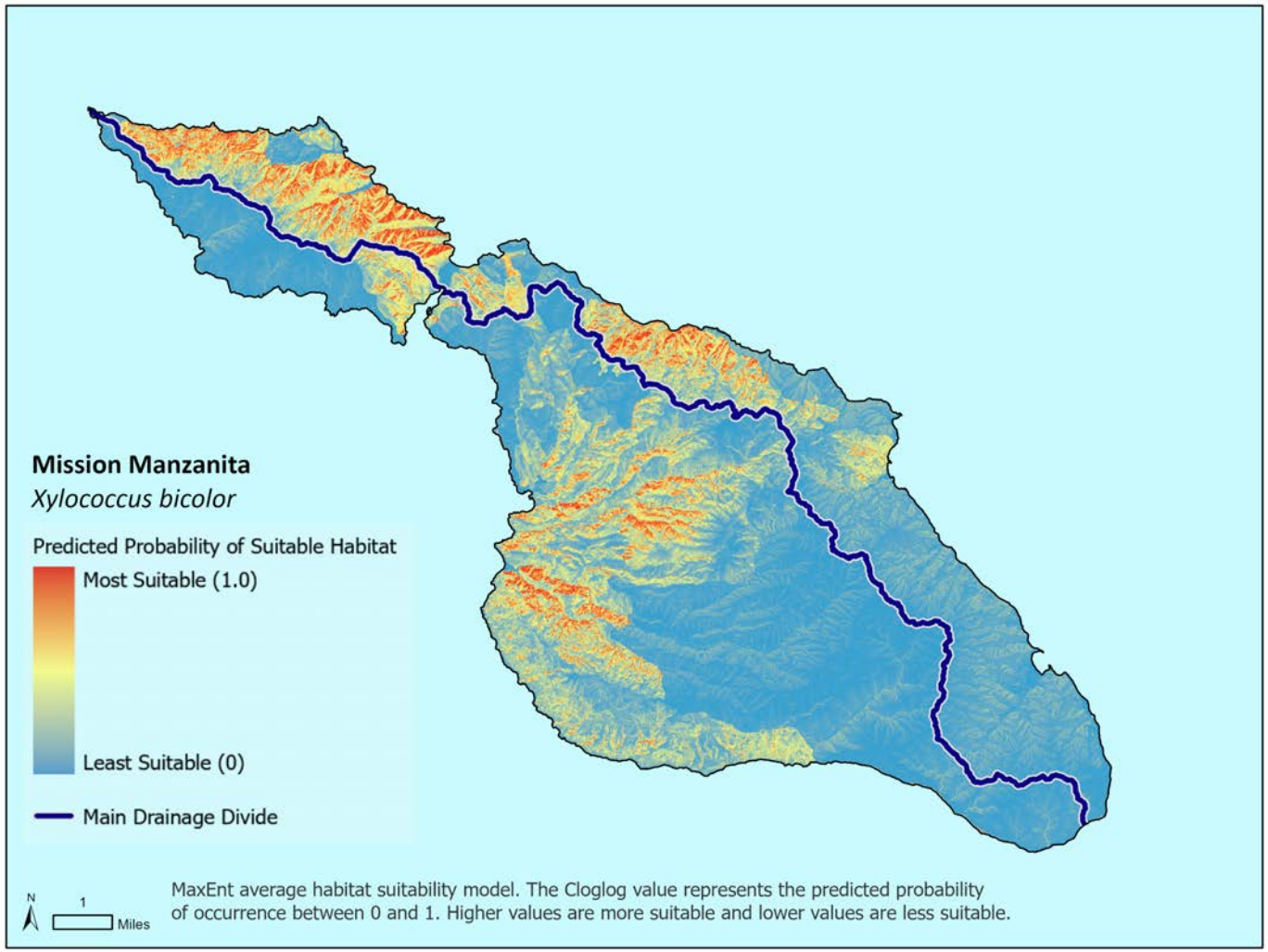

Figure 6-114 Potential Vegetation Map for Mission Manzanita (*Xylococcus bicolor*).

Table 6-4. Environmental Variable Permutation Importance in Models.

			CLIMATE								TOPOGRAPHY							GEOLOGY & SOILS			
Scientific Name	Common Name	Code	May Cloud Albedo	June Cloud Albedo	July Cloud Albedo	August Cloud Albedo	September Cloud Albedo	Winter Solstice Solar Insol.	Equinox Solar Insolation	Summer Solstice Solar Insol.	Elevation	Aspect	Northeastedness	Slope	Topographic Position Index	Terrain Wetness Index	Ruggedness	Geology	2008 Soils	1955 Soils	NDVI | VEG. PRODUCTIVITY
Abronia maritima	red sand verbena	abrmar											0.2	9.2		2.4			9.0		79.2
Achillea millefolium	common yarrow	achmil											9.6	23.1					16.7		50.6
Acmispon argophyllus	silver birds foot trefoil	acmarg								26.4				0.1	19.2			54.3			
Acmispon grandifloras	large leaved lotus	acmgra							0.7		26.6		2.5	29.3				20.2	20.7		
Adenostoma fasciculatum	chamise	adefas										13.7	14.2	0.6				21.6	49.9		
Anemopsis californica	yerba mansa	anecal									0.1		0.9	70.9	17.8				9.1		1.2
Aphanisma blitoides	aphanisma	aphbli					34.9				56.4		4.3						4.4		
Arctostaphylos catalinae - SCIE	Catalina Island manzanita	arccat								47.2		12.3	2.0	4.6	3.4	5.8		13.2	11.5		
Artemisia californica	California sagebrush	artcal		14.1							26.4	27.8		0.6		4.1			27.0		
*Arundo donax**	giant reed	arudon									78.0	1.5		6.7		0.1	0.5		13.2		
Asclepias fascicularis	narrowleaf milkweed	ascfas										0.0		0.0			0.0		79.3		20.7
Atriplex coulteri	Coulter's saltbush	atrcou								32.5	6.2	4.0						14.5	9.8		33.0
Atriplex pacifica	South Coast saltscale	atrpac								9.9	14.2	1.2		5.2		27.2			37.9		4.4
Baccharis pilularis	coyote bush	bacpil	0.2								35.5	3.8						24.2	36.3		
Bergerocactus emoryi - CIE	velvet cactus	beremo									65.8			0.8		0.6	1.1	3.3	28.4		
Bothriochloa barbinodis	cane bluestem	botbar						39.0			44.6			11.2	0.3				4.8		0.1

			CLIMATE								TOPOGRAPHY							GEOLOGY & SOILS			
Scientific Name	Common Name	Code	May Cloud Albedo	June Cloud Albedo	July Cloud Albedo	August Cloud Albedo	September Cloud Albedo	Winter Solstice Solar Insol.	Equinox Solar Insolation	Summer Solstice Solar Insol.	Elevation	Aspect	Northeastedness	Slope	Topographic Position Index	Terrain Wetness Index	Ruggedness	Geology	2008 Soils	1955 Soils	NDVI | VEG. PRODUCTIVITY
*Brassica nigra**	black mustard	branig	22.3								34.3	1.6		1.1	0.9		17.2		22.6		
Bromus sitchensis (*carinatus*)	California brome	brocar							9.9	0.9			6.2			7.2		50.9	24.9		
*Cakile maritima**	sea rocket	cakmar						7.4				5.5		35.6	9.0				42.5		
*Carduus pycnocephalus**	Italian thistle	carpyc									9.1	15.2		24.6	32.3	1.9			16.9		
Ceanothus arboreus - CIE	felt-leaf ceanothus	ceaarb							29.0			13.4	13.4	3.1	7.2	2.5	4.9		26.5		
Ceanothus megacarpus var. *insularis* - CIE	island ceanothus	ceamegins							0.0		24.5	2.8					0.1		72.6		
Ceanothus megacarpus var. *megacarpus*	bigpod ceanothus	ceamegmeg							27.2		22.1	27.3		0.6			0.2		22.6		
*Centranthus ruber**	red valerian	cenrub									7.7				4.9	5.8	4.2		76.9		0.5
Cercocarpus traskiae - SCIE	Catalina Island mountain-mahogany	certra					17.6				3.9	8.6	4.6		5.4		6.4		53.5		
Chlorogalum pomeridianum	soap plant	chlpom				66.0								17.8		0.4		3.0	12.8		
*Cirsium vulgare**	bull thistle	cirvul									0.8	5.9			28.8	0.3	40.3		22.4		1.5
Comarostaphylis diversifolia subsp. *planifolia*	summer holly	comdivpla				24.9							1.7	11.3		0.2			61.9		
*Cortaderia selloana**	pampas grass	corsel					5.6						3.9	1.1		54.4			30.8		4.2
Cressa truxillensis	alkali weed	cretru					3.6			3.2	91.2		0.4			0.6			0.2		0.8

			CLIMATE								TOPOGRAPHY							GEOLOGY & SOILS			
Scientific Name	**Common Name**	**Code**	**May Cloud Albedo**	**June Cloud Albedo**	**July Cloud Albedo**	**August Cloud Albedo**	**September Cloud Albedo**	**Winter Solstice Solar Insol.**	**Equinox Solar Insolation**	**Summer Solstice Solar Insol.**	**Elevation**	**Aspect**	**Northeastedness**	**Slope**	**Topographic Position Index**	**Terrain Wetness Index**	**Ruggedness**	**Geology**	**2008 Soils**	**1955 Soils**	**NDVI | VEG. PRODUCTIVITY**
Crocanthemum greenei - CIE	island rush-rose	crogre								9.8	20.4			2.1		4.8	19.6		43.3		
Crossosoma californicum - CIE/PVP	Catalina Island crossosoma	crocal									8.1	12.1		34.4		14.8		19.0	11.6		
Cylindropuntia prolifera	coastal cholla	cylpro					33.1				0.4			3.3					1.3		61.9
*Cynara cardunculus**	artichoke thistle	cyncar					93.1						0.1	2.2		0.3					4.3
Cyperus spp.	flatsedge	cypspp	2.5								1.0	9.1	7.7			1.2		43.6	34.9		
Deinandra clementina - CIE	island tarplant	deicle						1.2			85.1	3.4		0.8					9.5		
Deinandra fasciculata	clustered tarplant	deifas						0.3			11.8	0.5		0.0			51.1		36.3		
Delphinium parryi subsp. *maritimum*	maritime larkspur	delparmar	11.2					18.4			17.2	10.7	5.8			1.9		11.2	20.8		2.8
Dendromecon harfordii	Channel Island tree poppy	denhar		0.7					1.0		22.1	8.6	3.9	3.9		4.9			54.9		
Dichondra occidentalis	western dichondra	dicocc								4.7	0.7	3.1		47.6		6.3			37.6		0.0
Dissanthelium californicum - CIE	California dissanthelium	discal										12.3	10.5	0.9	2.7				73.6		
Dudleya virens ssp. *hassei* - SCIE	Catalina Island dudleya	dudvirhas									89.4		2.4	1.7		0.7	0.1		3.0		2.7
Dudleya virens subsp. *insularis*	island green dudleya	dudvirins						24.5			15.4	6.1	27.8	4.9		2.0	6.9		7.0		5.4
Elymus (Leymus) condensatus	giant wild rye	elycon									12.7	24.4				2.9	3.7	19.9	27.6		8.8

			CLIMATE								TOPOGRAPHY							GEOLOGY & SOILS			
Scientific Name	**Common Name**	**Code**	**May Cloud Albedo**	**June Cloud Albedo**	**July Cloud Albedo**	**August Cloud Albedo**	**September Cloud Albedo**	**Winter Solstice Solar Insol.**	**Equinox Solar Insolation**	**Summer Solstice Solar Insol.**	**Elevation**	**Aspect**	**Northeastedness**	**Slope**	**Topographic Position Index**	**Terrain Wetness Index**	**Ruggedness**	**Geology**	**2008 Soils**	**1955 Soils**	**NDVI | VEG. PRODUCTIVITY**
Encelia californica	California sunflower bush	enccal									88.8				9.8				1.4		0.0
Ericameria palmeri	Palmer's goldenbush	eripal										3.3		30.3	2.0	14.5			26.1		23.8
Eriodictyon traskiae ssp. *traskiae* - SCIE	Trask's yerba santa	eritra					37.3				8.6						9.0		45.1		
Eriogonum giganteum var. *giganteum* - SCIE	St. Catherine's lace	erigig	13.8							2.6	26.4			9.6				20.3	27.3		
Eriogonum grande var. *grande*	island buckwheat	erigra												0.1	1.7	1.7	3.6		52.3		40.6
Eschscholzia ramosa - CIE	Island poppy	escram									5.9	9.2		31.0		8.4		26.2	19.3		
Euphorbia misera - CIE	cliff spurge	eupmis										2.1			0.7		7.0	32.0	58.2		
*Foeniculum vulgare**	sweet fennel	foevul					1.7				25.1			7.8	4.8	1.1		12.1	46.4		1.0
Frankenia salina	alkali heath	frasal											2.2	2.0		2.9	4.7		53.7		34.5
Galium catalinense ssp. *catalinense* - SCIE	Catalina Island bedstraw	galcat						41.3			19.4	8.3		11.1			3.9	2.1	13.9		
Gambelia speciosa (Galvezia speciosa) - CIE	showy island snapdragon	gamspe	8.3				4.2				9.5		1.7			0.0			76.3		
*Genista linifolia**	Mediterranean broom	genlin						15.9			2.0	8.6	6.2	13.7		13.1			38.0		2.5
Gilia nevinii - CIE	Nevin's gilia	gilnev										22.9			0.1			20.3	56.7		
Heteromeles arbutifolia	toyon	hetarb		8.5							30.1	7.3	5.6		9.2				9.2		30.1
Hordeum intercedens	vernal barley	horint						52.6				6.7				2.9			12.4		25.4

			CLIMATE								TOPOGRAPHY							GEOLOGY & SOILS			
Scientific Name	Common Name	Code	May Cloud Albedo	June Cloud Albedo	July Cloud Albedo	August Cloud Albedo	September Cloud Albedo	Winter Solstice Solar Insol.	Equinox Solar Insolation	Summer Solstice Solar Insol.	Elevation	Aspect	Northeastedness	Slope	Topographic Position Index	Terrain Wetness Index	Ruggedness	Geology	2008 Soils	1955 Soils	NDVI | VEG. PRODUCTIVITY
Isocoma menziesii var. *menziesii*	Menzie's goldenbush	isomen									5.2	3.6	1.2		5.2	1.9			14.6		68.3
Jepsonia malvifolia - CIE	island jepsonia	jepmal						67.2						8.3				8.8	15.7		
Lepechinia fragrans	fragrant pitcher sage	lepfra			31.1						14.7	11.5		13.6		16.2					12.9
Leptosyne gigantea (Coreopsis gigantea)	giant coreopsis	lepgig			11.7			4.6			51.8	3.7		0.1		0.1			12.0		16.0
Lycium californicum	California boxthorn	lyccal			25.2						20.5			17.4		1.8	7.6		10.4		17.1
Lyonothamnus floribundus ssp. *floribundus* - SCIE	Catalina Island ironwood	lyoflo						75.1				4.2	4.1		0.8	1.0			14.8		
Malacothamnus fasciculatus var. *catalinensis* - SCIE	Catalina Island bushmallow	malfascat	13.3						26.5			20.0		6.2				16.7	17.3		
Malosma laurina	laurel sumac	mallau		5.4						15.0	5.6	12.0	6.6	14.7					40.7		
Muhlenbergia microsperma	littleseed muhly	muhmic										10.2		28.1		10.6	8.1	7.1	18.1		17.8
Opuntia littoralis	coastal prickly pear	opulit						37.5				11.6		1.5		5.7			24.5		19.2
*Pennisetum setaceum**	fountaingrass	penset									89.1			2.9	0.1	0.3					7.6
Peritoma arborea	bladderpod	perarb									66.4	2.3		0.0	0.4	0.2	6.7		24.0		
*Phalaris aquatica**	Harding grass	phaaqu						7.7				8.7		69.2		10.6					3.8
Piperia spp.	orchid	pipspp					38.1	10.8			5.4	3.7				2.3			30.3		9.4

			CLIMATE								TOPOGRAPHY							GEOLOGY & SOILS			
Scientific Name	Common Name	Code	May Cloud Albedo	June Cloud Albedo	July Cloud Albedo	August Cloud Albedo	September Cloud Albedo	Winter Solstice Solar Insol.	Equinox Solar Insolation	Summer Solstice Solar Insol.	Elevation	Aspect	Northeastedness	Slope	Topographic Position Index	Terrain Wetness Index	Ruggedness	Geology	2008 Soils	1955 Soils	NDVI | VEG. PRODUCTIVITY
Plagiobothrys collinus	popcornflower	placol								9.1	35.4	9.0		0.6		6.2	27.5		12.2		
Prunus ilicifolia ssp. *lyonii* - CIE	Catalina cherry	pruililyo									8.5	8.0	19.5		5.8	1.3			56.9		
Quercus pacifica - CIE	island scrub oak	quepac									17.7	38.9		13.0					30.4		
Quercus tomentella - CIE	island live oak	quetom	11.0				45.5							5.8	5.5		10.8	6.8	14.6		
Quercus x macdonaldii - CIE	MacDonald oak	quemac									4.9	6.7	1.8	14.4	50.5	6.5			10.6		4.6
Rhamnus pirifolia - CIE	island redberry	rhapir										18.0		0.5	8.3		8.6		64.6		
Rhus integrifolia	lemonade berry	rhuint									32.1	4.7	6.8	15.3		8.4			20.4		12.3
Ribes viburnifolium - CIE	Catalina Island currant	ribvib					7.5	19.4				10.6	10.3	16.2	0.1				35.9		
Salvia apiana	white sage	salapi									34.3			2.8		10.2	2.2		46.5		4.0
Salvia mellifera	black sage	salmel									25.7	4.2		0.3		1.2	0.3	19.3	24.6	21.3	3.1
Sambucus mexicana	blue elderberry	sammex									27.3	31.0		6.6			1.4		30.7		3.0
Scrophularia villosa - CIE	Catalina Island figwort	scrvil						20.9			17.1		8.6	13.5				20.3	19.6		
Sibara filifolia - CIE	island rockcress	sibfil								9.4	17.5	0.6		0.3	1.1	0.6	5.6		47.2	14.9	2.8
*Silybum marianum**	milk thistle	silmar								8.8				55.7	21.4						14.1
Solanum wallacei - CIE	Wallace's nightshade	solwal					59.9				5.0	3.1		0.4	14.5		0.3				16.8
Stipa cernua	nodding needlegrass	sticer								0.4	46.1	5.8	3.8	25.7		4.7	0.3		6.6		6.6
Stipa spp.	needlegrass	stipa								3.2	1.7	6.1	3.3	5.2		2.6			7.7		70.2
*Tamarix ramosissima**	saltcedar	tamram									23.7			42.8	4.4						29.1

			CLIMATE								TOPOGRAPHY							GEOLOGY & SOILS			
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Trifolium palmeri - CIE	southern island clover	tripal								0.7	94.5		3.2		0.5				1.1		
Typha domingensis	southern cattail	typdom									10.4	3.1		2.6	9.7	4.7	4.9		56.0		8.6
Xylococcus bicolor	Mission manzanita	xylbic									4.9	13.2		4.2	0.6	3.9	9.7		59.8		3.7

Appendix E

Co-Occurrence Models of Catalina Island Plants

Prepared for

CATALINA ISLAND CONSERVANCY™

708 Crescent Ave.
Avalon, CA 90704

Prepared by

LAND IQ

Travis Brooks, Restoration Ecologist
Rhona McChesney, Staff

JUNE 2024

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EXECUTIVE SUMMARY

The introduction of invasive ungulates has led to considerable alterations in the distribution and composition of native communities on Catalina Island, resulting in a limited understanding of pre-European vegetation communities. While a few high-quality reference habitats exist, most of the island lacks suitable reference sites for determining the plant species composition of a restored ecosystem.

To tackle this challenge, we utilized the Consortium of California Herbaria (CCH2) database, containing 17,428 digitized herbarium records from Catalina Island (1831 to 2022). By examining a subset of these records with reliable geospatial information, we explored co-occurrence frequencies of plant species in the herbarium records, which can indicate ecological relationships. To identify high-likelihood species groups, we employed clustering and network analyses.

Our study focused on 50 native and endemic plant species, along with one invasive species (*Genista linifolia*) that is a significant ecological threat. Throughout the various clustering algorithms, numerous diagnostic species formed highly significant clusters (AU ≥80). Network analysis further elucidated the interconnectedness among plants, providing context for clustering results. Some species did not group neatly due to their wide distribution across multiple vegetation communities or their representation of underrepresented communities.

Based on these groupings, we identified potential vegetation alliances and associations following the Manual of California Vegetation (MCV) classification system. These communities can serve as a valuable resource for developing ecologically suitable plant palettes to restore and preserve Catalina Island's unique habitats and biodiversity.

1 INTRODUCTION

In the early 19th century (circa 1827), Spanish missionaries introduced novel ranching practices and nonnative hoofed mammals (ungulates) to Catalina Island (Preston 1997), which had a significant impact on the native plant species that evolved without exposure to ungulate browsing pressure (e.g., Knapp 2007). This disturbance led to substantial changes in the island's natural vegetation communities and the wildlife habitat they support, including the following legacy impacts: an overrepresentation of browse-resistant plants, loss of nesting habitat for understory nesting birds, and loss of topsoil due to the denuded vegetation cover caused by overbrowsing. Since the removal of feral goats and pigs by the early 2000s, mule deer have been responsible for most of the browsing pressure, which is especially intense during periods of sustained drought that severely limits available browse in the summer and fall.

Due to the lack of a comprehensive floristic record and vegetation community mapping before this ecological shift, our understanding of the historic (pre-European) vegetation communities on Catalina Island remains limited. Fortunately, a few high-quality existing reference native habitats still exist on the island, primarily in areas less accessible such as steep, wetter sites (e.g., eastern leeward, channel-facing watersheds), coastal bluffs, and deep riparian drainages. However, these reference habitats do not provide insight into suitable restoration targets for plant community composition for most of the island.

The Catalina Island Conservancy, which owns and manages 88% of the island (approximately 170 square km), is planning to remove the invasive mule deer, which will allow for passive habitat recovery and more successful active habitat restoration projects. To better understand historical plant associations to inform island habitat restoration planning, we examined historical herbarium records to determine which island plant species most frequently co-occur.

The Consortium of California Herbaria (CCH2) database (https://www.cch2.org/portal/) includes 17,428 digitized herbarium records from Catalina Island, between 1831 to 2022. Most of the historic island herbarium records do not have reliable location information which could be used for fine-grained spatial analysis, such as in recent ecological studies that analyze high precision measurements of species locations (e.g., Losapio et al. 2019, Minor et al. 2009). However, the frequency of co-occurring species in the herbarium record may be indicators of various interactions and dependencies within the ecosystem (e.g., shared ecological niche, mutualism, competition, facilitation, predator-prey relationships, pollinator and seed dispersal, disturbance regimes). We used clustering and network analysis techniques to analyze the relative association between a selection of co-occurring species, independent of spatial distance, to identify high-likelihood groups of species. These groups can be used to help inform the development ecologically suitable plant palettes for restoration of island vegetation communities.

2 METHODS

A set of 51 plants species (Table 2-1) were selected for analysis that were well represented in the CHH2 database: 50 native species that were either possible indicator species of island habitat types and/or island endemic species and one highly invasive species (*Genistia linifolia*) that has very high potential to spread over large areas of the island plants, especially after fire. These species are referred to as "diagnostic species" for the purposes of our analysis. If the diagnostic species co-occurred with another plant species in the herbarium database at least three times, this association was recorded in a co-occurring species dataset.

The co-occurring species data was transformed to presence/absence data for analysis because this approach provides a more objective and reliable representation of species relationships for the purposes of this study. The frequency of co-occurring species observations recorded by botanists in herbarium specimen records may be subjective and vary based on the observer's focus, sampling effort, or other factors. In contrast, a cumulative presence/absence dataset compiled from multiple records offers a more comprehensive view of species co-occurrences and is less prone to observer bias. By using presence/absence data, we can more accurately assess the likelihood of species co-occurring in the same habitat or ecosystem.

We used clustering analysis to place the diagnostic species (objects) into clusters based on the level of similarity between each object and its co-occurring species. Clustering analysis is a technique used to identify natural groupings or clusters within a larger dataset based on the similarities or distances between different objects. In clustering analysis, each data point or observation that is being analyzed and grouped together with similar data points is treated as an individual object. We used three different clustering algorithms (complete agglomerative, average agglomerative, and ward's minimum variance) to control for algorithm-based variations in results.

To better understand the results of the clustering analysis, multiscale bootstrap resampling was conducted for each of the three results. The number of times each cluster was replicated under each algorithm is then expressed through an approximately unbiased (AU) p-value. A high AU p-value indicates that the cluster is more replicable; a low AU p-value indicates that the cluster is less replicable. Diagnostic species that clustered with an AU p-value of ≥80 were considered significant for this study. In addition, each of the dendrograms resulting from the three clustering algorithms underwent pairwise comparison to help understand which objects clustered consistently and which objects clustered anomalously. Analysis was performed in R using scripts provided by Borcard et al. (2018).

Finally, network analysis was used to demonstrate the degree of association between each diagnostic species and the commonly co-occurring species. This type of analysis is computationally intensive, making it difficult to investigate every diagnostic species cluster produced through the cluster analysis.

Table 2-1. Diagnostic Species Included in the Analysis.

Scientific Name	Common Name	Family Name	Number of Herbarium Records in Study
Abronia maritima	Red sand verbena	Nyctaginaceae	25
Achillea millefolium	Common yarrow	Asteraceae	43
Anemopsis californica	Yerba mansa / lizard tail	Saururaceae	20
Arctostaphylos catalinae	Santa Catalina Island manzanita	Ericaceae	55
Artemisia californica	California sagebrush	Asteraceae	51
Asclepias fascicularis	Narrowleaf milkweed / Mexican whorled milkweed	Apocynaceae	11
Astragalus trichopodus var. *lonchus*	Santa Barbara milk vetch	Fabaceae	71
Baccharis salicifolia	Mule fat	Asteraceae	34
Bromus sitchensis (*B. carinatus*)	California brome	Poaceae	48
Ceanothus arboreus	Feltleaf ceanothus / island ceanothus / island mountain lilac	Rhamnaceae	110
Ceanothus megacarpus var. *insularis*	Island bigpod ceanothus / Island ceanothus	Rhamnaceae	70
Cercocarpus traskiae	Santa Catalina Island mountain-mahogany / Catalina mahogany	Rosaceae	46
Cercocarpus betuloides var. *blancheae*	Island mountain-mahogany	Rosaceae	140
Cleomella arborea	Bladder pod / bladder pod spiderflower and burro-fat	Cleomaceae	36
Cylindropuntia prolifera	Coastal cholla	Cactaceae	4
Deinandra clementina	Island tarplant	Asteraceae	65
Deinandra fasciculata	Clustered tarplant / fascicled spikeweed	Asteraceae	28
Dendromecon harfordii	Channel Islands tree poppy / Harford's tree poppy	Papaveraceae	61
Distichlis spicata	Desert saltgrass	Poaceae	29
Dudleya virens subsp. *hassei*	Green liveforever / bright green dudleya	Crassulaceae	37
Dudleya virens subsp. *insularis*	Island green dudleya	Crassulaceae	22
Elymus condensatus	Giant wildrye	Poaceae	15
Elymus glaucus	Blue wild rye	Poaceae	25
Elymus triticoides	Creeping wild rye / beardless wild rye	Poaceae	9
Encelia californica	California brittlebush	Asteraceae	50
Ericameria palmeri var. *pachylepis*	Thickbracted goldenbush	Asteraceae	14
Eriodictyon traskiae subsp. *traskiae*	Trask's yerba santa	Namaceae	19
Eriogonum giganteum var. *giganteum*	Saint Catherine's lace	Polygonaceae	56

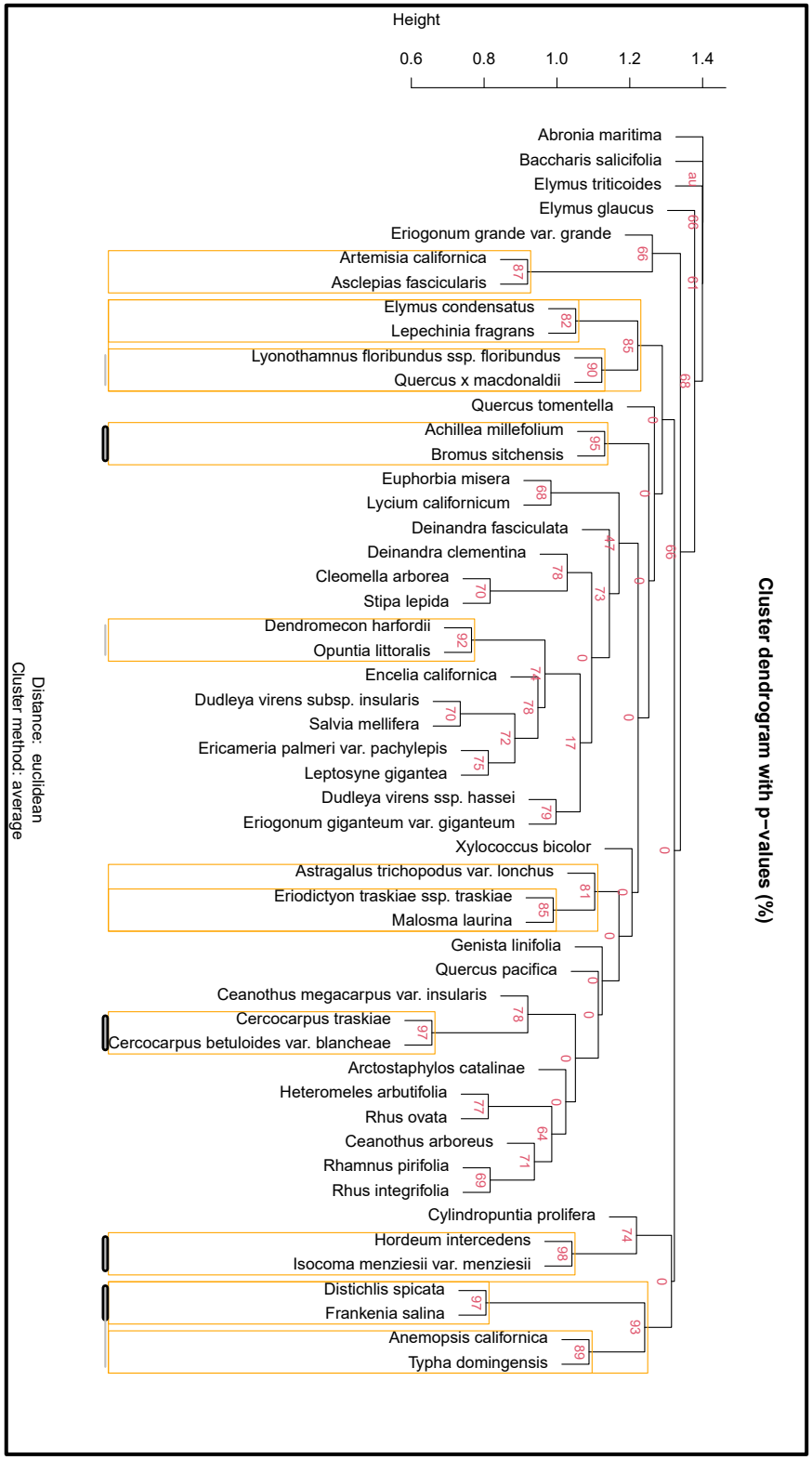
Scientific Name	Common Name	Family Name	Number of Herbarium Records in Study
Eriogonum grande var. *grande*	Island Buckwheat	Polygonaceae	24
Euphorbia misera	Cliff spurge / coast spurge	Euphorbiaceae	5
Frankenia salina	Alkali heath / alkali seaheath	Frankeniaceae	38
*Genista linifolia**	Mediterranean broom	Fabaceae	36
Heteromeles arbutifolia	Toyon	Rosaceae	94
Hordeum intercedens	Bobtail barley / vernal barley	Poaceae	79
Isocoma menziesii var. *menziesii*	Menzies' goldenbush	Asteraceae	21
Lepechinia fragrans	Island pitchersage / fragrant pitchersage	Lamiaceae	41
Leptosyne gigantea	Giant coreopsis	Asteraceae	25
Lycium californicum	California boxthorn / California desert-thorn	Solanaceae	21
Lyonothamnus floribundus subsp. *floribundus*	Catalina ironwood	Rosaceae	164
Malosma laurina	Laurel sumac	Anacardiaceae	43
Opuntia littoralis	Coastal prickly pear	Cactaceae	8
Quercus pacifica	Island scrub oak / Channel Island scrub oak / Pacific oak	Fagaceae	145
Quercus tomentella	Island oak / island live oak / Channel Island oak	Fagaceae	99
Quercus x macdonaldii	MacDonald's oak / Macdonald oak	Fagaceae	58
Rhamnus pirifolia	Island redberry	Rhamnaceae	132
Rhus integrifolia	Lemonade berry	Anacardiaceae	69
Rhus ovata	Sugar bush / sugar sumac	Anacardiaceae	33
Salvia mellifera	Californian black sage	Lamiaceae	41
Stipa lepida	Foothill needlegrass	Poaceae	11
Typha domingensis	Southern cattail	Typhaceae	22
Xylococcus bicolor	Mission manzanita	Ericaceae	54

Instead, this study focused on conducting a network analysis for highly replicable clusters of diagnostic species with an AU p-value ≥80. This produced networks of diagnostic species and commonly co-occurring species, where each species makes up a network node. A network is a collection of interconnected elements, and in this context, a node is one of those individual elements. Nodes which frequently co-occur are placed together into modules, which are groups of commonly co-occurring species and can be considered potential natural vegetation communities. In the visualization of this study's results, nodes are connected to other nodes by lines, the length of which represent the relative frequency they are observed together. Modules are enclosed within large bubbles and nodes are color coded to indicate module membership. Each of the high-significance diagnostic species clusters were analyzed with network analysis to (1) validate the relationship between diagnostic species predicted by cluster analysis and (2) to examine the relationship between diagnostic species and the larger database of co-occurring species.

Those diagnostic species that do not cluster consistently between at least two cluster algorithms, as identified by pairwise analysis, are referred to as “outlier” species. These diagnostic outlier species were further analyzed with network analysis within the context of their co-occurring species. To create the dataset for the network analysis, the cluster containing the outlier species with the highest AU p-value was isolated, then all diagnostic species within this cluster were included in the analysis. Occasionally, the list of diagnostic species was made more inclusive if the AU p-value of the next cluster up was within 5 points of the highest AU p-value. Overall, this analysis helped to determine if the species are true outliers in the dataset that cannot be reliably interpreted or if the species are so well connected (e.g., common or keystone plants) that they commonly occur in more than one diagnostic species cluster (i.e., potential vegetation community).

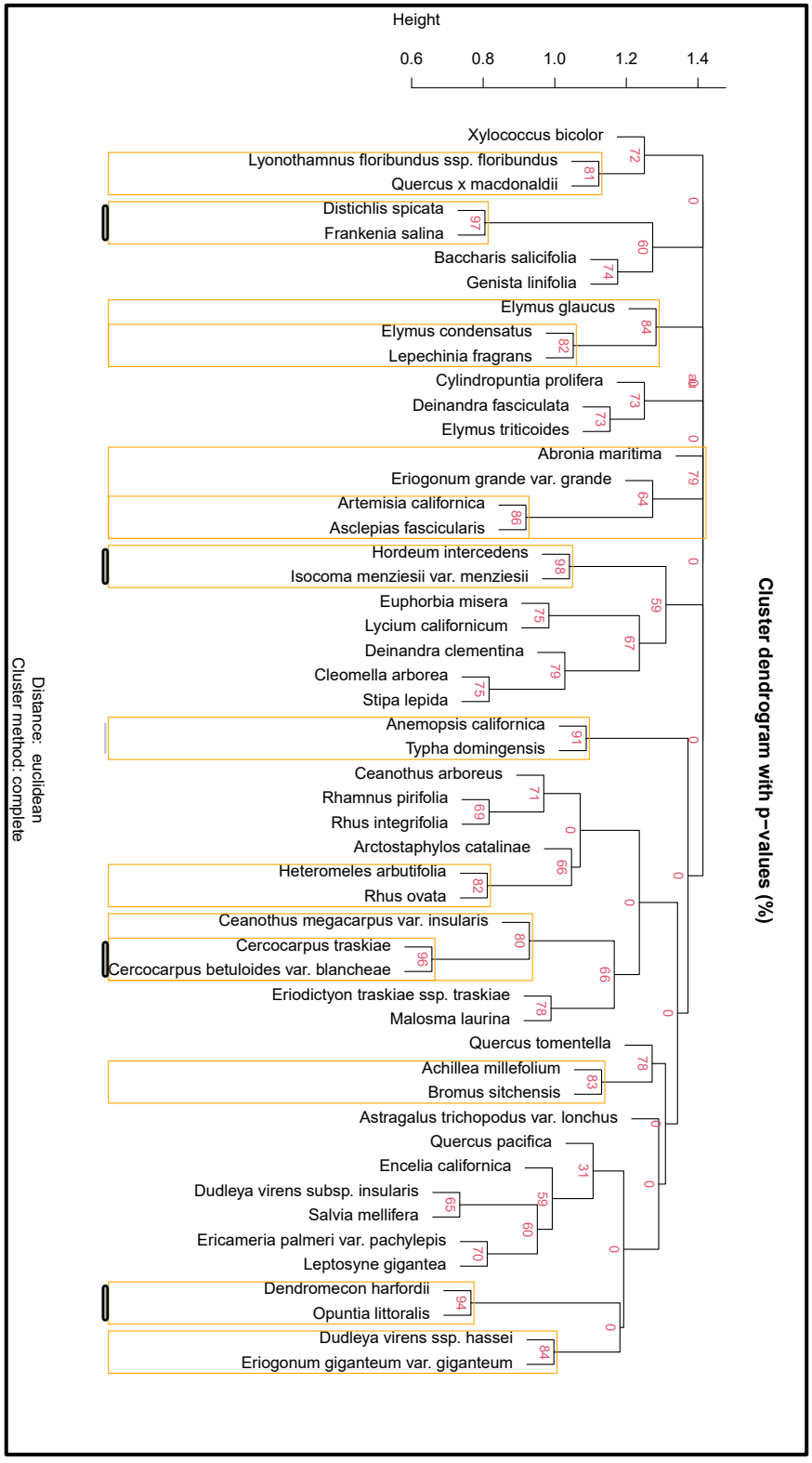
3 RESULTS

Many of the diagnostic species consistently formed clusters with high significance (AU ≥80) (Figure 3-1 to Figure 3-3), and many of these clusters also occurred consistently across clustering algorithms (Table 3-1). These specific clusters underwent network analysis and in each of the resulting figures, one of two general patterns emerged. The diagnostic species either (1) all grouped together within the same module or (2) grouped into different modules, with at least one species occurring in a separate module. The specific placement of each diagnostic species within the network and the degree of connectivity each species exhibits also provide valuable information about the species assemblages but are too varied and complex within each figure to broadly generalize. However, these factors can still be considered while analyzing the network analysis results.



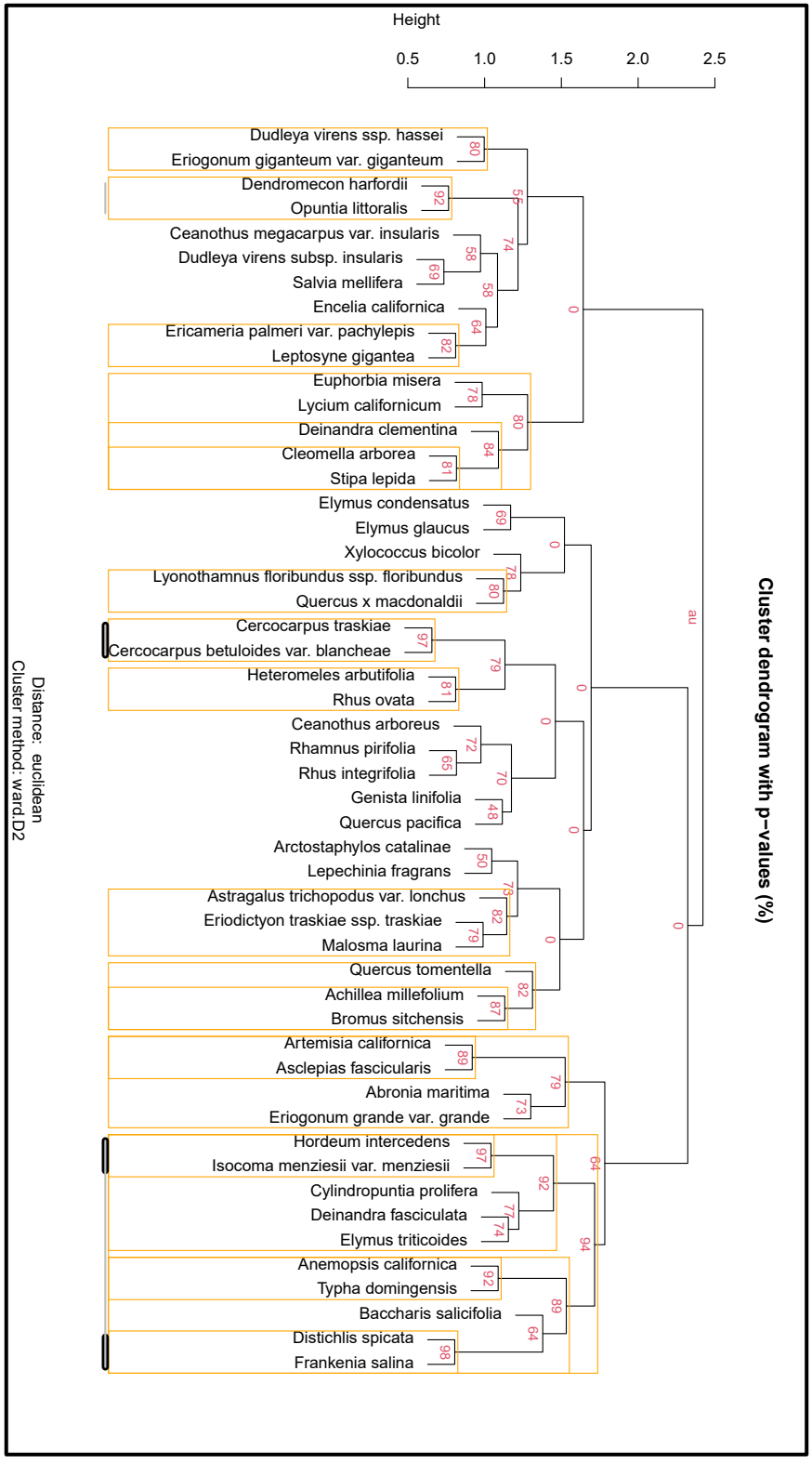
Including AU p-values obtained through multiscale bootstrap resampling
Black lines indicate an AU p-value ≥95, yellow boxes indicate AU p-value ≥80

Figure 3-1 Average Agglomerative Clustering.



Including AU p-values obtained through multiscale bootstrap resampling
Black lines indicate an AU p-value ≥95, yellow boxes indicate AU p-value ≥80

Figure 3-2 Complete Linkage Agglomerative Clustering.



Including AU p-values obtained through multiscale bootstrap resampling
Black lines indicate an AU p-value ≥95, yellow boxes indicate AU p-value ≥80

Figure 3-3 Ward's Minimum Variance Clustering.

Table 3-1. Diagnostic Species Included in the Analysis.

*Species groupings and associated AU p-values: ** ≥95, * ≥90*

	MBR Complete AU p-value	MBR Average Unweighted AU p-value	MBR Ward's Minimum Variance AU p-value
Distichlis spicata & Frankenia salina **	97	97	98
Hordeum intercedens & Isocoma menziesii var. menziesii **	98	98	97
Cercocarpus traskiae & Cercocarpus betuloides var. Blancheae **	96	97	97
Achillea millefolium & Bromus sitchensis **	83	95	
Anemopsis californica & Typha domingensis *	91	89	92
Lyonothamnus floribundus ssp. floribundus & Quercus x macdonaldii *	81	90	80
Dendromecon harfordii & Opuntia littoralis *	94	92	92
Distichlis spicata, Frankenia salina, Anemopsis californica & Typha domingensis *		93	
Hordeum intercedens, Isocoma menziesii var. menziesii, Cylindropuntia prolifera , Deinandra fasciculata, Elymus triticoides, Anemopsis californica,Typha domingensis , Baccharis salicifolia, Distichlis spicata & Frankenia salina *			94
Hordeum intercedens, Isocoma menziesii var. menziesii, Cylindropuntia prolifera , Deinandra fasciculata & Elymus triticoides *			92
Elymus glaucus, Elymus condensatus & Lepechinia fragrans	84		
Elymus condensatus & Lepechinia fragrans	82	82	
Artemisia californica & Asclepias fascicularis	86	87	89
Heteromeles arbutifolia & Rhus ovata	82		91
Ceanothus megacarpus var. insularis, Cercocarpus traskiae & Cercocarpus betuloides var. Blancheae	80		
Dudleya virens ssp. hassei & Eriogonum giganteum var. giganteum	84		80
Elymus condensatus, Lepechinia fragrans, Lyonothamnus floribundus ssp. floribundus & Quercus x macdonaldii		85	
Astragalus trichopodus var. lonchus, Eriodictyon traskiae ssp. traskiae, & Malosma laurina		81	82
Eriodictyon traskiae ssp. traskiae & Malosma laurina		85	
Ericameria palmeri var. pachylepis & Leptosyne gigantea			82
Euphorbia misera, Lycium californicum, Deinandra clementina, Cleomella arborea, & Stipa lepida			80
Deinandra clementina, Cleomella arborea, & Stipa lepida			84
Cleomella arborea, & Stipa lepida			81
Quercus tomentella, Achillea millefolium & Bromus sitchensis			82
Achillea millefolium & Bromus sitchensis			87
Anemopsis californica,Typha domingensis , Baccharis salicifolia, Distichlis spicata & Frankenia salina			89

Distichlis spicata and *Frankenia salina* (Figure 6-1), for example, organized in accordance with the first pattern - both diagnostic species were placed within proximity of one another within the same module. The likelihood of co-occurrence between *Distichlis spicata* and *Frankenia salina* appears to be higher than the average likelihood of co-occurrence with many of the other associated species. Additionally, both *Distichlis spicata* and *Frankenia salina* have connections to every other species in the network, indicating that they are highly connected within the larger set of plants depicted in Figure 6-1.

A different relationship occurs between *Hordeum intercedens* and *Isocoma menziesii var. menziesii*, adhering more closely to the second pattern. In Figure 6-2, *Hordeum intercedens* is placed centrally within the co-occurrence network and is highly connected to species within both modules. *Isocoma menziesii* var*. menziesii*, on the other hand, is isolated within a separate module from *Hordeum intercedens,* has a lower likelihood of co-occurrence with many of the species within this module, and has no direct connections to the module within which *Hordeum intercedens* is placed. This indicates that *Hordeum intercedens* and *Isocoma menziesii* var. *menziesii* do not actually co-occur together more frequently than they do with the other co-occurring species included in this analysis. However, both *Hordeum intercedens* and *Isocoma menziesii* var. *menziesii* have similar co-occurring species groupings.

A more nuanced version of the second pattern can be seen in Figure 6-8, showing how *Hordeum intercedens, Isocoma menziesii* var. *menziesii, Cylindropuntia prolifera, Deinandra fasciculata* and *Elymus triticoides* relate to one another within a broader vegetation community. Once again, *Isocoma menziesii* var. *menziesii* is isolated on the edge of its module*,* doesn't have a high likelihood of co-occurrence with many of the species within this module, and has no direct connections to species in any other module. However, in this instance, *Cylindropuntia prolifera* is placed within the same module as *Isocoma menziesii* var*. menziesii* and the two species are directly connected to each other. A very similar relationship occurs between *Deinandra fasciculata* and *Elymus triticoides,* where *Elymus triticoides* exhibits a similar intramodular placement to *Isocoma menziesii* var. *menziesii.* However, even though *Deinandra fasciculata* occurs within the same module as *Isocoma menziesii* var. *menziesii*, the two species aren't directly connected. Finally, *Hordeum intercedens* is located within a separate module. Evidently, a more complex relationship is expressed within Figure 6-8, where all diagnostic species are part of a broader vegetation community but may not necessarily all co-occur spatially.

The pairwise comparison of the three clustering algorithms identified 17 diagnostic species which clustered anomalously (not consistently) between at least two of the clustering result dendrograms (Figure 6-26 to Figure 6-28). Network analysis was used to explain why these species might have been clustering anomalously and revealed a variety of complex interspecific relationships. According to the results of this analysis, diagnostic species were either (1) centrally located in the species assemblage, with many intermodular connections or (2) isolated, with few to no intermodular connections.

In Figure 6-36, *Deinandra fasciculata* is positioned centrally within the co-occurrence network and is highly connected to many of the other species both within its own module and within adjacent modules. However, this pattern isn't ubiquitous. *Abronia maritima* (Figure 6-33), for example, is placed on the edge of the species co-occurrence network within an isolated module. Additionally, this species only appears to be connected to species within its own module and has no direct association with co-occurring species in separate modules. *Baccharis salicifolia* (Figure 6-36) exhibits a similar pattern and is located on the edge of its module. However, *Baccharis salicifolia* does have connections to several other species within different modules.

4 DISCUSSION

Each of the results from this analysis should be individually considered. However, each diagnostic species cluster and diagnostic species outlier have associated co-occurrence network analyses from which the broader ecological patterns discussed above can be discerned and placed in the context of existing research.

For example, *Distichlis spicata* and *Frankenia salina* (Figure 6-1) exhibit a strong association with one another and are grouped together closely within the same module. Both *Distichlis spicata* and *Frankenia salina* are distributed along the California coast, having been shown to occur together in high marsh environments (Greer 2014, Tanner et al. 2022). Moreover, a study by Shikuzawa et al. (2024) demonstrates that *Distichlis spicata* and *Frankenia salina* serve different ecosystem functions while being adapted to similar environmental conditions. This could imply that the two species are similar enough to coexist while still occupying separate niches, reducing the threat of competition. This provides evidence for the claim that species which clustered together and appeared within the same module by network analysis, such as *Distichlis spicata* and *Frankenia salina,* might be more likely to co-occur.

While the relationship between *Distichlis spicata* and *Frankenia salina* was represented broadly within the literature, the relationship between many of the other diagnostic species previously discussed is less intensely researched. Literature on the relationship between *Hordeum intercedens* and *Isocoma menziesii var. menziesii*, diagnostic species which weren't placed into the same module through the network analysis (Figure 6-2), is not readily available. However, at least one paper cites that *Hordeum intercedens* and *Lycium californicum* grew near one another. Interestingly, *Lycium californicum* is one of the main species that co-occurs with both diagnostic species in the network analysis (Laskey et al. 2020). As such, species which clustered together yet didn't appear within the same module in the network analysis might be likely to share co-occurring species assemblages but not actually occur together.

When more diagnostic species are included in the network analysis, as was seen in Figure 6-8, the network analysis results get more complicated but likely represents real-word vegetation communities more accurately. In Figure 6-8, each of the diagnostic species are spread out across three modules, with some species grouped together

within the same module and other species grouped within different modules. *Isocoma menziesii var. menziesii* is again included within this analysis and is again located in a separate module from *Hordeum intercedens* (as was true in Figure 6-2). However, once more diagnostic species were included in the analysis which produced Figure 6-8, *Isocoma menziesii var. menziesii* grouped together with a different diagnostic species - *Cylindropuntia prolifera*. This indicates that interspecific relationships revealed in these network analyses are restricted by the selection of species included as part of the initial input.

Research involving *Deinandra fasciculata* (Figure 6-36) also elucidates one of the patterns exhibited within the diagnostic outlier species co-occurrence network. Specifically, *Deinandra fasciculata* is likely placed at the center of this network because it is a highly abundant grassland forb (Nabors et al. 2018, Watts et al. 2011). In other words, this species might have been an outlier because its abundance allows for the species to exist within many different vegetation communities. However, both *Abronia maritima* (Figure 6-33) *and Baccharis salicifolia (Figure 6-36)* are also relatively abundant species but don't necessarily occur at the center of their associated co-occurrence networks. This could imply that these species don't commonly co-occur with any of the diagnostic species included within the cluster analysis but might still consistently exist within an assemblage of co-occurring species. In this case, it may be possible that these outlier species are characteristic of a species assemblage not represented within the dataset for this analysis.

Overall, the species co-occurrence network analysis sheds light on connectedness between plants that may not have been initially evident in the clustering analysis. Even though a set of diagnostic species may have initially clustered together, network analysis helps to reveal whether this clustering is because the species co-occurs or if this clustering is because the species share a set of associated species without co-occurring themselves. Moreover, the relationships demonstrated through each network analysis may be restricted by the input dataset; the diagnostic species included in each analysis dictate how the network result is constructed. Additionally, species which don't fit neatly into the clustering analysis results may easily be present because the outlier species is widespread and belongs to a multitude of potential island vegetation communities. In this situation, a diagnostic outlier species might appear centrally within the network analysis. However, not all outliers exhibit this central placement within the respective co-occurrence network, possibly because these species are part a vegetation community not represented within the dataset for this analysis.

Regardless, all figures developed through this analysis depict species co-occurrence patterns and can be placed into the context of different ecological and physiological parameters to provide a more comprehensive view of interspecific interactions. The results of the clustering and network analyses provide a basis for future research which takes into consideration factors such as ecological niche overlap, competition, and variation in terrain and climate to describe vegetation communities on Catalina Island more fully.

To facilitate the creation of ecologically appropriate habitat restoration plant palettes, we identified vegetation assemblages based on high-likelihood groupings of co-occurring plants. Drawing from the Manual of California Vegetation (MCV) nomenclature and classification system, we present potential Vegetation Alliances or Associations in Table 4-1.

These assemblages can serve as a valuable resource for informing the development of ecologically suitable plant palettes, aiding in the restoration of the island's vegetation communities. By considering the natural co-occurrence patterns of plant species, these groupings will help optimize the selection of species for reintroduction efforts, ultimately enhancing the ecological integrity and resilience of restored habitats on Catalina Island.

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Table 4-1. Potential Vegetation Alliance or Associations from Review of Plant Species Co-Occurrence Models.

Catalina Island 2000 Vegetation Map Classification (Knapp 2005)	Classification by Junak et al. (2007) in Terrestrial Vegetation of California	Potential Macro Group	Potential Vegetation Group	Potential MCV Vegetation Alliance or Association	Modeled Diagnostic Species	Selected Corresponding Network Analysis Figure No.
Island Woodland (IW)	Island woodland	California Forest and Woodland	Californian broadleaf forest and woodland	***Lyonothamnus floribundus* subsp. *floribundus* Forest & Woodland Association** (*Quercus tomentella - Lyonothamnus floribundus* Forest & Woodland Alliance)	*Lyonothamnus floribundus* subsp. *floribundus*	Figure 6-12 Figure 6-21
Island Woodland (IW)	Island woodland	California Forest and Woodland	Californian broadleaf forest and woodland	***Prunus ilicifolia subsp. lyonii* Forest & Woodland Association** (*Quercus tomentella - Lyonothamnus floribundus* Forest & Woodland Alliance)	*Lyonothamnus floribundus* subsp. *floribundus*	Figure 6-12 Figure 6-21
Island Woodland (IW)	Island woodland	California Forest and Woodland	Californian broadleaf forest and woodland	***Quercus tomentella* Forest & Woodland Association** (*Quercus tomentella - Lyonothamnus floribundus* Forest & Woodland Alliance)	*Quercus tomentella*	Figure 6-28 Figure 6-47
Island Chaparral (IC)	Island chaparral	California Chaparral	Californian maritime chaparral	***Arctostaphylos catalinae* Shrubland Association** (*Arctostaphylos* spp. Shrubland Alliance)	*Arctostaphylos catalinae*	Figure 6-34
Island Chaparral (IC)	Island chaparral	California Chaparral	Californian maritime chaparral	***Quercus pacifica* Shrubland Association** (*Quercus dumosa - Quercus pacifica* Shrubland Alliance)	*Cercocarpus betuloides* var. blancheae, *Cercocarpus traskiae, Heteromeles arbutifolia, Quercus pacifica,* and *Quercus* x *macdonaldii*	Figure 6-6 Figure 6-12 Figure 6-19 Figure 6-27 Figure 6-46

Catalina Island 2000 Vegetation Map Classification (Knapp 2005)	Classification by Junak et al. (2007) in Terrestrial Vegetation of California	Potential Macro Group	Potential Vegetation Group	Potential MCV Vegetation Alliance or Association	Modeled Diagnostic Species	Selected Corresponding Network Analysis Figure No.
Island Chaparral (IC)	Island chaparral	California Chaparral	Californian xeric chaparral	***Adenostoma fasciculatum - Salvia* spp. Shrubland Alliance**	*Cercocarpus traskiae, Eriodictyon traskiae* subsp. *traskiae, Lepechinia fragrans,* and *Malosma laurina*	Figure 6-17 Figure 6-18 Figure 6-21 Figure 6-22 Figure 6-23 Figure 6-25 Figure 6-45
Island Chaparral (IC)	Island chaparral	California Chaparral	Californian xeric chaparral	***Ceanothus megacarpus* var. *insularis* Shrubland Association** *(Ceanothus megacarpus* Shrubland Alliance*)*	*Ceanothus megacarpus* var. *insularis*	Figure 6-18 Figure 6-37
Island Chaparral (IC)	Island chaparral	California Chaparral	Californian xeric chaparral	***Xylococcus bicolor - Rhus integrifolia* Shrubland Association** (*Xylococcus bicolor* Shrubland Alliance)	*Xylococcus bicolor*	Figure 6-48
Coastal Sage Scrub (CSS)	Coastal sage scrub	California Coastal Scrub	Central and South Coastal Californian coastal sage scrub	***Artemisia californica - Opuntia littoralis* Shrubland Association** (*Artemisia californica* Shrubland Alliance)	*Artemisia californica*	Figure 6-16 Figure 6-20 Figure 6-37
Coastal Sage Scrub (CSS)	Coastal sage scrub	California Coastal Scrub	Central and South Coastal Californian coastal sage scrub	***Encelia californica* Shrubland Association** (*Encelia californica - Eriogonum cinereum* Shrubland Alliance)	*Encelia californica*	Figure 6-43
Coastal Sage Scrub (CSS)	Coastal sage scrub	California Coastal Scrub	Central and South Coastal Californian coastal sage scrub	***Eriogonum grande* var. *grande* Shrubland Association** (*Eriogonum arborescens - Eriogonum grande* Shrubland Alliance)	*Eriogonum grande* var. *grande*	Figure 6-44

Catalina Island 2000 Vegetation Map Classification (Knapp 2005)	Classification by Junak et al. (2007) in Terrestrial Vegetation of California	Potential Macro Group	Potential Vegetation Group	Potential MCV Vegetation Alliance or Association	Modeled Diagnostic Species	Selected Corresponding Network Analysis Figure No.
Coastal Sage Scrub (CSS)	Coastal sage scrub	California Coastal Scrub	Central and South Coastal Californian coastal sage scrub	***Salvia mellifera* Shrubland Alliance**	*Rhus ovata*	Figure 6-27
Coastal Sage Scrub (CSS)	Coastal sage scrub	California Coastal Scrub	Central and South Coastal Californian coastal sage scrub	***Salvia apiana* Shrubland Alliance**	Astragalus trichopodus var. lonchus	Figure 6-17 Figure 6-35
Coastal Bluff Scrub (CBS)	Coastal bluff scrub	Viscaino-Baja California Desert Scrub	Coastal Baja California Norte maritime succulent scrub	***Deinandra clementina* - *Eriogonum giganteum* Shrubland Alliance**	*Deinandra clementina*	Figure 6-19
Coastal Bluff Scrub (CBS)	Coastal bluff scrub	Viscaino-Baja California Desert Scrub	Coastal Baja California Norte maritime succulent scrub	***Dudleya virens subsp. hassei* Succulent Scrub Association** *(Dudleya greenei - Dudleya spp*. Succulent Scrub Alliance*)*	*Dudleya virens* subsp. *hassei*	Figure 6-20
Coastal Bluff Scrub (CBS)	Coastal bluff scrub	Viscaino-Baja California Desert Scrub	Coastal Baja California Norte maritime succulent scrub	***Leptosyne (Coreopsis) gigantea* Shrubland Alliance**	*Leptosyne gigantea*	Figure 6-24 Figure 6-43
Coastal Bluff Scrub (CBS)	Coastal bluff scrub	Viscaino-Baja California Desert Scrub	Coastal Baja California Norte maritime succulent scrub	***Opuntia littoralis* - *Opuntia oricola* - *Cylindropuntia prolifera* Shrubland Alliance**	*Cleomella arborea, Cylindropuntia prolifera,* and *Stipa lepida*	Figure 6-8 Figure 6-19
Coastal Bluff Scrub (CBS)	Coastal bluff scrub	Viscaino-Baja California Desert Scrub	Coastal Baja California Norte maritime succulent scrub	***Eriogonum giganteum* var. *giganteum* Shrubland Association** (*Deinandra clementina* - *Eriogonum giganteum* Shrubland Alliance)	*Eriogonum giganteum* var. *giganteum*	Figure 6-20

Catalina Island 2000 Vegetation Map Classification (Knapp 2005)	Classification by Junak et al. (2007) in Terrestrial Vegetation of California	Potential Macro Group	Potential Vegetation Group	Potential MCV Vegetation Alliance or Association	Modeled Diagnostic Species	Selected Corresponding Network Analysis Figure No.
Maritime Cactus Scrub (MCS)	Maritime cactus scrub	Viscaino-Baja California Desert Scrub	Coastal Baja California Norte maritime succulent scrub	***Lycium californicum* Shrubland Alliance**	*Cleomella arborea, Cylindropuntia prolifera, Deinandra clementina, Euphorbia misera, Lycium californicum,* and *Stipa lepida*	Figure 6-8 Figure 6-8 Figure 6-26 Figure 6-38
Mulefat Scrub (MFS)	No Equivalent Classification	Southwestern North American Riparian, Flooded and Swamp Forest	Southwestern North American riparian/wash scrub	***Baccharis salicifolia* Shrubland Alliance**	*Baccharis salicifolia*	Figure 6-36 Figure 6-42 Figure 6-46
Coastal Marsh (CM)	Coastal marsh	North American Pacific Coastal Salt Marsh	Temperate Pacific tidal salt and brackish meadow	***Distichlis spicata* Herbaceous Alliance**	*Cressa truxillensis, Distichlis spicata,* and *Frankenia salina*	Figure 6-2 Figure 6-8 Figure 6-10 Figure 6-15
Southern Beach and Dune (SBD)	Southern beach and dune	Vancouverian Coastal Dune and Bluff	Vancouverian/Pacific dune mat	***Ambrosia chamissonis - Abronia maritima - Cakile maritima* Herbaceous Association** (*Abronia latifolia - Ambrosia chamissonis* Herbaceous Alliance)	*Abronia maritima*	Figure 6-33 Figure 6-44
Vernal Ponds and Reservoirs (VPR)	Freshwater wetland	Western North America Vernal Pool	Californian mixed annual/perennial freshwater vernal pool / swale bottomland	***Deinandra fasciculata* Herbaceous Alliance**	*Hordeum intercedens* and *Deinandra fasciculata*	Figure 6-2 Figure 6-8 Figure 6-8 Figure 6-36 Figure 6-36

Catalina Island 2000 Vegetation Map Classification (Knapp 2005)	Classification by Junak et al. (2007) in Terrestrial Vegetation of California	Potential Macro Group	Potential Vegetation Group	Potential MCV Vegetation Alliance or Association	Modeled Diagnostic Species	Selected Corresponding Network Analysis Figure No.
Vernal Ponds and Reservoirs (VPR)	Freshwater wetland	Western North American Freshwater Marsh	Arid West freshwater emergent marsh	***Typha* spp. Herbaceous Alliance**	*Anemopsis californica* and *Typha domingensis*	Figure 6-8 Figure 6-9 Figure 6-10 Figure 6-15
Grassland (GR)	Valley and foothill grassland	Warm Semi-Desert/Mediterranean Alkali-Saline Wetland	Southwestern North American alkali marsh/seep vegetation	***Elymus (Leymus) triticoides* - *Bromus* spp. - *Avena* spp. Herbaceous Association** (*Leymus cinereus - Leymus triticoides* Herbaceous Alliance)	*Elymus triticoides* and *Deinandra fasciculata*	Figure 6-8 Figure 6-8 Figure 6-42
Grassland (GR)	Valley and foothill grassland	Western North American Temperate Grassland and Meadow	Western dry upland perennial grassland	***Bromus sitchensis (carinatus)* - *Elymus glaucus* Herbaceous Alliance**	*Achillea millefolium* and *Bromus sitchensis*	Figure 6-7 Figure 6-14 Figure 6-28
Grassland (GR)	Valley and foothill grassland	California Annual and Perennial Grassland	California annual herb/grass	***Amsinckia* spp. - *Phacelia* spp. Herbaceous Alliance**	*Ericameria palmeri var. pachylepis*	Figure 6-24
Grassland (GR)	Valley and foothill grassland	California Annual and Perennial Grassland	California perennial grassland	***Elymus (Leymus) condensatus* Herbaceous Alliance**	*Elymus condensatus*	Figure 6-21 Figure 6-22 Figure 6-23 Figure 6-40
Nonnative Scrub (NNS)	Nonnative vegetation	California Coastal Scrub	Naturalized non-native Mediterranean scrub	***Genista linifolia Shrubland Semi-Natural Association*** *(Cytisus scoparius - Genista monspessulana - Cotoneaster spp. Shrubland Semi-Natural Alliance)*	*Genista linifolia*	Figure 6-49

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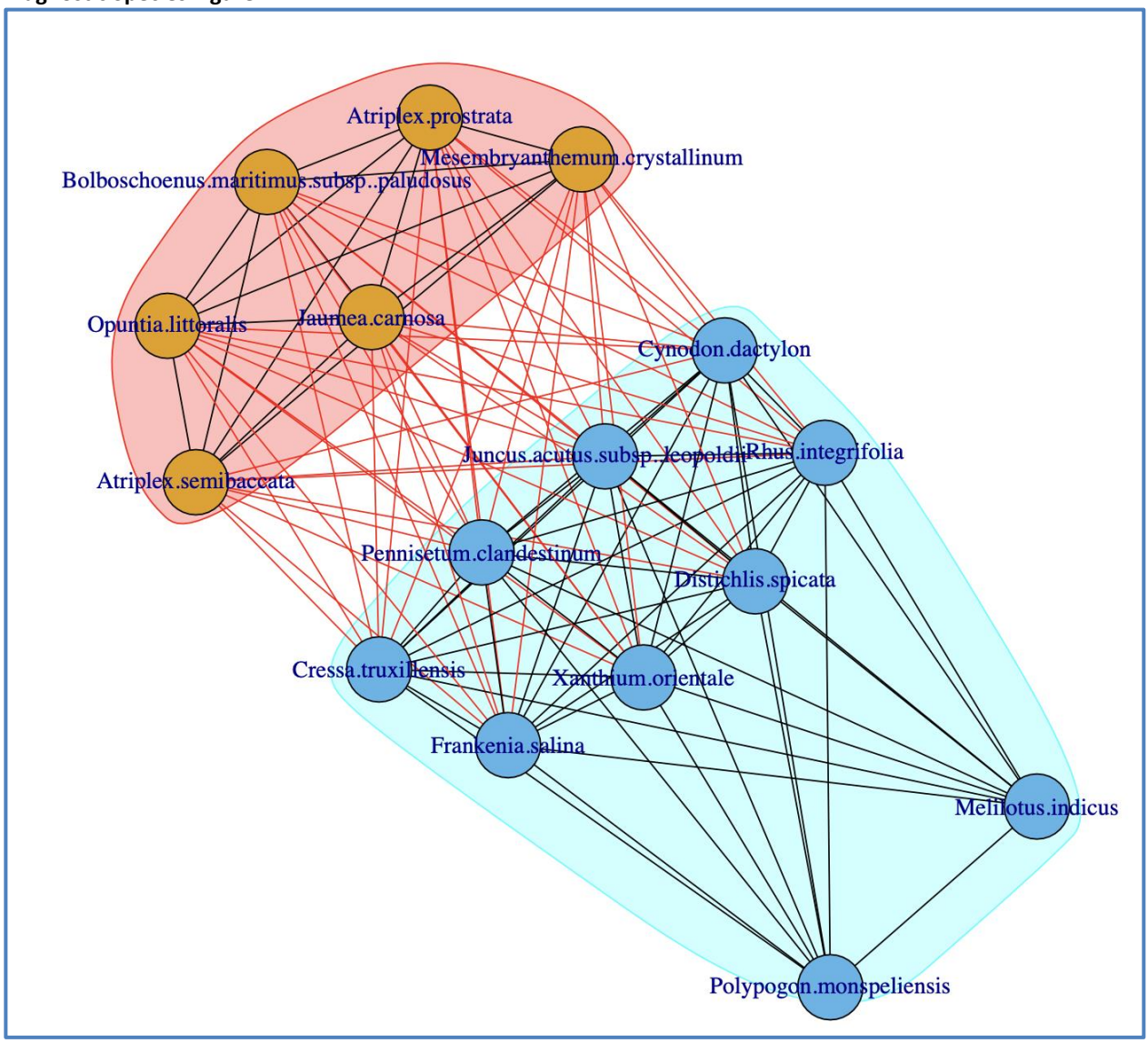
6 SUPPORTING MATERIALS ATTACHMENT

This section includes additional figures and tables that support the conclusions of the report and can be used as a reference for the development of site-specific habitat restoration projects.

Figure 6-1. High Confidence Assemblages (≥95) – *Distichlis spicata* & *Frankenia salina*

Diagnostic Species Figure



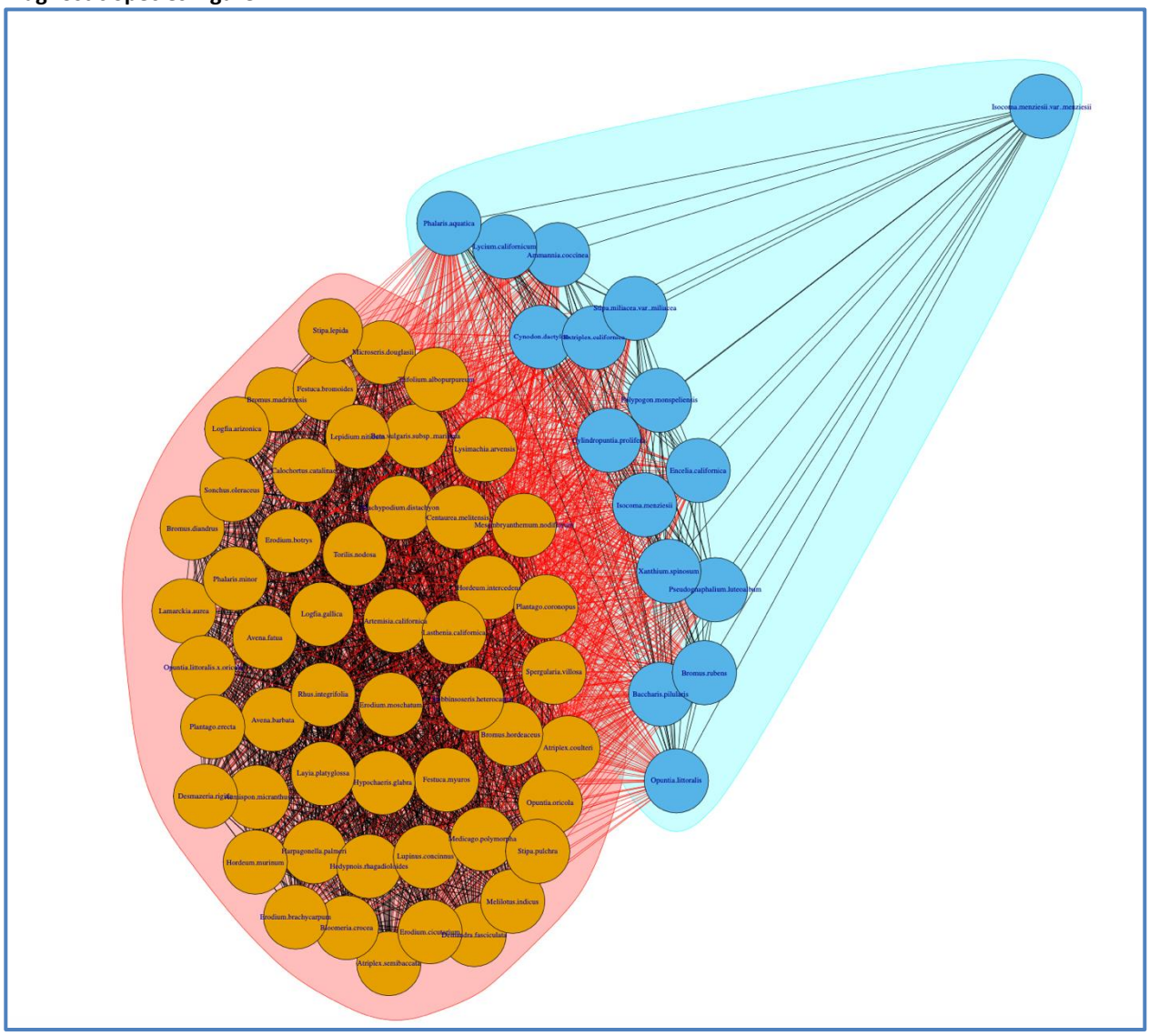
Diagnostic Species Table: *Distichlis spicata* & *Frankenia salina*

Red Module (Orange Node)	Blue Module (Blue Node)
*Atriplex prostrata**	*Cressa truxillensis*
*Atriplex semibaccata**	*Cynodon dactylon**
Bolboschoenus maritimus subsp. *paludosus*	***Distichlis spicata***
Jaumea carnosa	***Frankenia salina***
*Mesembryanthemum crystallinum**	*Juncus acutus* subsp. *leopoldii*
Opuntia littoralis	*Melilotus indicus**
	*Pennisetum clandestinum**
	*Polypogon monspeliensis**
	Rhus integrifolia
	Xanthium orientale

** nonnative species*

Figure 6-2. High Confidence Assemblages (≥95) – *Hordeum intercedens* & *Isocoma menziesii* var. *menziesii*

Diagnostic Species Figure



Species within each module are listed on next page.

Diagnostic Species Table: *Hordeum intercedens* & *Isocoma menziesii* var. *menziesii*

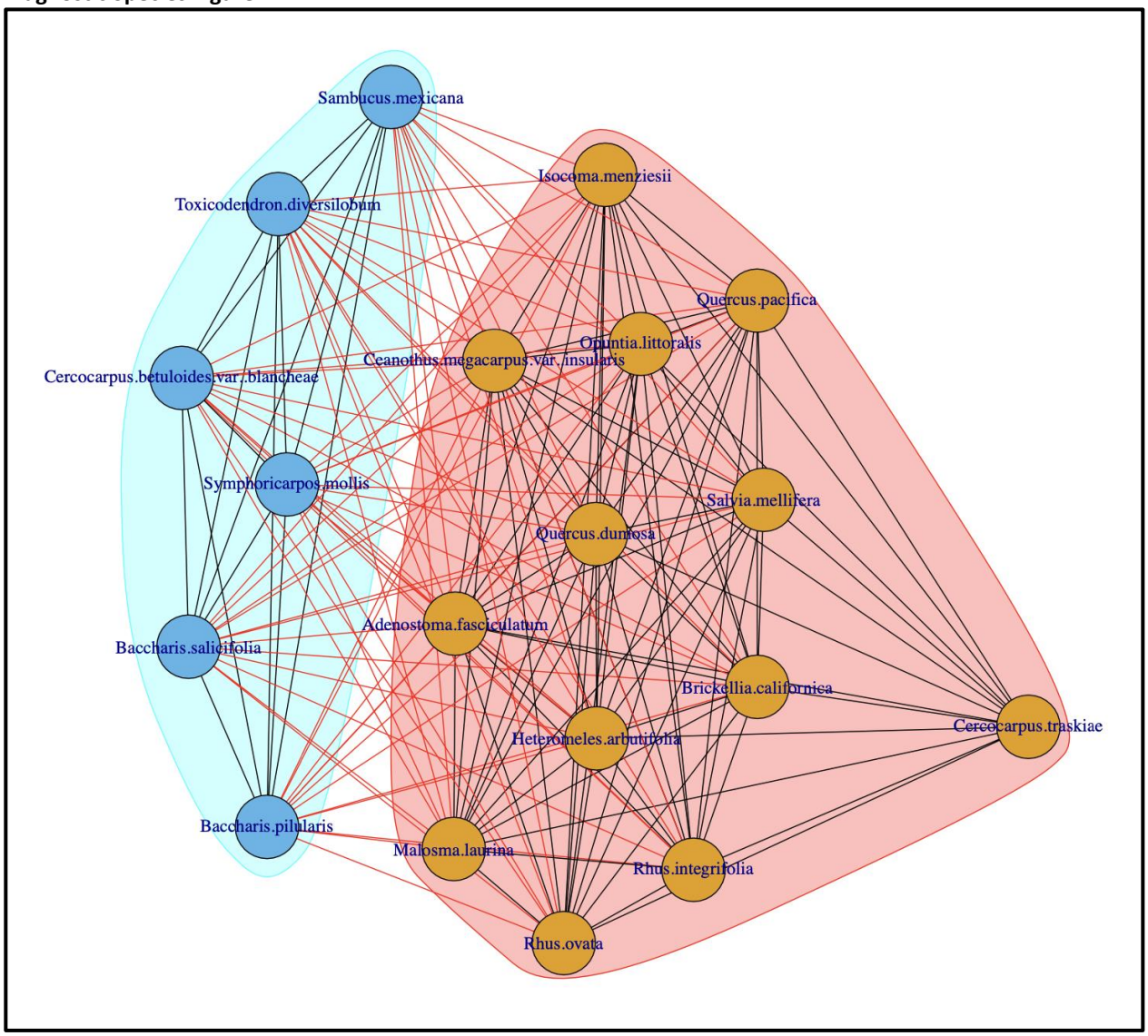
Red Module (Orange Node)	**Blue Module (Blue Node)**
Acmispon micranthus	*Ammannia coccinea*
Artemisia californica	*Baccharis pilularis*
Atriplex coulteri	*Bromus rubens**
*Atriplex semibaccata**	*Cylindropuntia prolifera*
*Avena barbata**	*Cynodon dactylon**
*Avena fatua**	*Encelia californica*
Beta vulgaris subsp. *maritima**	*Extriplex californica*
Bloomeria crocea	*Isocoma menziesii*
*Brachypodium distachyon**	***Isocoma menziesii* var. *menziesii***
*Bromus diandrus**	*Lycium californicum*
*Bromus hordeaceus**	*Opuntia littoralis*
*Bromus madritensis**	*Phalaris aquatica**
Calochortus catalinae	*Polypogon monspeliensis**
*Centaurea melitensis**	*Pseudognaphalium luteoalbum**
Deinandra fasciculata	*Stipa miliacea* var. *miliacea**
*Desmazeria rigida**	*Xanthium spinosum**
*Erodium botrys**	
*Erodium brachycarpum**	
*Erodium cicutarium**	
*Erodium moschatum**	
*Festuca bromoides**	
*Festuca myuros**	
Harpagonella palmeri	
*Hedypnois rhagadioloides**	
Hordeum intercedens	
*Hordeum murinum**	
*Hypochaeris glabra**	
*Lamarckia aurea**	
Lasthenia californica	
Layia platyglossa	
Lepidium nitidum	
Logfia arizonica	
*Logfia gallica**	
Lupinus concinnus	
*Lysimachia arvensis**	
*Medicago polymorpha**	
*Melilotus indicus**	
*Mesembryanthemum nodiflorum**	
Microseris douglasii	
Opuntia littoralis x *oricola*	
Opuntia oricola	
*Phalaris minor**	
*Plantago coronopus**	
Plantago erecta	
Rhus integrifolia	
*Sonchus oleraceus**	
*Spergularia villosa**	
Stebbinsoseris heterocarpa	

Stipa lepida	
Stipa pulchra	
*Torilis nodosa**	
Trifolium albopurpureum	

*** nonnative species***

Figure 6-6. High Confidence Assemblages (≥95) – *Cercocarpus traskiae* & *Cercocarpus betuloides* var. *blancheae*

Diagnostic Species Figure



Species within each module are listed on next page.

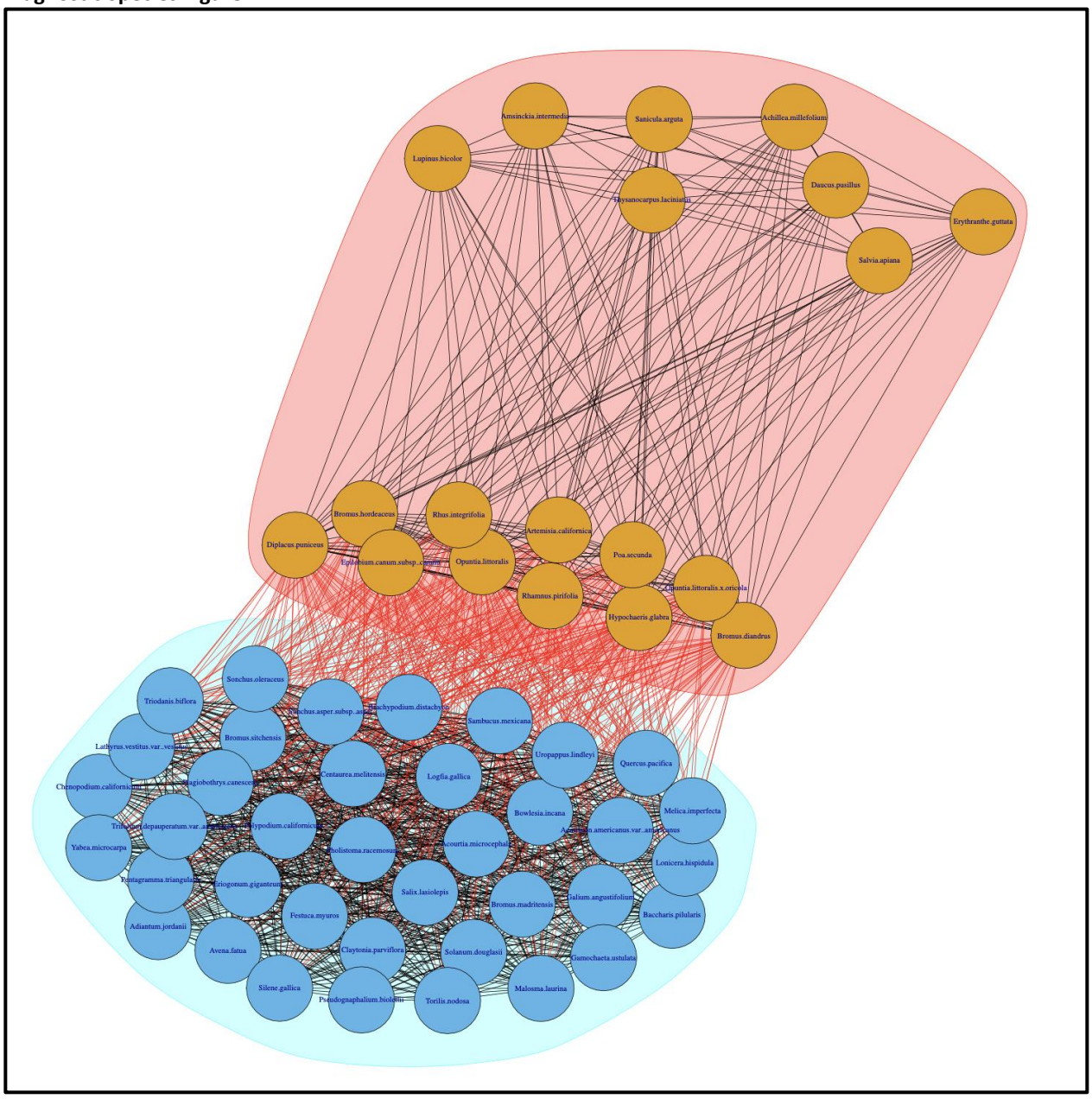
Diagnostic Species Table: *Cercocarpus traskiae; Cercocarpus betuloides* var. *blancheae*

Red Module (Orange Node)	**Blue Module (Blue Node)**
Adenostoma fasciculatum	*Baccharis pilularis*
Brickellia californica	*Baccharis salicifolia*
Ceanothus megacarpus var. *insularis*	***Cercocarpus betuloides var. blancheae***
Cercocarpus traskiae	*Sambucus mexicana*
Heteromeles arbutifolia	*Symphoricarpos mollis*
Isocoma menziesii	*Toxicodendron diversilobum*
Malosma laurina	
Opuntia littoralis	
Quercus pacifica (previously *Q. dumosa*)	
Rhus integrifolia	
Rhus ovata	
Salvia mellifera	

** nonnative species*

Figure 6-7. High Confidence Assemblages (≥95) – *Achillea millefolium* & *Bromus sitchensis*

Diagnostic Species Figure



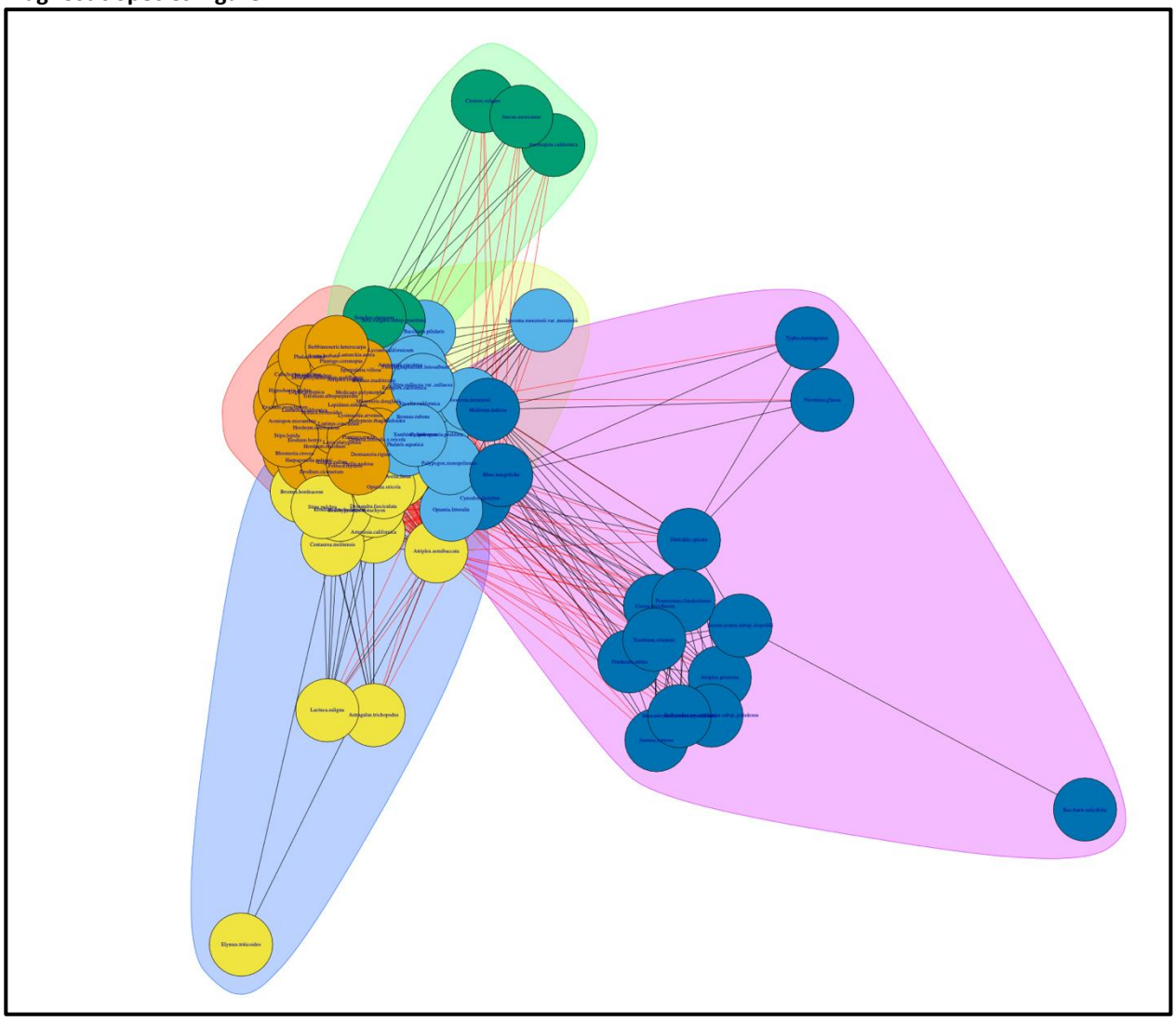
Species within each module are listed on next page.

Diagnostic Species Table: *Achillea millefolium* & *Bromus sitchensis*

Red Module (Orange Node)	Blue Module (Blue Node)
Achillea millefolium	*Acmispon americanus* var. *americanus*
Amsinckia intermedia	*Acourtia microcephala*
Artemisia californica	*Adiantum jordanii*
*Bromus diandrus**	*Avena fatua**
*Bromus hordeaceus**	*Baccharis pilularis*
Daucus pusillus	*Bowlesia incana*
Diplacus puniceus	*Brachypodium distachyon**
Epilobium canum subsp. *canum*	*Bromus madritensis**
Erythranthe guttata	***Bromus sitchensis* (*B. carinatus*)**
*Hypochaeris glabra**	*Centaurea melitensis**
Lupinus bicolor	*Chenopodium californicum*
Opuntia littoralis	*Claytonia parviflora*
Opuntia littoralis x oricola	*Eriogonum giganteum* var. *giganteum*
Poa secunda	*Festuca myuros**
Rhamnus pirifolia	*Galium angustifolium*
Rhus integrifolia	*Gamochaeta ustulata*
Salvia apiana	*Lathyrus vestitus* var. *vestitus*
Sanicula arguta	*Logfia gallica**
Thysanocarpus laciniatus	*Lonicera hispidula*
	Malosma laurina
	Melica imperfecta
	Pentagramma triangularis
	Pholistoma racemosum
	Plagiobothrys canescens
	Polypodium californicum
	Pseudognaphalium biolettii
	Quercus pacifica
	Salix lasiolepis
	Sambucus mexicana
	*Silene gallica**
	Solanum douglasii
	Sonchus asper subsp. *asper**
	*Sonchus oleraceus**
	*Torilis nodosa**
	Trifolium depauperatum var. *amplectens*
	Triodanis biflora
	Uropappus lindleyi
	Yabea microcarpa

Figure 6-8. High Confidence Assemblages (≥90) – *Hordeum intercedens, Isocoma menziesii* var. *menziesii, Cylindropuntia prolifera, Deinandra fasciculata, Elymus triticoides, Anemopsis californica, Typha domingensis, Baccharis salicifolia, Distichlis spicata*, & *Frankenia salina*

Diagnostic Species Figure



Species within each module are listed on next page.

Diagnostic Species Table: *Hordeum intercedens, Isocoma menziesii* var. *menziesii, Cylindropuntia prolifera, Deinandra fasciculata, Elymus triticoides, Anemopsis californica, Typha domingensis, Baccharis salicifolia, Distichlis spicata,* & *Frankenia salina*

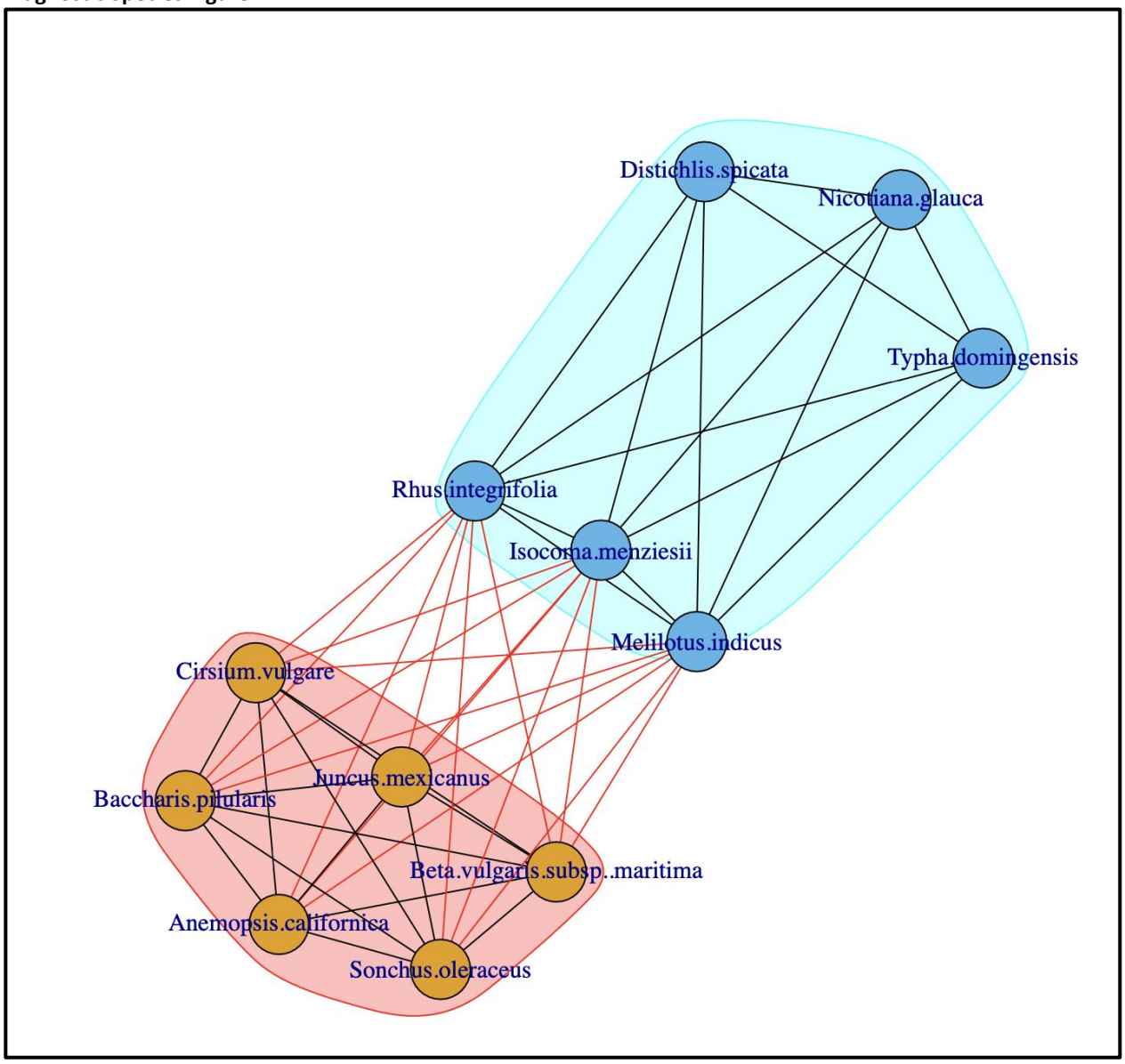
Green Module (Green Node)	Yellow Module (Light Blue Node)	Red Module (Orange Node)	Blue Module (Yellow Node)	Purple Module (Dark Blue Node)
Anemopsis californica	*Ammannia coccinea*	*Acmispon micranthus*	*Artemisia californica*	*Atriplex prostrata**
Beta vulgaris subsp. *maritima**	*Baccharis pilularis*	*Atriplex coulteri*	*Astragalus trichopodus*	***Baccharis salicifolia***
*Cirsium vulgare**	*Bromus rubens**	*Avena barbata**	*Atriplex semibaccata**	*Bolboschoenus maritimus* subsp. *paludosus*
Juncus mexicanus	***Cylindropuntia prolifera***	*Bloomeria crocea*	*Avena fatua**	*Cressa truxillensis*
*Sonchus oleraceus**	*Encelia californica*	*Bromus diandrus**	*Brachypodium distachyon**	*Cynodon dactylon**
	Extriplex californica	*Bromus madritensis**	*Bromus hordeaceus**	***Distichlis spicata***
	Isocoma menziesi	*Desmazeria rigida**	*Centaurea melitensis**	***Frankenia salina***
	Isocoma menziesii var. menziesii	*Erodium botrys**	***Deinandra fasciculata***	*Jaumea carnosa*
	Lycium californicum	*Erodium cicutarium**	***Elymus triticoides***	*Juncus acutus* subsp. *leopoldii*
	Opuntia littoralis	*Erodium moschatum**	*Erodium brachycarpum**	*Melilotus indicus**
	*Phalaris aquatica**	*Festuca bromoides**	*Lactuca saligna**	*Mesembryanthemum crystallinum**
	*Polypogon monspeliensis**	*Festuca myuros**	*Opuntia oricola*	*Nicotiana glauca**
	*Pseudognaphalium luteoalbum**	*Harpagonella palmeri*	*Stipa pulchra*	*Pennisetum clandestinum**
	Stipa miliacea var. *miliacea**	*Hedypnois rhagadioloides**		*Rhus integrifolia*
	*Xanthium spinosum**	***Hordeum intercedens***		***Typha domingensis***
		*Hordeum murinum**		*Xanthium orientale*
		*Hypochaeris glabra**		
		*Lamarckia aurea**		
		Lasthenia californica		
		Layia platyglossa		
		Lepidium nitidum		
		Logfia arizonica		
		*Logfia gallica**		
		Lupinus concinnus		
		*Lysimachia arvensis**		
		*Medicago polymorpha**		

		*Mesembryanthemum nodiflorum**		
		Microseris douglasii		
		Opuntia littoralis x oricola		
		*Phalaris minor**		
		*Plantago coronopus**		
		Plantago erecta		
		*Spergularia villosa**		
		Stebbinsoseris heterocarpa		
		Stipa lepida		
		*Torilis nodosa**		
		Trifolium albopurpureum		

** nonnative species*

Figure 6-9. High Confidence Assemblages (≥90) – *Anemopsis californica* & *Typha domingensis*

Diagnostic Species Figure



Species within each module are listed on next page.

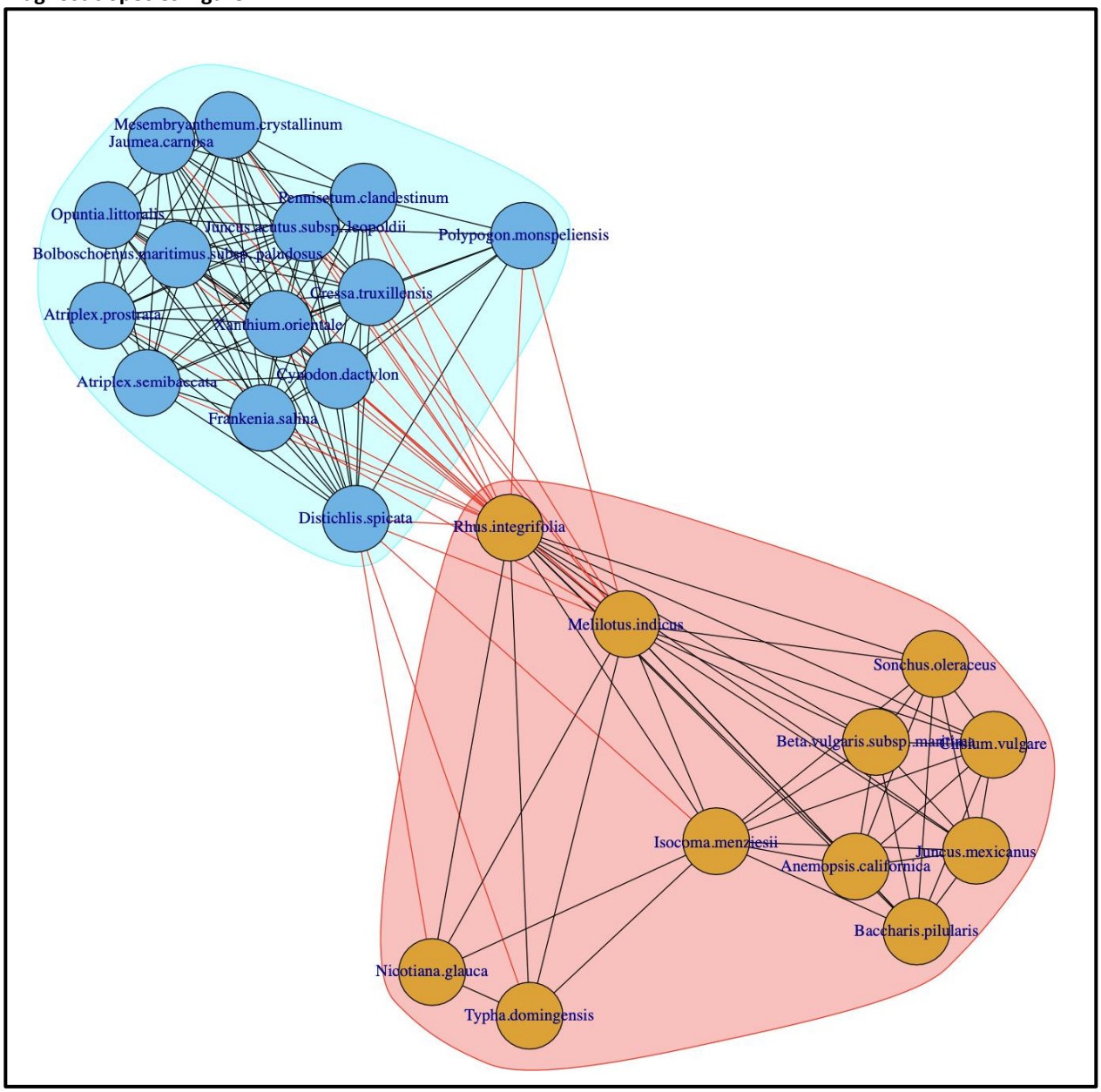
Diagnostic Species Table: *Anemopsis californica* & *Typha domingensis*

Red Module (Orange Node)	Blue Module (Blue Node)
Anemopsis californica	*Distichlis spicata*
Baccharis pilularis	*Isocoma menziesii*
Beta vulgaris subsp. *maritima**	*Melilotus indicus**
*Cirsium vulgare**	*Nicotiana glauca**
Juncus mexicanus	*Rhus integrifolia*
*Sonchus oleraceus**	***Typha domingensis***

** nonnative species*

Figure 6-10. High Confidence Assemblages (≥90) – *Anemopsis californica, Distichlis spicata, Frankenia salina,* & *Typha domingensis*

Diagnostic Species Figure



Species within each module are listed on next page.

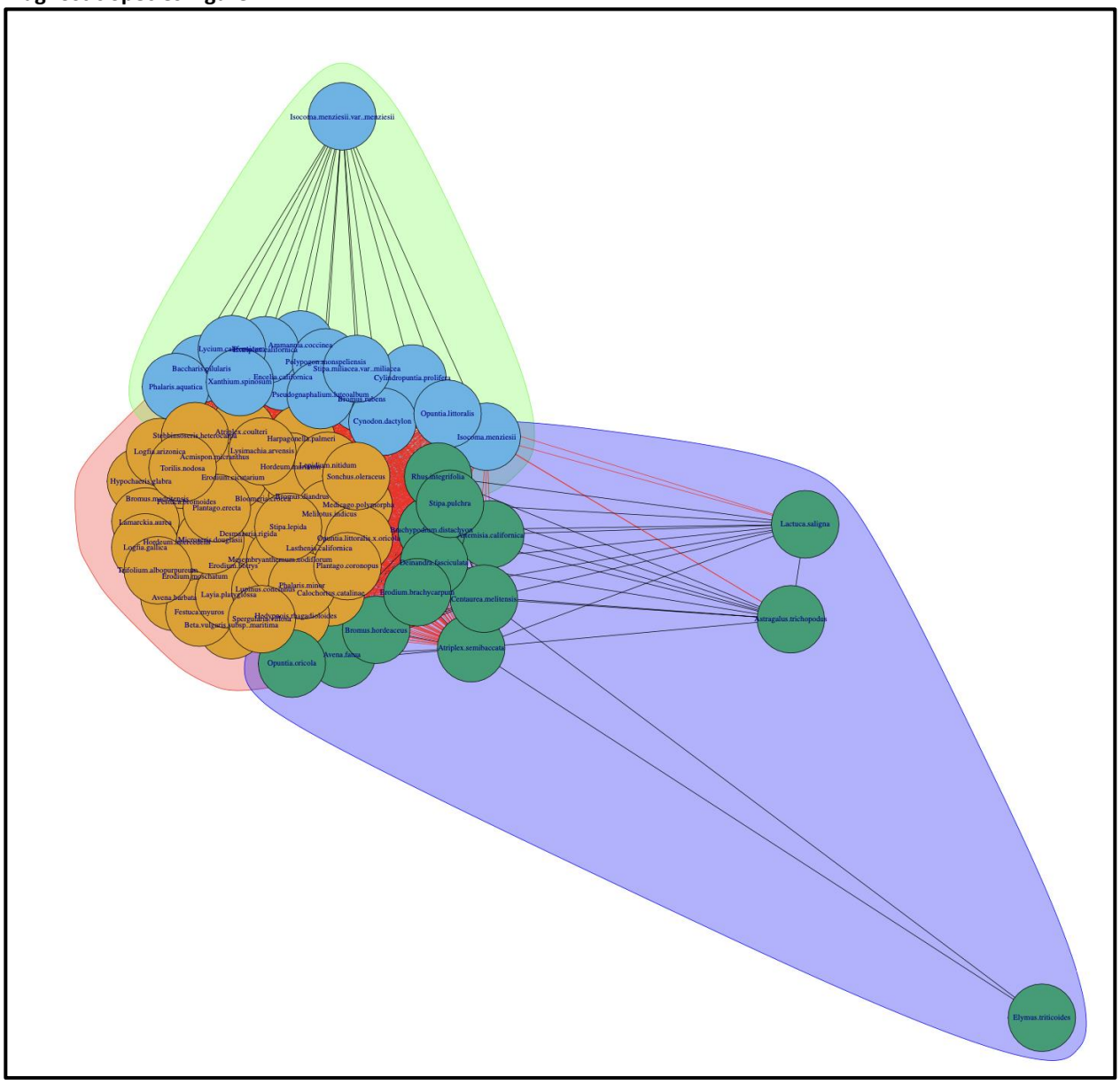
Diagnostic Species Table: *Distichlis spicata, Frankenia salina, Anemopsis californica,* & *Typha domingensis*

Blue Module (Blue Node)	Red Module (Orange Node)
*Atriplex prostrata**	***Anemopsis californica***
*Atriplex semibaccata**	*Baccharis pilularis*
Bolboschoenus maritimus subsp. *paludosus*	*Beta vulgaris* subsp. *maritima**
Cressa truxillensis	*Cirsium vulgare**
*Cynodon dactylon**	*Isocoma menziesii*
Distichlis spicata	*Juncus mexicanus*
Frankenia salina	*Melilotus indicus**
Jaumea carnosa	*Nicotiana glauca**
Juncus acutus subsp. *leopoldii*	*Rhus integrifolia*
*Mesembryanthemum crystallinum**	*Sonchus oleraceus**
Opuntia littoralis	***Typha domingensis***
*Pennisetum clandestinum**	
*Polypogon monspeliensis**	
Xanthium orientale	

** nonnative species*

Figure 6-8. High Confidence Assemblages (≥90) – *Hordeum intercedens, Isocoma menziesii* var. *menziesii, Cylindropuntia prolifera, Deinandra fasciculata,* & *Elymus triticoides*

Diagnostic Species Figure



Species within each module are listed on next page.

Diagnostic Species Table: *Hordeum intercedens, Isocoma menziesii* var. *menziesii, Cylindropuntia prolifera, Deinandra fasciculata,* & *Elymus triticoides*

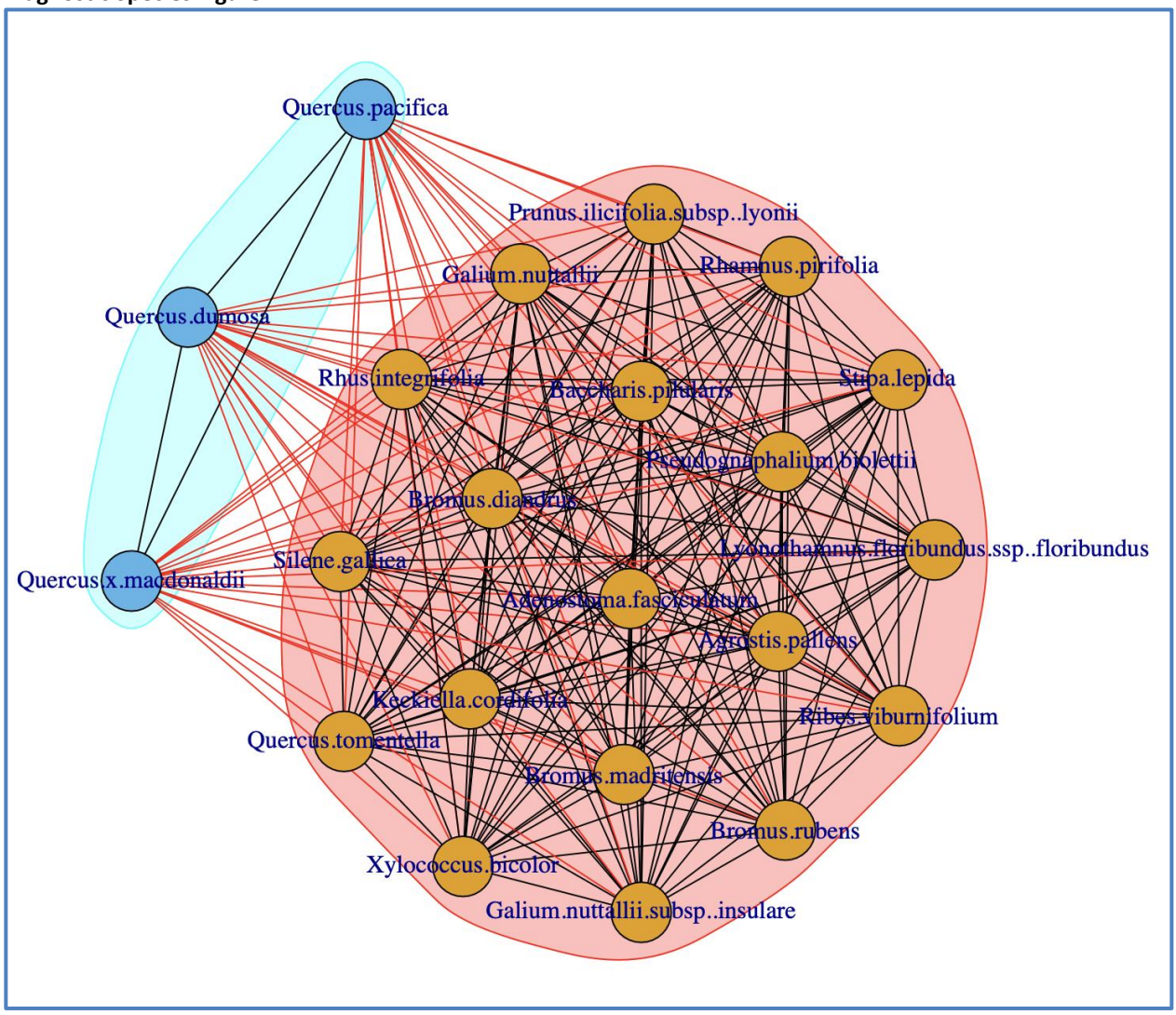
Green Module (Light Blue Node)	**Red Module (Orange Node)**	**Purple Module (Green Node)**
Ammannia coccinea	*Acmispon micranthus*	*Artemisia californica*
Baccharis pilularis	*Atriplex coulteri*	*Astragalus trichopodus*
*Bromus rubens**	*Avena barbata**	*Atriplex semibaccata**
Cylindropuntia prolifera	*Beta vulgaris* subsp. *maritima**	*Avena fatua**
*Cynodon dactylon**	*Bloomeria crocea*	*Brachypodium distachyon**
Encelia californica	*Bromus diandrus**	*Bromus hordeaceus**
Extriplex californica	*Bromus madritensis**	*Centaurea melitensis**
Isocoma menziesii	*Calochortus catalinae*	***Deinandra fasciculata***
Isocoma menziesii var. menziesii	*Desmazeria rigida**	***Elymus triticoides***
Lycium californicum	*Erodium botrys**	*Erodium brachycarpum**
Opuntia littoralis	*Erodium cicutarium**	*Lactuca saligna**
*Phalaris aquatica**	*Erodium moschatum**	*Opuntia oricola*
*Polypogon monspeliensis**	*Festuca bromoides**	*Rhus integrifolia*
*Pseudognaphalium luteoalbum**	*Festuca myuros**	*Stipa pulchra*
Stipa miliacea var. *miliacea**	*Harpagonella palmeri*	
*Xanthium spinosum**	*Hedypnois rhagadioloides**	
	Hordeum intercedens	
	*Hordeum murinum**	
	*Hypochaeris glabra**	
	*Lamarckia aurea**	
	Lasthenia californica	
	Layia platyglossa	
	Lepidium nitidum	
	Logfia arizonica	
	*Logfia gallica**	
	Lupinus concinnus	
	*Lysimachia arvensis**	
	*Medicago polymorpha**	
	*Melilotus indicus**	
	*Mesembryanthemum nodiflorum**	
	Microseris douglasii	
	Opuntia littoralis x oricola	
	*Phalaris minor**	
	*Plantago coronopus**	
	Plantago erecta	

	*Sonchus oleraceus**	
	*Spergularia villosa**	
	Stebbinsoseris heterocarpa	
	Stipa lepida	
	*Torilis nodosa**	
	Trifolium albopurpureum	

*** nonnative species***

Figure 6-12. High Confidence Assemblages (≥90) – *Lyonothamnus floribundus* subsp. *floribundus* & *Quercus x macdonaldii*

Diagnostic Species Figure



Species within each module are listed on next page.

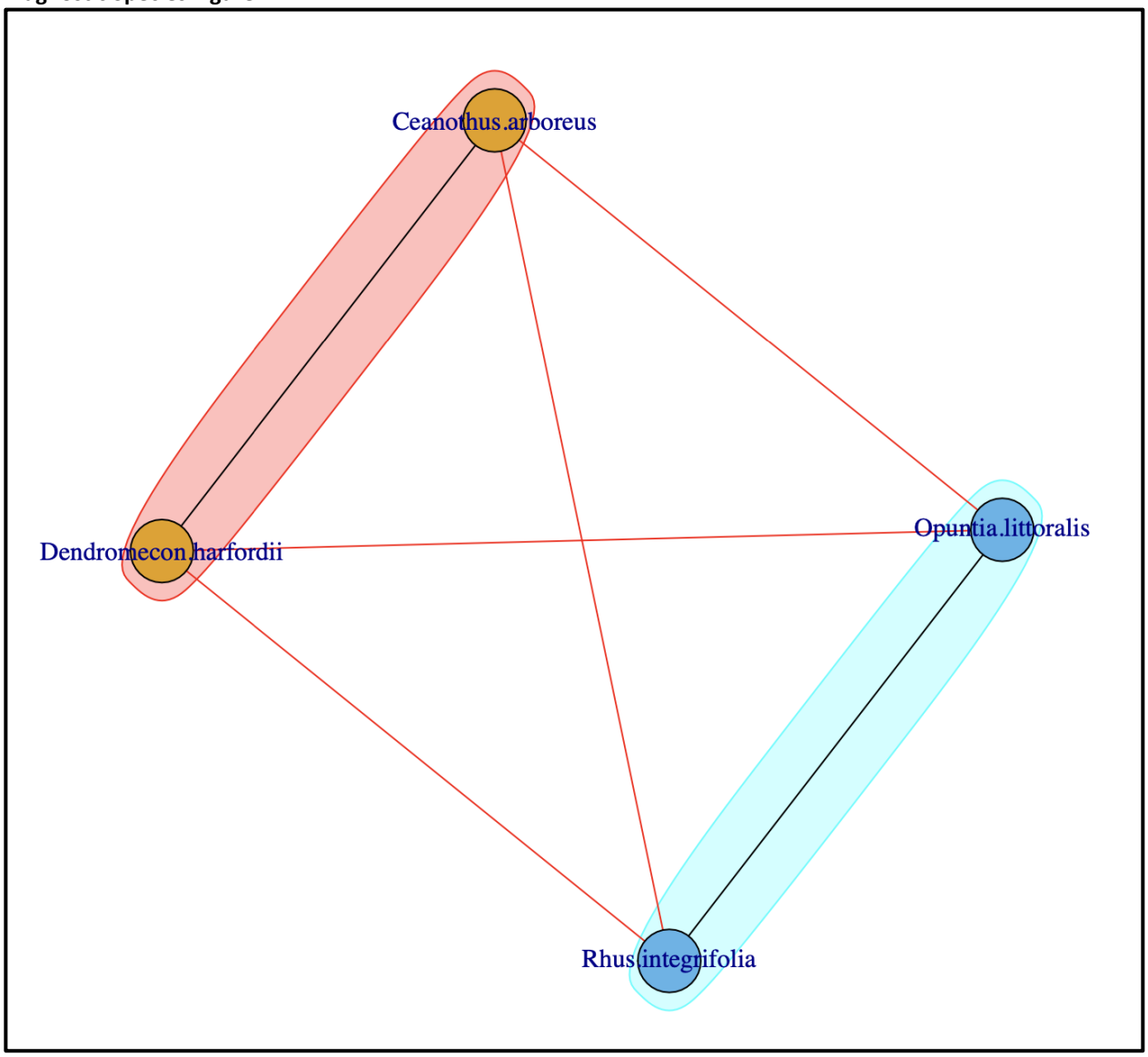
Diagnostic Species Table: *Lyonothamnus floribundus* subsp. *floribundus* & *Quercus x macdonaldii*

Blue Module (Blue Node)	**Red Module (Orange Node)**
Quercus pacifica (previously *Q. dumosa*)	*Adenostoma fasciculatum*
Quercus x macdonaldii	*Agrostis pallens*
	Baccharis pilularis
	*Bromus diandrus**
	*Bromus madritensis**
	*Bromus rubens**
	Galium nuttallii
	Galium nuttallii subsp. *insulare*
	Keckiella cordifolia
	Lyonothamnus floribundus subsp. floribundus
	Prunus ilicifolia subsp. *lyonii*
	Pseudognaphalium biolettii
	Quercus tomentella
	Rhamnus pirifolia
	Rhus integrifolia
	Ribes viburnifolium
	*Silene gallica**
	Stipa lepida
	Xylococcus bicolor

** nonnative species*

Figure 6-13. High Confidence Assemblages (≥90) – *Dendromecon harfordii* & *Opuntia littoralis*

Diagnostic Species Figure



Species within each module are listed on next page.

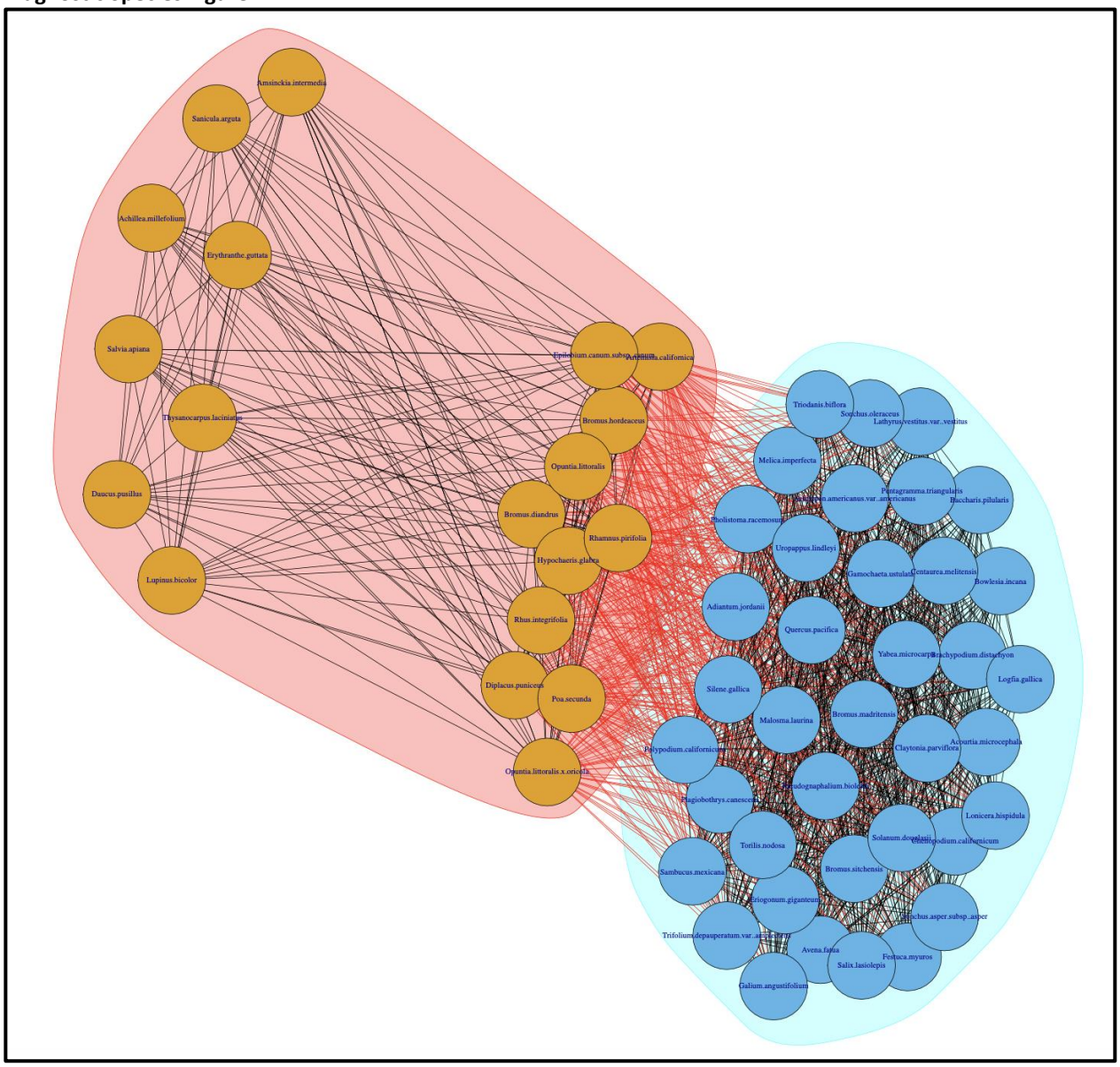
Diagnostic Species Table: *Dendromecon harfordii* & *Opuntia littoralis*

Red Module (Orange Node)	Blue Module (Blue Node)
Ceanothus arboreus	***Opuntia littoralis***
Dendromecon harfordii	*Rhus integrifolia*

** nonnative species*

Figure 6-14. High Confidence Assemblages (≥80) – *Achillea millefolium* & *Bromus sitchensis*

Diagnostic Species Figure



Species within each module are listed on next page.

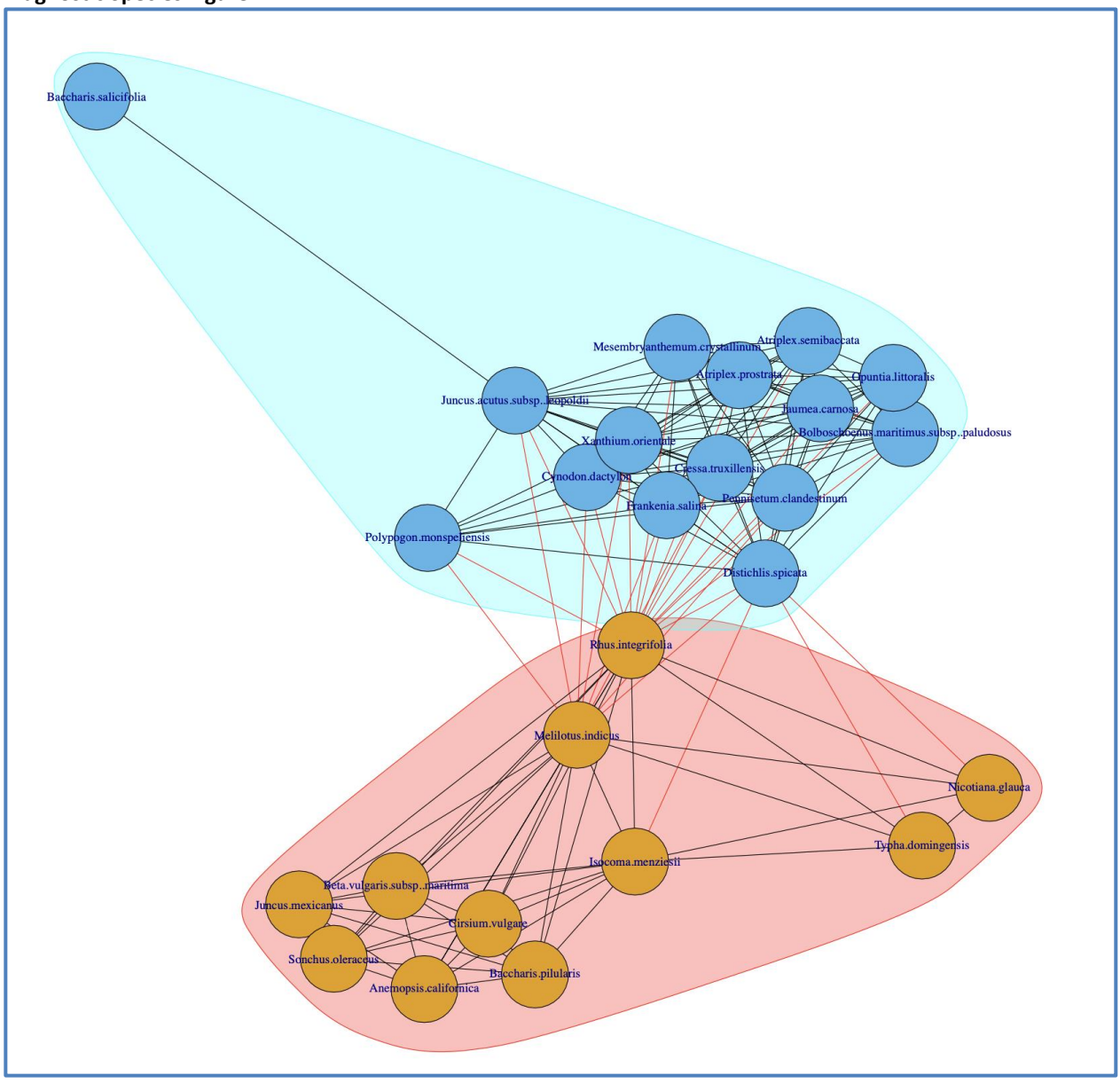
Diagnostic Species Table: *Achillea millefolium & Bromus sitchensis*

Red Module (Orange Node)	Blue Module (Blue Node)
Achillea millefolium	*Acmispon americanus* var. *americanus*
Amsinckia intermedia	*Acourtia microcephala*
Artemisia californica	*Adiantum jordanii*
*Bromus diandrus**	*Avena fatua**
*Bromus hordeaceus**	*Baccharis pilularis*
Daucus pusillus	*Bowlesia incana*
Diplacus puniceus	*Brachypodium distachyon**
Epilobium canum subsp. *canum*	*Bromus madritensis**
Erythranthe guttata	***Bromus sitchensis* (*B. carinatus*)**
*Hypochaeris glabra**	*Centaurea melitensis**
Lupinus bicolor	*Chenopodium californicum*
Opuntia littoralis	*Claytonia parviflora*
Opuntia littoralis x oricola	*Eriogonum giganteum* var. *giganteum*
Poa secunda	*Festuca myuros**
Rhamnus pirifolia	*Galium angustifolium*
Rhus integrifolia	*Gamochaeta ustulata*
Salvia apiana	*Lathyrus vestitus* var. *vestitus*
Sanicula arguta	*Logfia gallica**
Thysanocarpus laciniatus	*Lonicera hispidula*
	Malosma laurina
	Melica imperfecta
	Pentagramma triangularis
	Pholistoma racemosum
	Plagiobothrys canescens
	Polypodium californicum
	Pseudognaphalium biolettii
	Quercus pacifica
	Salix lasiolepis
	Sambucus mexicana
	*Silene gallica**
	Solanum douglasii
	Sonchus asper subsp. *asper**
	*Sonchus oleraceus**
	*Torilis nodosa**
	Trifolium depauperatum var. *amplectens*
	Triodanis biflora
	Uropappus lindleyi
	Yabea microcarpa

** nonnative species*

Figure 6-15. High Confidence Assemblages (≥80) – *Anemopsis californica,Typha domingensis , Baccharis salicifolia, Distichlis spicata* & *Frankenia salina*

Diagnostic Species Figure



Species within each module are listed on next page.

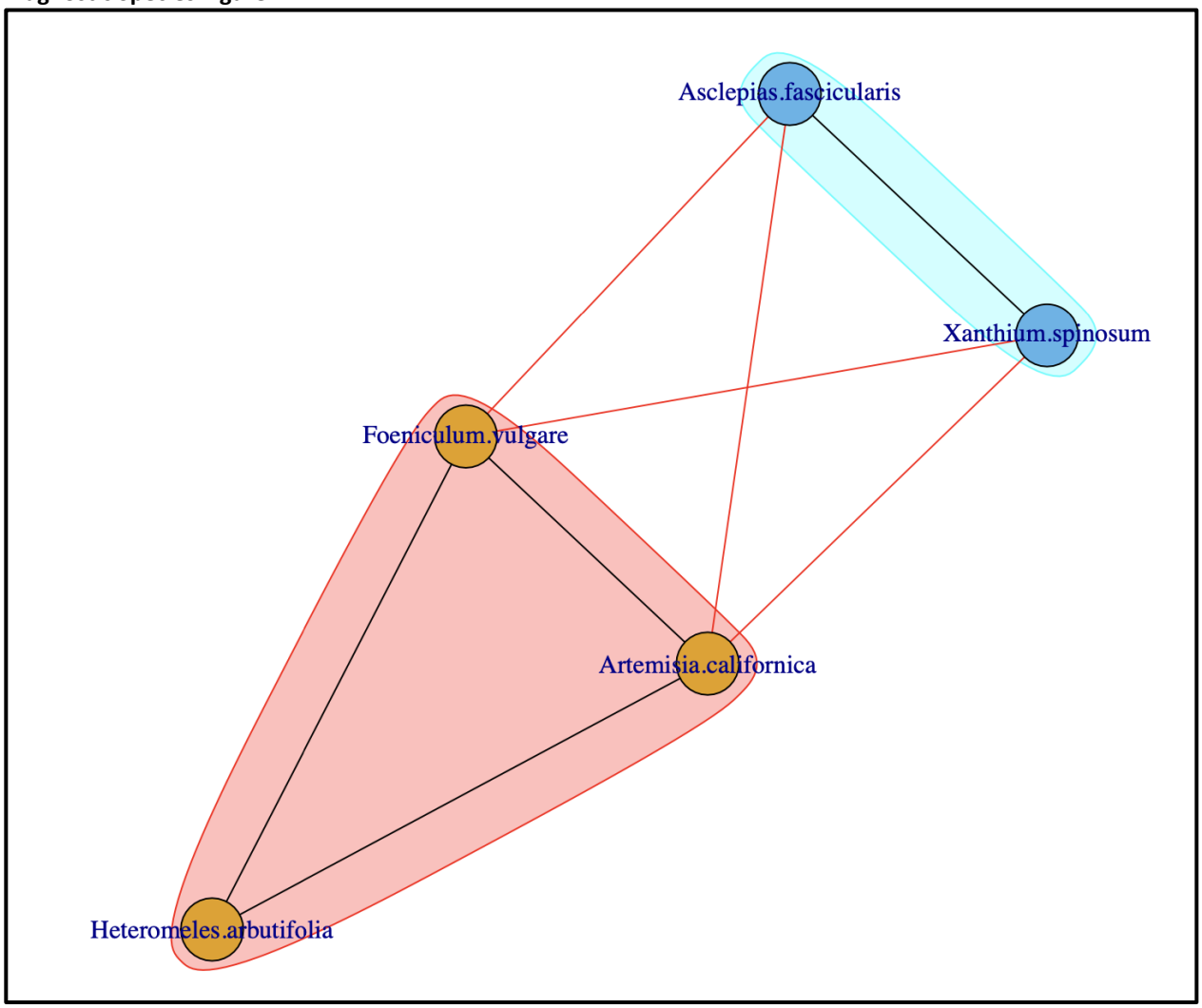
Diagnostic Species Table: *Anemopsis californica, Typha domingensis, Baccharis salicifolia, Distichlis spicata,* & *Frankenia salina*

Blue Module (Blue Node)	Red Module (Orange Node)
*Atriplex prostrata**	***Anemopsis californica***
*Atriplex semibaccata**	*Baccharis pilularis*
Baccharis salicifolia	*Beta vulgaris* subsp. *maritima**
Bolboschoenus maritimus subsp. *paludosus*	*Cirsium vulgare**
Cressa truxillensis	*Isocoma menziesii*
*Cynodon dactylon**	*Juncus mexicanus*
Distichlis spicata	*Melilotus indicus**
Frankenia salina	*Nicotiana glauca**
Jaumea carnosa	*Rhus integrifolia*
Juncus acutus subsp. *leopoldii*	*Sonchus oleraceus**
*Mesembryanthemum crystallinum**	***Typha domingensis***
Opuntia littoralis	
*Pennisetum clandestinum**	
*Polypogon monspeliensis**	
Xanthium orientale	

** nonnative species*

Figure 6-16. High Confidence Assemblages (≥80) – *Artemisia californica* & *Asclepias fascicularis*

Diagnostic Species Figure



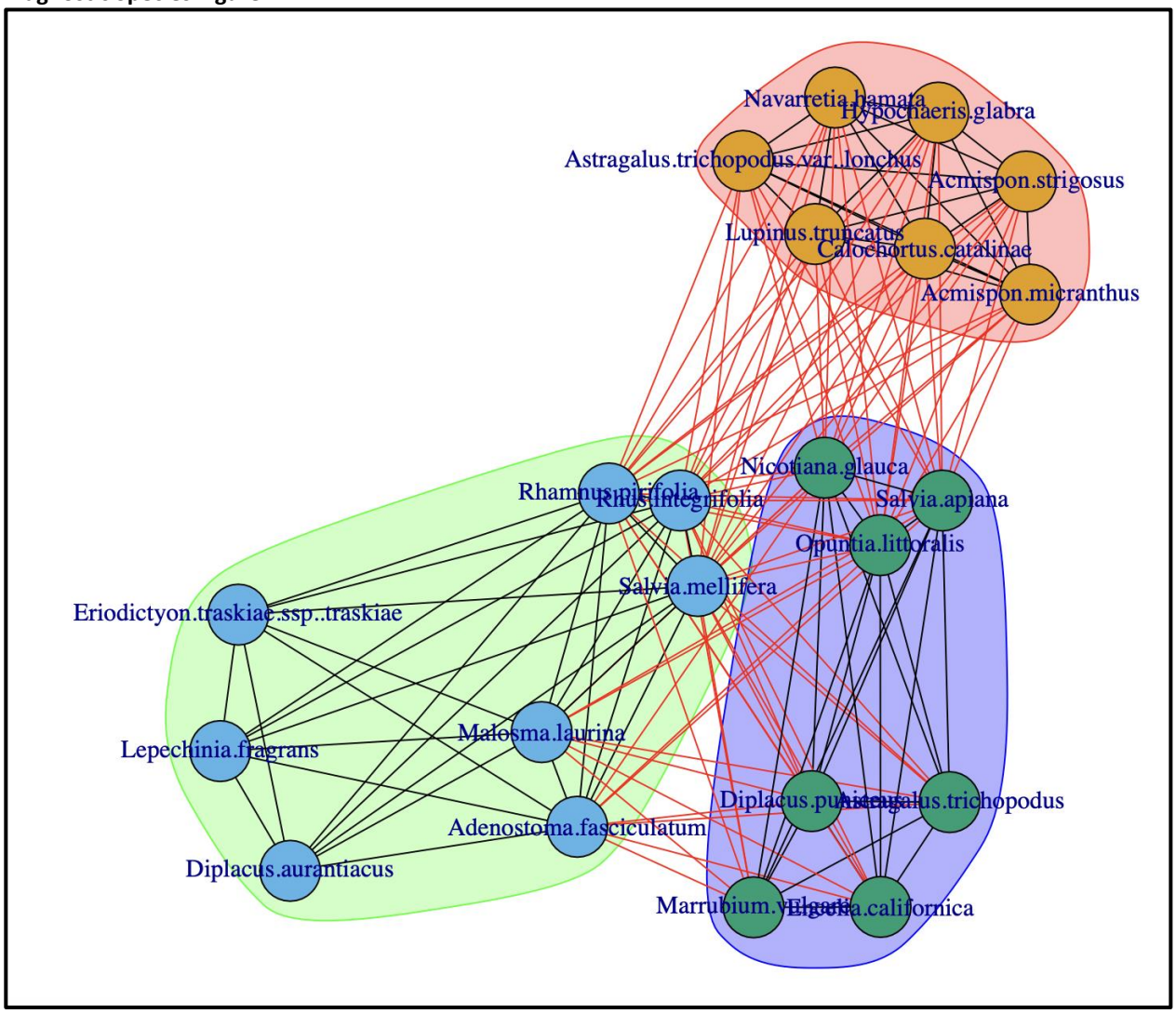
Diagnostic Species Table: *Artemisia californica* & *Asclepias fascicularis*

Red Module (Orange Node)	Blue Module (Blue Node)
Artemisia californica	***Asclepias fascicularis***
*Foeniculum vulgare**	*Xanthium spinosum**
Heteromeles arbutifolia	

** nonnative species*

Figure 6-17. High Confidence Assemblages (≥80) – *Astragalus trichopodus* var. *lonchus, Eriodictyon traskiae* subsp. *traskiae,* & *Malosma laurina*

Diagnostic Species Figure



Species within each module are listed on next page.

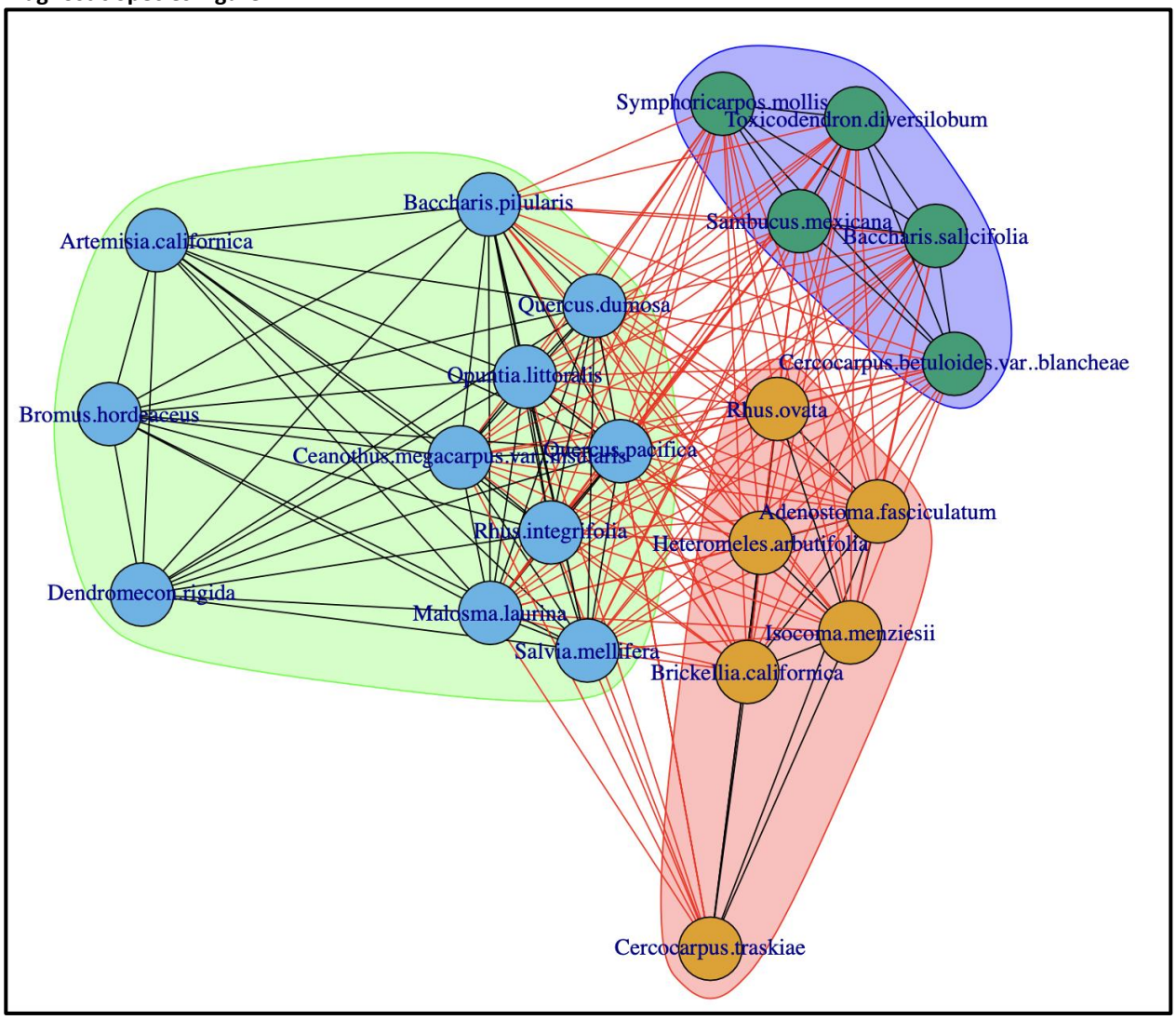
Diagnostic Species Table: *Astragalus trichopodus var. lonchus, Eriodictyon traskiae* subsp. *traskiae,* & *Malosma laurina*

Green Module (Blue Node)	Purple Module (Green Node)	Red Module (Orange Node)
Adenostoma fasciculatum	*Astragalus trichopodus*	*Acmispon micranthus*
Diplacus aurantiacus	*Diplacus puniceus*	*Acmispon strigosus*
Eriodictyon traskiae* subsp. *traskiae	*Encelia californica*	***Astragalus trichopodus* var. *lonchus***
Lepechinia fragrans	*Marrubium vulgare**	*Calochortus catalinae*
Malosma laurina	*Nicotiana glauca**	*Hypochaeris glabra**
Rhamnus pirifolia	*Opuntia littoralis*	*Lupinus truncatus*
Rhus integrifolia	*Salvia apiana*	*Navarretia hamata*
Salvia mellifera		

** nonnative species*

Figure 6-18. High Confidence Assemblages (≥80) – *Ceanothus megacarpus* var. *insularis, Cercocarpus traskiae,*& *Cercocarpus betuloides* var. *blancheae*

Diagnostic Species Figure



Species within each module are listed on next page.

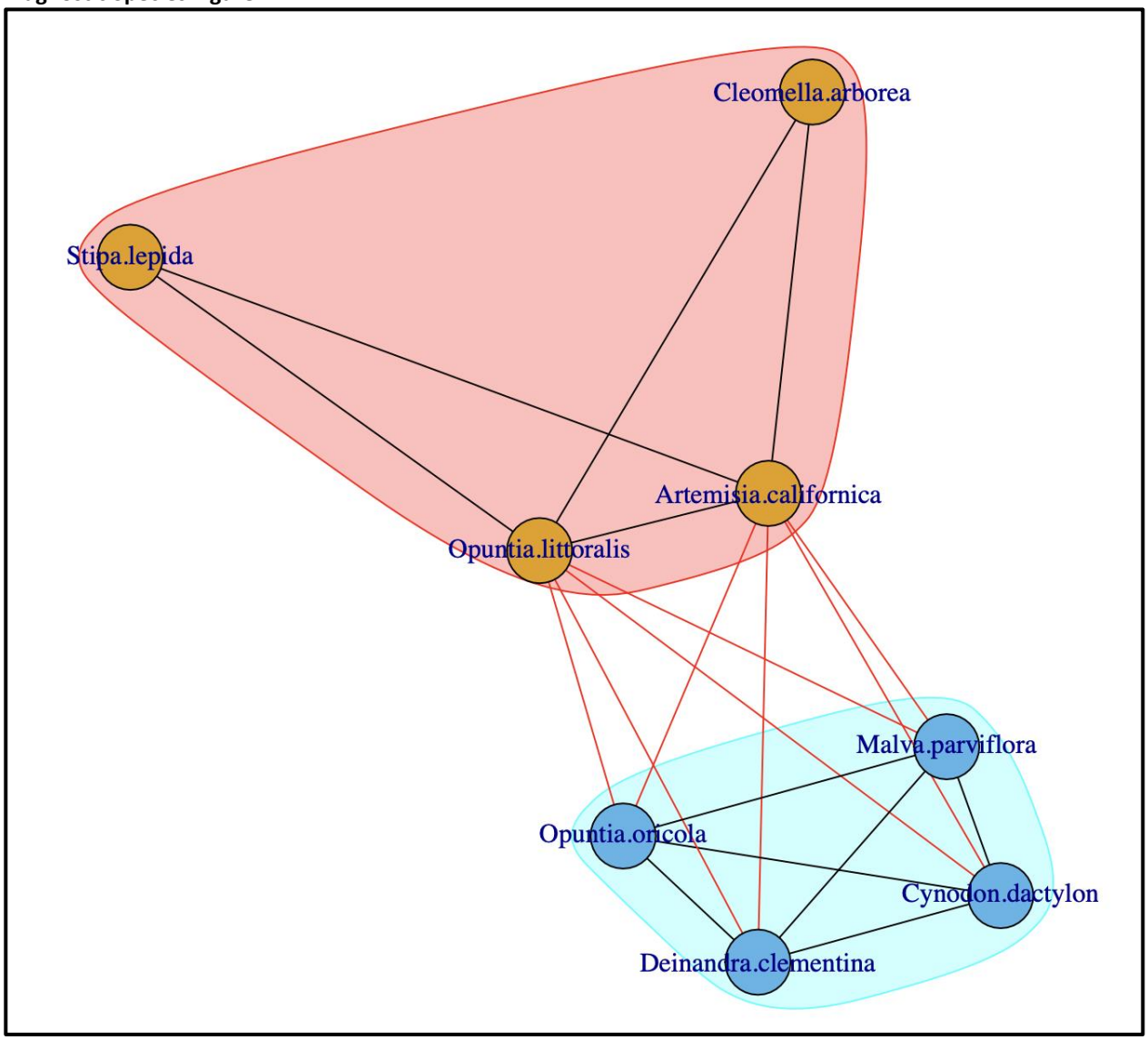
Diagnostic Species Table: *Ceanothus megacarpus* var. *insularis, Cercocarpus traskiae* & *Cercocarpus betuloides* var. *blancheae*

Green Module (Blue Node)	Red Module (Orange Node)	Purple Module (Green Node)
Artemisia californica	*Adenostoma fasciculatum*	*Baccharis salicifolia*
Baccharis pilularis	*Brickellia californica*	***Cercocarpus betuloides var. blancheae***
*Bromus hordeaceus**	***Cercocarpus traskiae***	*Sambucus mexicana*
Ceanothus megacarpus var. insularis	*Heteromeles arbutifolia*	*Symphoricarpos mollis*
Dendromecon rigida	*Isocoma menziesii*	*Toxicodendron diversilobum*
Malosma laurina	*Rhus ovata*	
Opuntia littoralis		
Quercus pacifica (previously *Q. dumosa*)		
Rhus integrifolia		
Salvia mellifera		

** nonnative species*

Figure 6-19. High Confidence Assemblages (≥80) – *Deinandra clementina, Cleomella arborea,* & *Stipa lepida*

Diagnostic Species Figure



Species within each module are listed on next page.

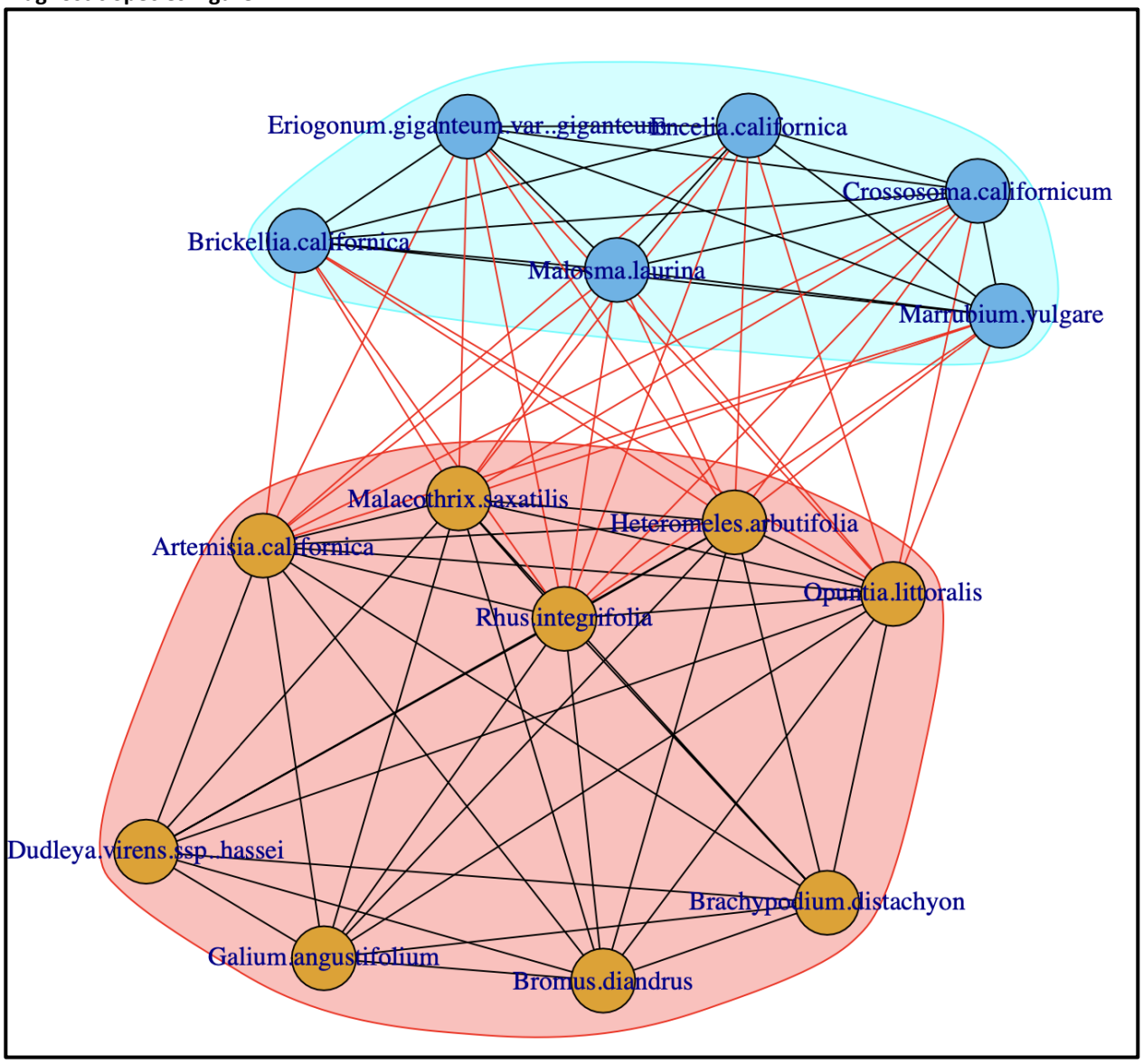
Diagnostic Species Table*:* *Deinandra clementina, Cleomella arborea,* & *Stipa lepida*

Red Module (Orange Node)	**Blue Module (Blue Node)**
Artemisia californica	*Cynodon dactylon**
Cleomella arborea	***Deinandra clementina***
Opuntia littoralis	*Malva parviflora**
Stipa lepida	*Opuntia oricola*

** nonnative species*

Figure 6-20. High Confidence Assemblages (≥80) – *Dudleya virens* subsp. *hassei* & *Eriogonum giganteum* var. *giganteum*

Diagnostic Species Figure



Species within each module are listed on next page.

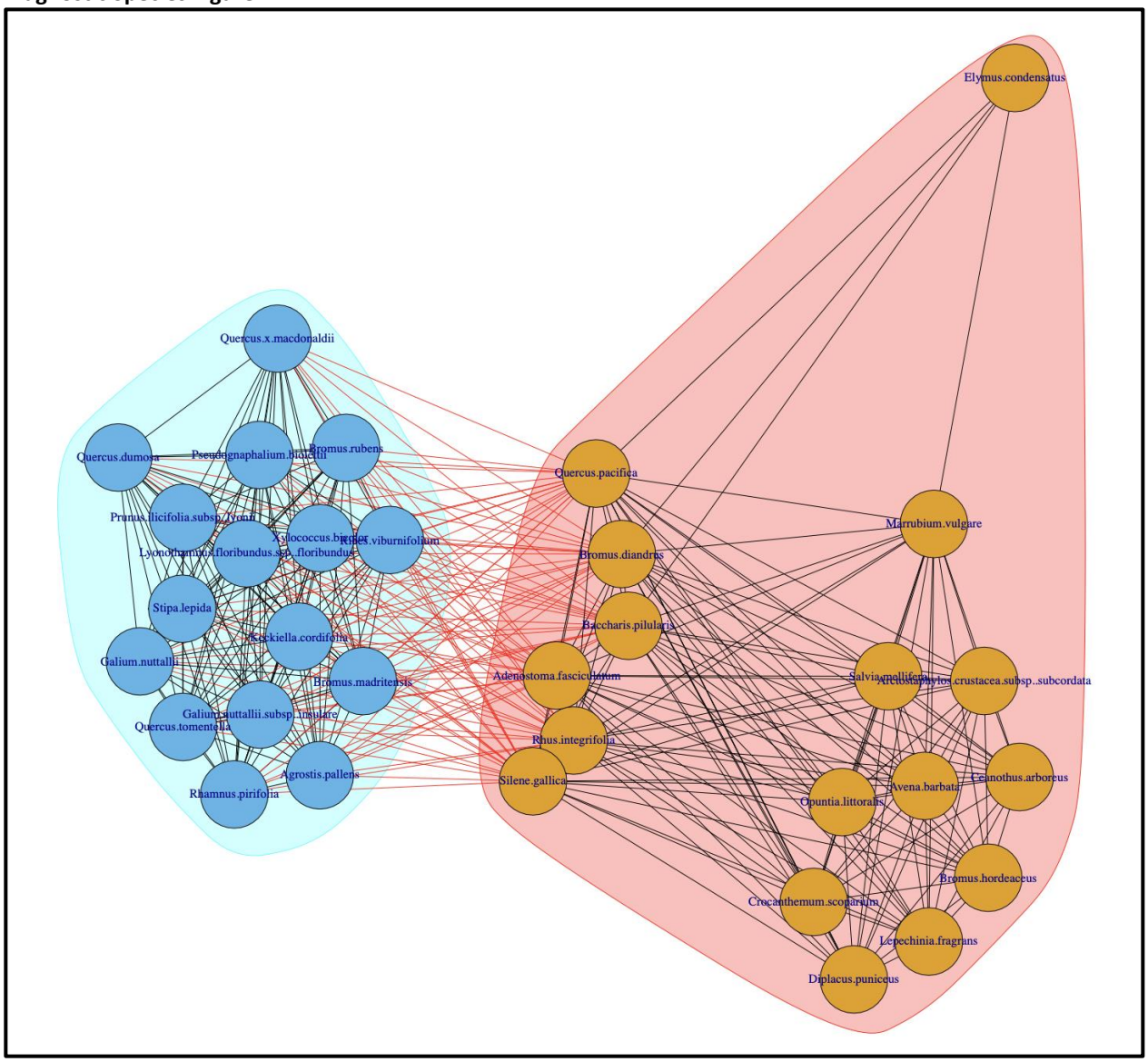
Diagnostic Species Table: *Dudleya virens* subsp. *hassei & Eriogonum giganteum* var. *giganteum*

Red Module (Orange Node)	Blue Module (Blue Node)
Artemisia californica	*Brickellia californica*
*Brachypodium distachyon**	*Crossosoma californicum*
*Bromus diandrus**	*Encelia californica*
Dudleya virens subsp. hassei	***Eriogonum giganteum* var. *giganteum***
Galium angustifolium	*Malosma laurina*
Heteromeles arbutifolia	*Marrubium vulgare**
Malacothrix saxatilis	
Opuntia littoralis	
Rhus integrifolia	

** nonnative species*

Figure 6-21. High Confidence Assemblages (≥80) – *Elymus condensatus, Lepechinia fragrans, Lyonothamnus floribundus* subsp. *floribundus* &*Quercus x macdonaldii*

Diagnostic Species Figure



Species within each module are listed on next page.

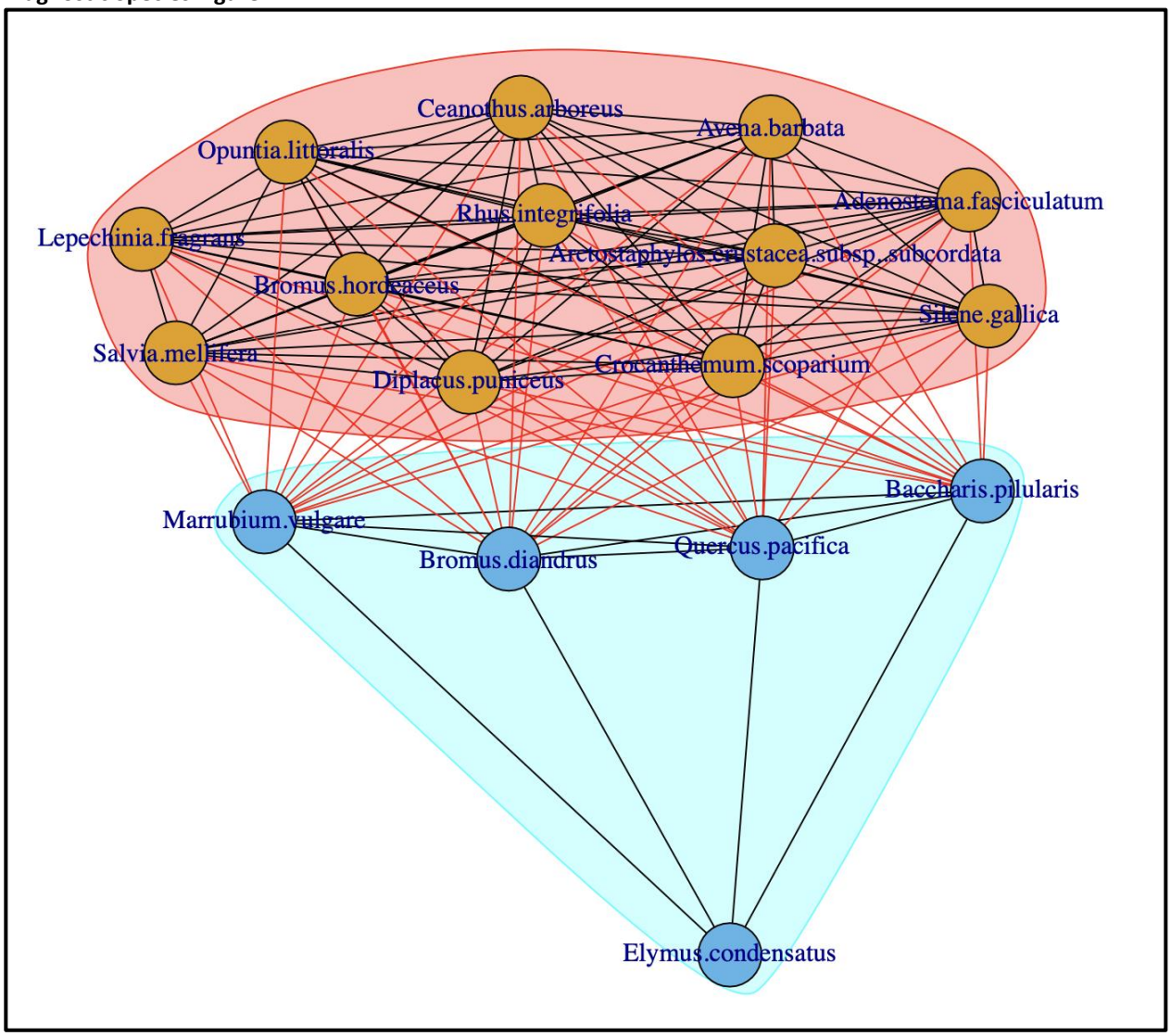
Diagnostic Species Table: *Elymus condensatus, Lepechinia fragrans, Lyonothamnus floribundus* subsp. *floribundus* & *Quercus x macdonaldii*

Blue Module (Blue Node)	Red Module (Orange Node)
Agrostis pallens	*Adenostoma fasciculatum*
*Bromus madritensis**	*Arctostaphylos crustacea* subsp. *subcordata*
*Bromus rubens**	*Avena barbata**
Galium nuttalli	*Baccharis pilularis*
Galium nuttallii subsp. *insulare*	*Bromus diandrus**
Keckiella cordifolia	*Bromus hordeaceus**
Lyonothamnus floribundus subsp. floribundus	*Ceanothus arboreus*
Prunus ilicifolia subsp. *lyonii*	*Crocanthemum scoparium*
Pseudognaphalium biolettii	*Diplacus puniceus*
Quercus pacifica (previously *Q. dumosa*)	***Elymus condensatus***
Quercus tomentella	***Lepechinia fragrans***
Quercus x macdonaldii	*Marrubium vulgare**
Rhamnus pirifolia	*Opuntia littoralis*
Ribes viburnifolium	*Quercus pacifica*
Stipa lepida	*Rhus integrifolia*
Xylococcus bicolor	*Salvia mellifera*
	*Silene gallica**

** nonnative species*

Figure 6-22. High Confidence Assemblages (≥80) – *Elymus condensatus* & *Lepechinia fragrans*

Diagnostic Species Figure



Species within each module are listed on next page.

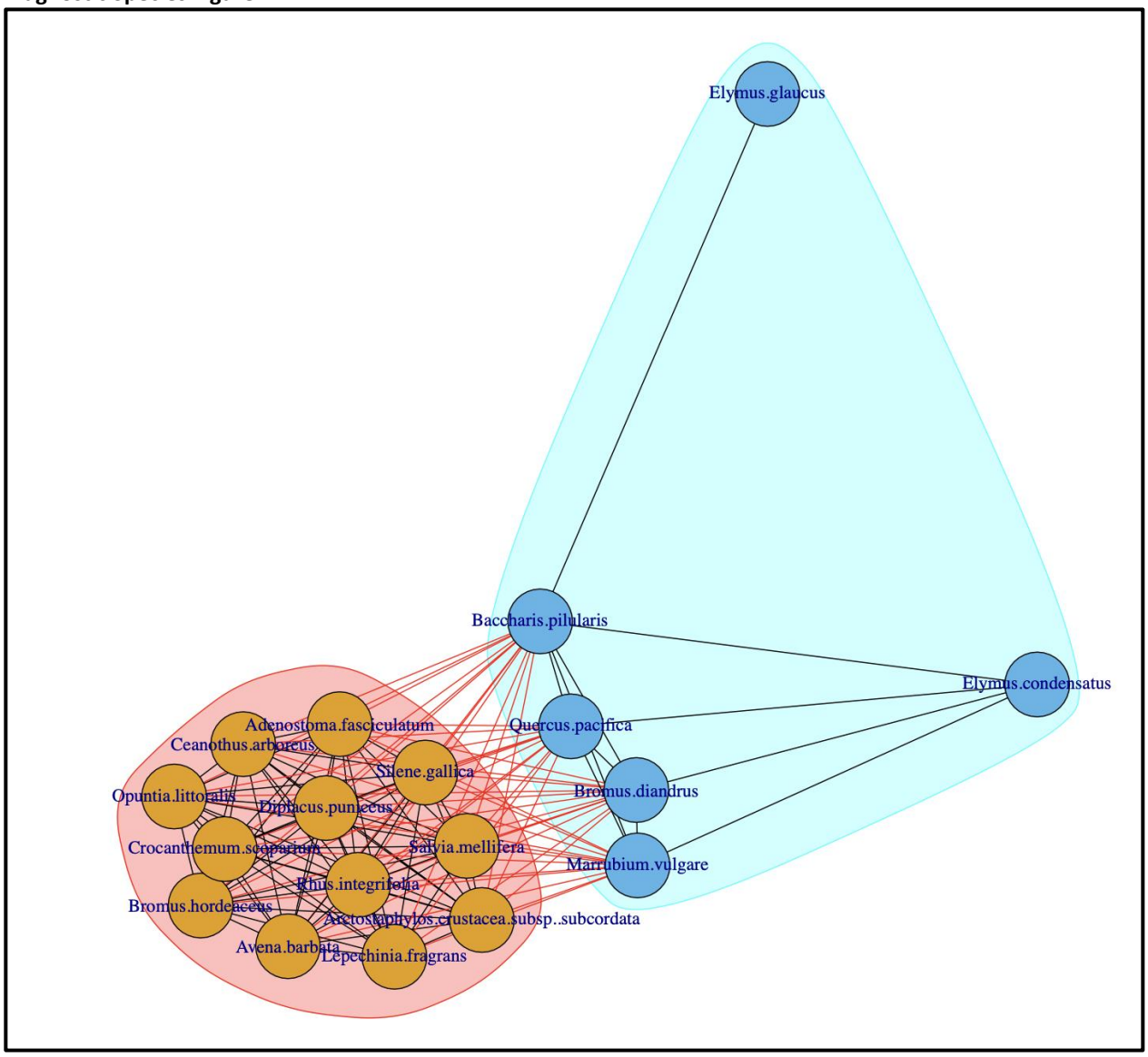
Diagnostic Species Table: *Elymus condensatus* & *Lepechinia fragrans*

Red Module (Orange Node)	**Blue Module (Blue Node)**
Adenostoma fasciculatum	*Baccharis pilularis*
Arctostaphylos crustacea subsp. *subcordata*	*Bromus diandrus**
*Avena barbata**	***Elymus condensatus***
*Bromus hordeaceus**	*Marrubium vulgare**
Ceanothus arboreus	*Quercus pacifica*
Crocanthemum scoparium	
Diplacus puniceus	
Lepechinia fragrans	
Opuntia littoralis	
Rhus integrifolia	
Salvia mellifera	
*Silene gallica**	

** nonnative species*

Figure 6-23. High Confidence Assemblages (≥80) – *Elymus glaucus, Elymus condensatus*, & *Lepechinia fragrans*

Diagnostic Species Figure



Species within each module are listed on next page.

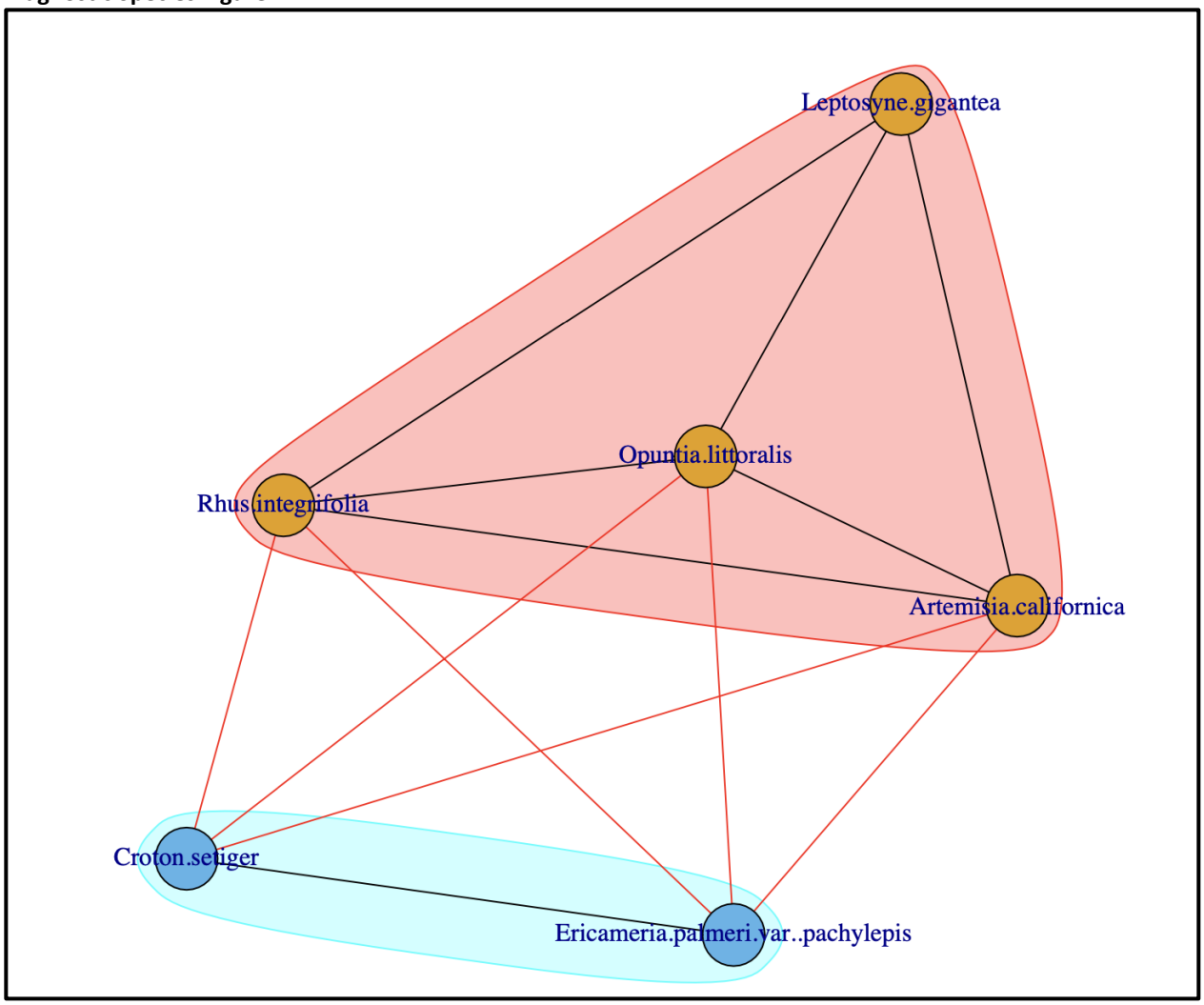
Diagnostic Species Table: *Elymus glaucus, Elymus condensatus,* & *Lepechinia fragrans*

Red Module (Orange Node)	**Blue Module (Blue Node)**
Adenostoma fasciculatum	*Baccharis pilularis*
Arctostaphylos crustacea subsp. *subcordata*	*Bromus diandrus**
*Avena barbata**	***Elymus condensatus***
*Bromus hordeaceus**	***Elymus glaucus***
Ceanothus arboreus	*Marrubium vulgare**
Crocanthemum scoparium	*Quercus pacifica*
Diplacus puniceus	
Lepechinia fragrans	
Opuntia littoralis	
Rhus integrifolia	
Salvia mellifera	
*Silene gallica**	

** nonnative species*

Figure 6-24. High Confidence Assemblages (≥80) – *Ericameria palmeri* var. *pachylepis* & *Leptosyne gigantea*

Diagnostic Species Figure



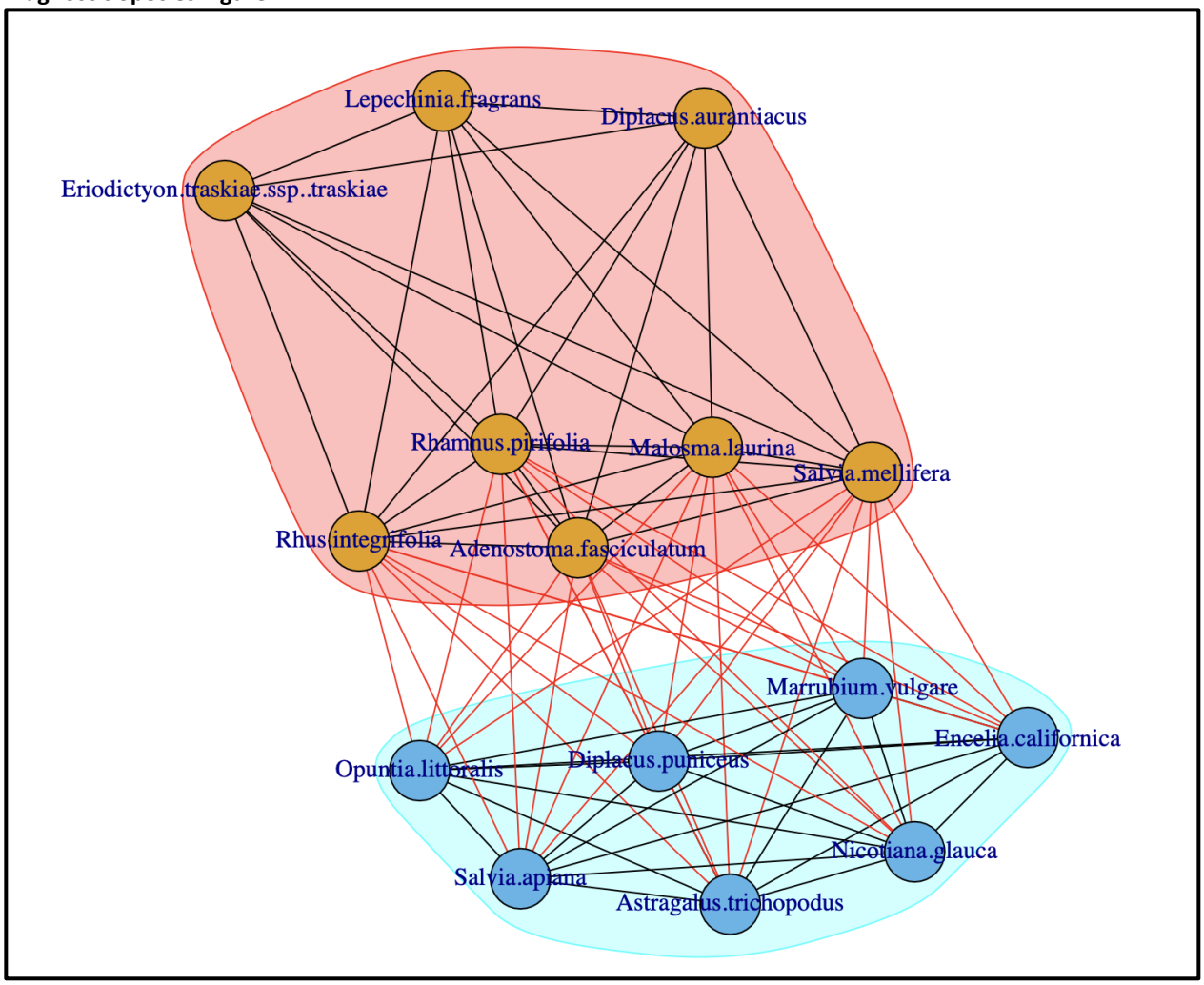
Diagnostic Species Table: *Ericameria palmeri* var. *pachylepis* & *Leptosyne gigantea*

Red Module (Orange Node)	**Blue Module (Blue Node)**
Artemisia californica	*Croton setiger*
Leptosyne gigantea	***Ericameria palmeri* var. *pachylepis***
Opuntia littoralis	

** nonnative species*

Figure 6-25. High Confidence Assemblages (≥80) – *Eriodictyon traskiae* subsp. *traskiae* & *Malosma laurina*

Diagnostic Species Figure



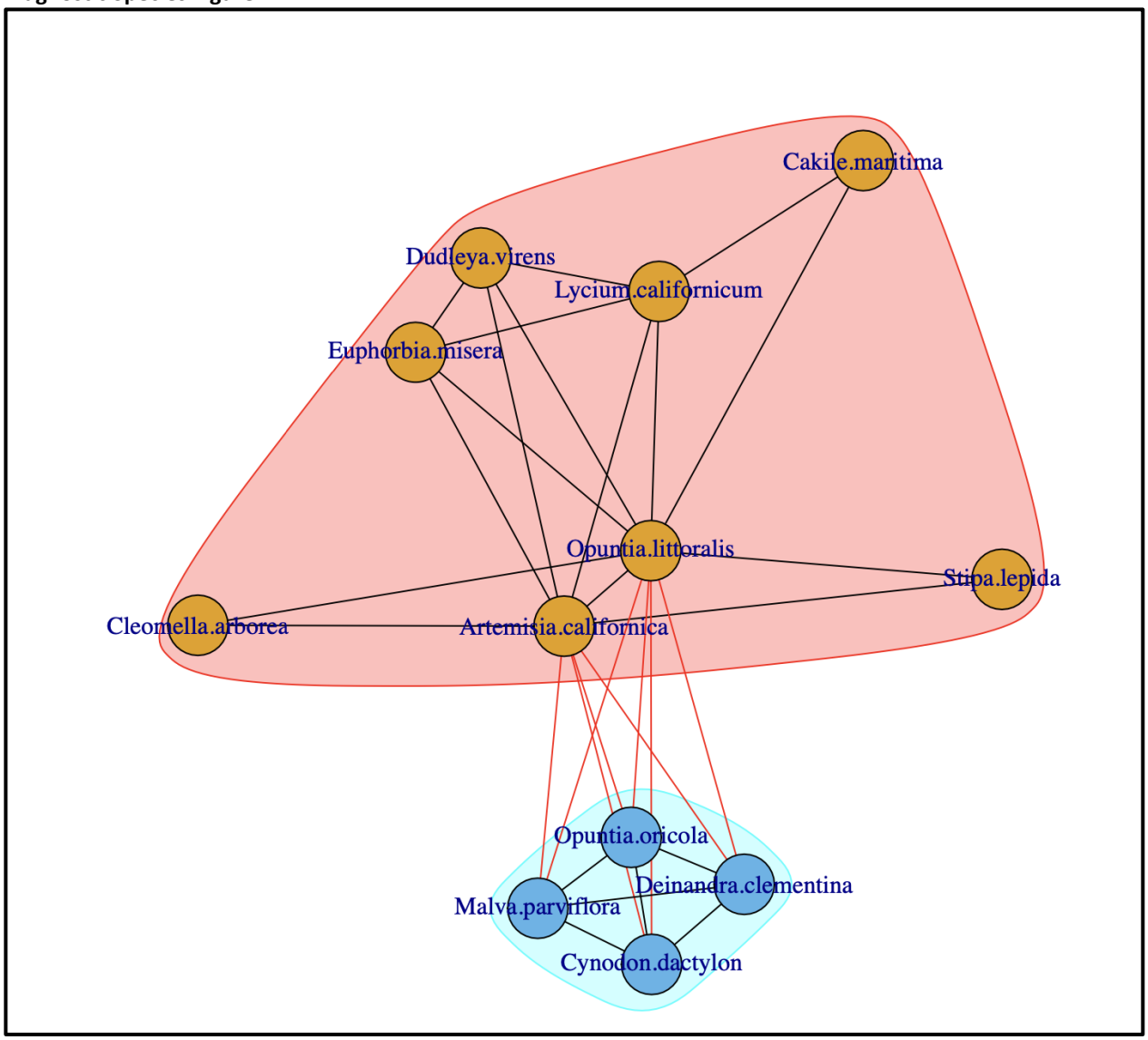
Diagnostic Species Table: *Eriodictyon traskiae* subsp. *traskiae* & *Malosma laurina*

Red Module (Orange Node)	**Blue Module (Blue Node)**
Adenostoma fasciculatum	*Astragalus trichopodus*
Diplacus aurantiacus	*Diplacus puniceus*
Eriodictyon traskiae* subsp. *traskiae	*Encelia californica*
Lepechinia fragrans	*Marrubium vulgare**
Malosma laurina	*Nicotiana glauca**
Rhamnus pirifolia	*Opuntia littoralis*
Rhus integrifolia	*Salvia apiana*
Salvia mellifera	

** nonnative species*

Figure 6-26. High Confidence Assemblages (≥80) – *Cleomella arborea, Deinandra clementina, Lycium californicum, Euphorbia misera, & Stipa lepida*

Diagnostic Species Figure



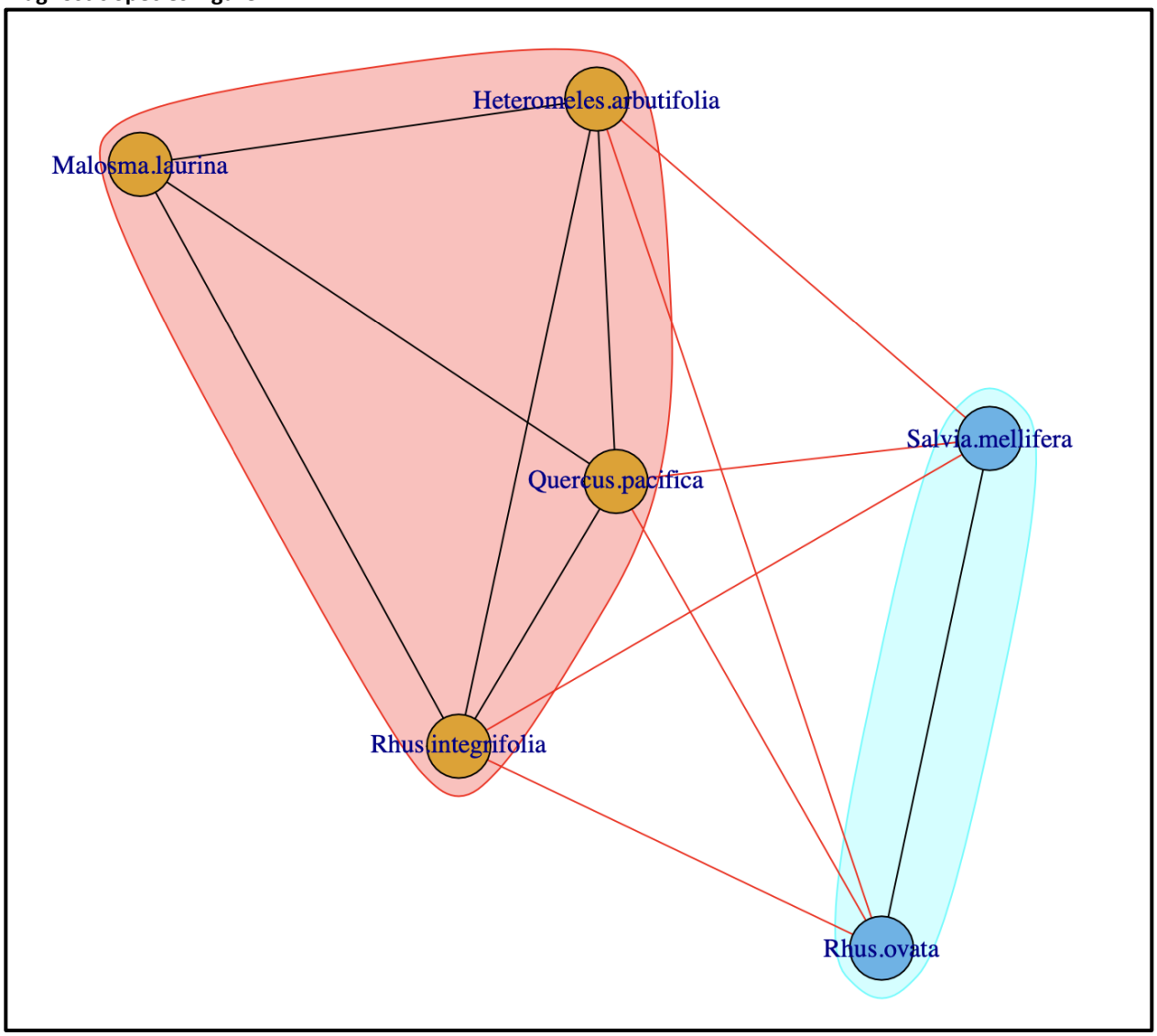
Diagnostic Species Table*:* *Euphorbia misera, Lycium californicum, Deinandra clementina, Cleomella arborea,* & *Stipa lepida*

Red Module (Orange Node)	Blue Module (Blue Node)
Artemisia californica	*Cynodon dactylon**
*Cakile maritima**	***Deinandra clementina***
Cleomella arborea	*Malva parviflora**
Dudleya virens	*Opuntia oricola*
Euphorbia misera	
Lycium californicum	
Opuntia littoralis	
Stipa lepida	

** nonnative species*

Figure 6-27. High Confidence Assemblages (≥80) – *Heteromeles arbutifolia* & *Rhus ovata*

Diagnostic Species Figure



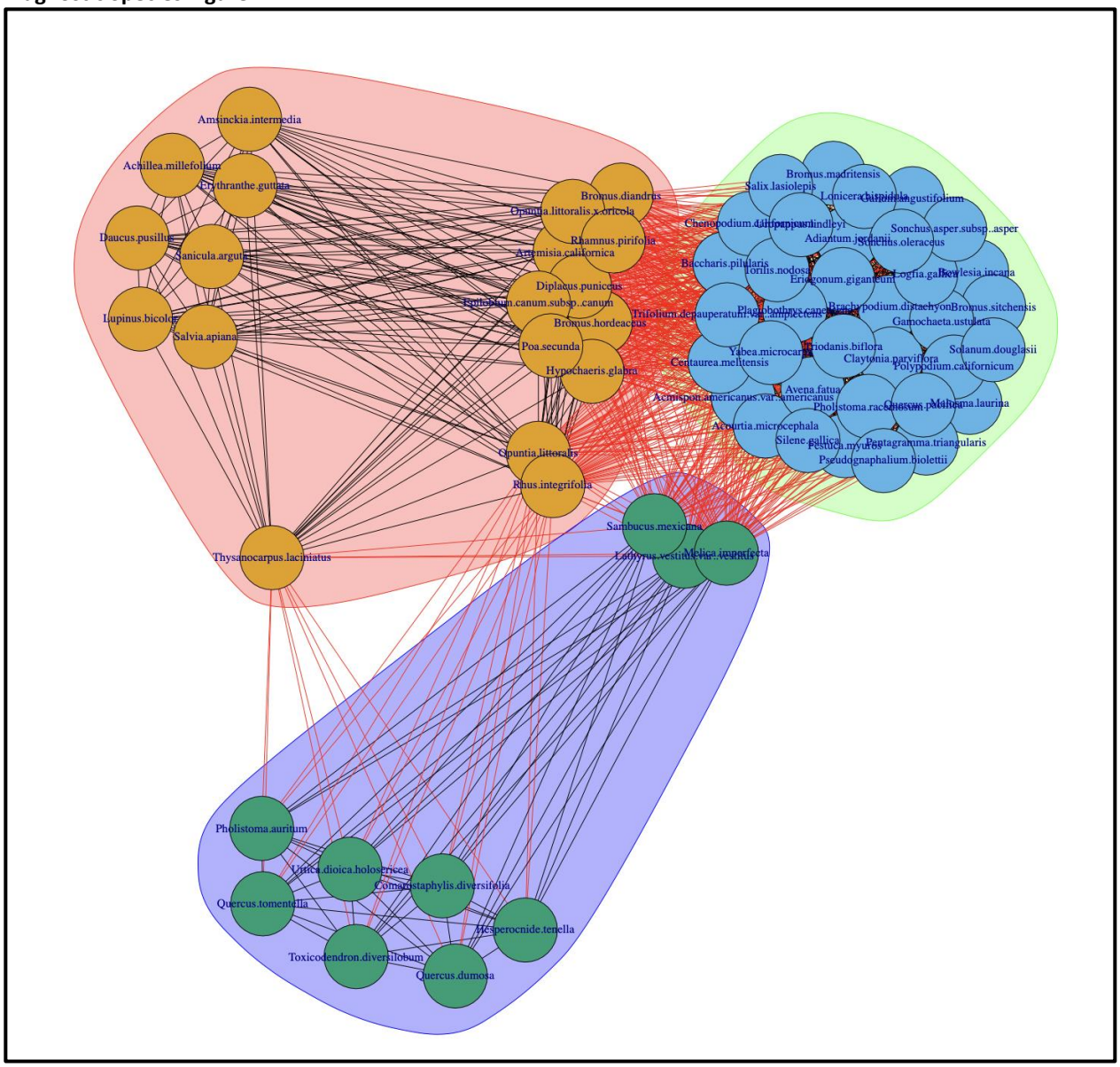
Diagnostic Species Table: *Heteromeles arbutifolia* & *Rhus ovata*

Red Module (Orange Node)	Blue Module (Blue Node)
Heteromeles arbutifolia	*Salvia mellifera*
Quercus pacifica	***Rhus ovata***
Rhus integrifolia	
Malosma laurina	

** nonnative species*

Figure 6-28. High Confidence Assemblages (≥80) – *Quercus tomentella, Achillea millefolium* & *Bromus sitchensis*

Diagnostic Species Figure



Species within each module are listed on next page.

Diagnostic Species Table: *Quercus tomentella, Achillea millefolium* & *Bromus sitchensis*

Purple Module (Green Group)	Red Module (Orange Node)	Green Module (Blue Node)
Comarostaphylis diversifolia	***Achillea millefolium***	*Acmispon americanus* var. *americanus*
Hesperocnide tenella	*Amsinckia intermedia*	*Acourtia microcephala*
Lathyrus vestitus var. *vestitus*	*Artemisia californica*	*Adiantum jordanii*
Melica imperfecta	*Bromus diandrus**	*Avena fatua**
Pholistoma auritum	*Bromus hordeaceus**	*Baccharis pilularis*
Quercus pacifica (previously *Q. dumosa*)	*Daucus pusillus*	*Bowlesia incana*
Quercus tomentella	*Diplacus puniceus*	*Brachypodium distachyon**
Sambucus mexicana	*Epilobium canum* subsp. *canum*	*Bromus madritensis**
Toxicodendron diversilobum	*Erythranthe guttata*	***Bromus sitchensis* (*B. carinatus*)**
Urtica dioica holosericea	*Hypochaeris glabra**	*Centaurea melitensis**
	Lupinus bicolor	*Chenopodium californicum*
	Opuntia littoralis	*Claytonia parviflora*
	Opuntia littoralis x oricola	*Eriogonum giganteum* var. *giganteum*
	Poa secunda	*Festuca myuros**
	Rhamnus pirifolia	*Galium angustifolium*
	Rhus integrifolia	*Gamochaeta ustulata*
	Salvia apiana	*Logfia gallica**
	Sanicula arguta	*Lonicera hispidula*
	Thysanocarpus laciniatus	*Malosma laurina*
		Pentagramma triangularis
		Pholistoma racemosum
		Plagiobothrys canescens
		Polypodium californicum
		Pseudognaphalium biolettii
		Quercus pacifica
		Salix lasiolepis
		*Silene gallica**
		Solanum douglasii
		Sonchus asper subsp. *asper**
		*Sonchus oleraceus**
		*Torilis nodosa**
		Trifolium depauperatum var. *amplectens*
		Triodanis biflora
		Uropappus lindleyi
		Yabea microcarpa

** nonnative species*

Figure 6-26. Average Agglomerative Clustering vs. Complete Linkage Agglomerative Clustering

Black lines indicative of outliers

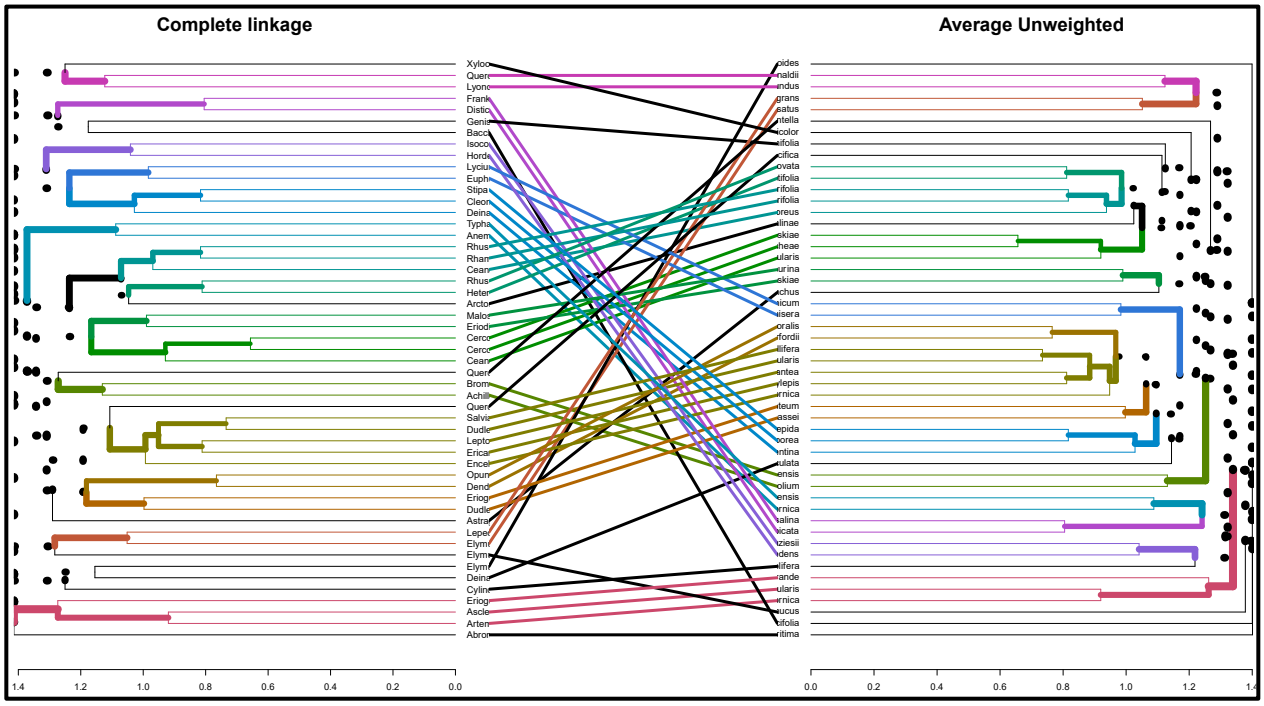


Figure 6-30. Average Agglomerative Clustering vs. Ward's Minimum Variance Clustering

Black lines indicative of outliers

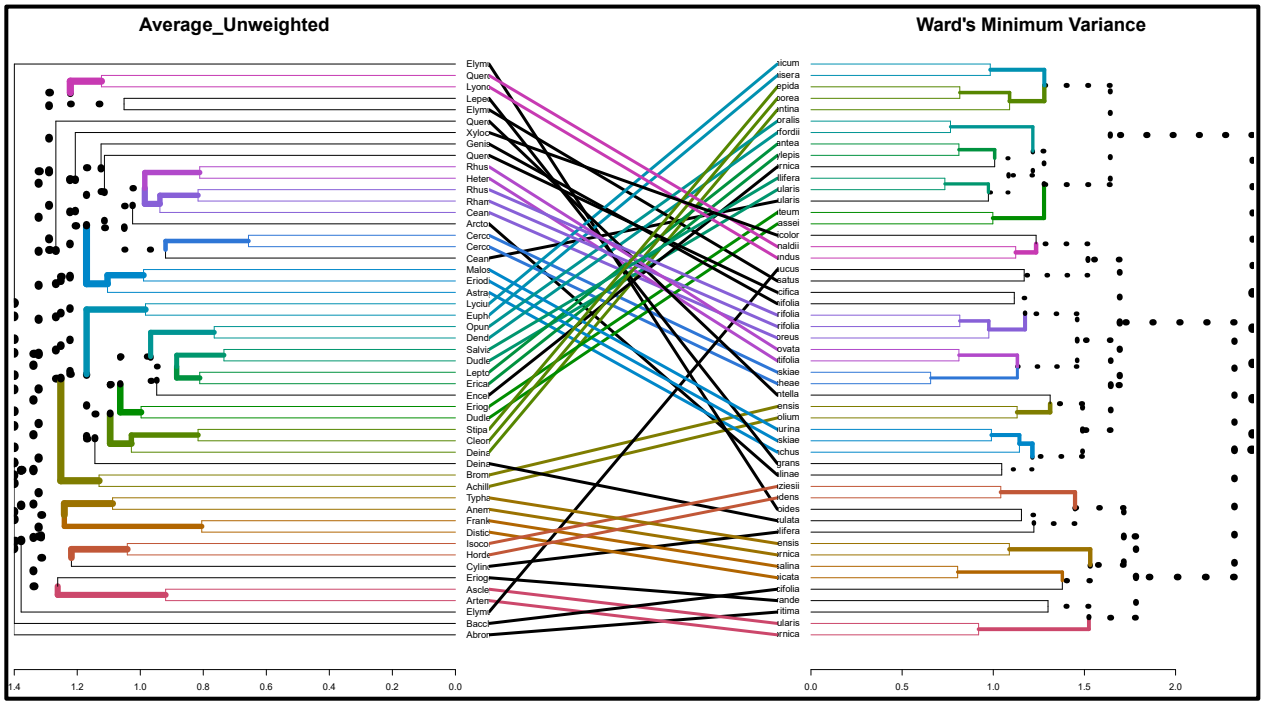


Figure 6-28. Complete Linkage Agglomerative Clustering vs. Ward's Minimum Variance Clustering

Black lines indicative of outliers

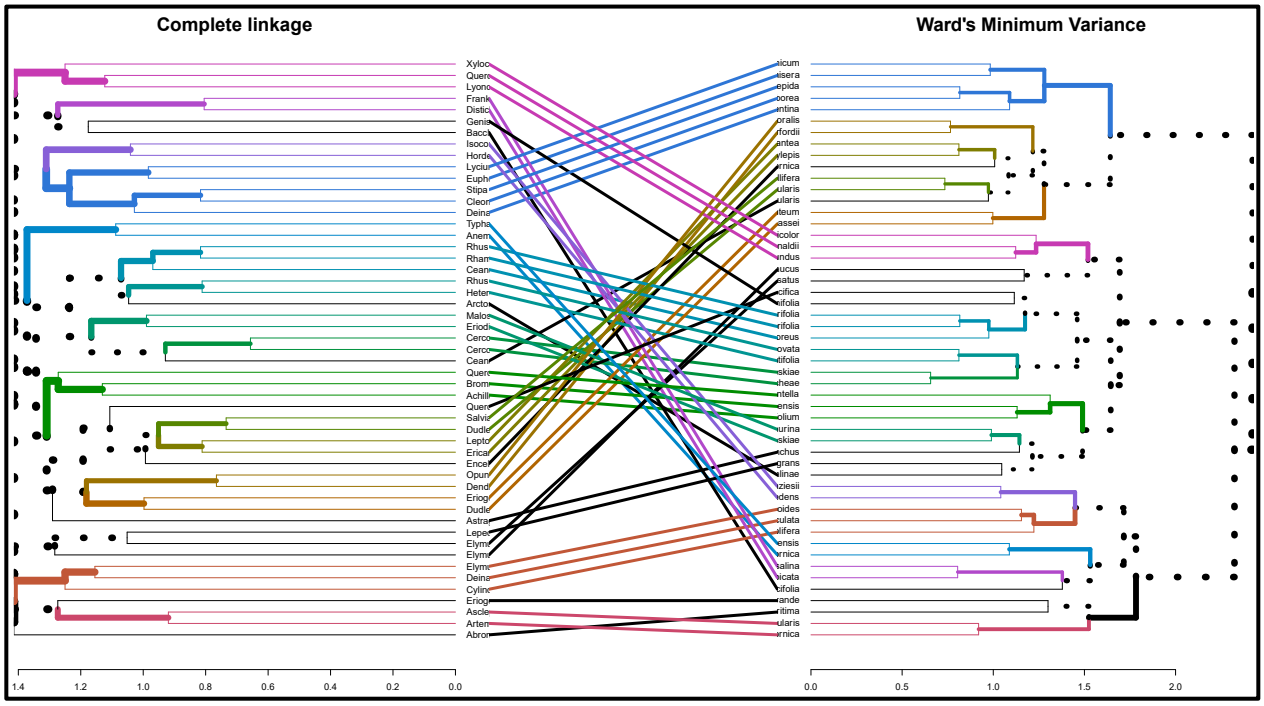


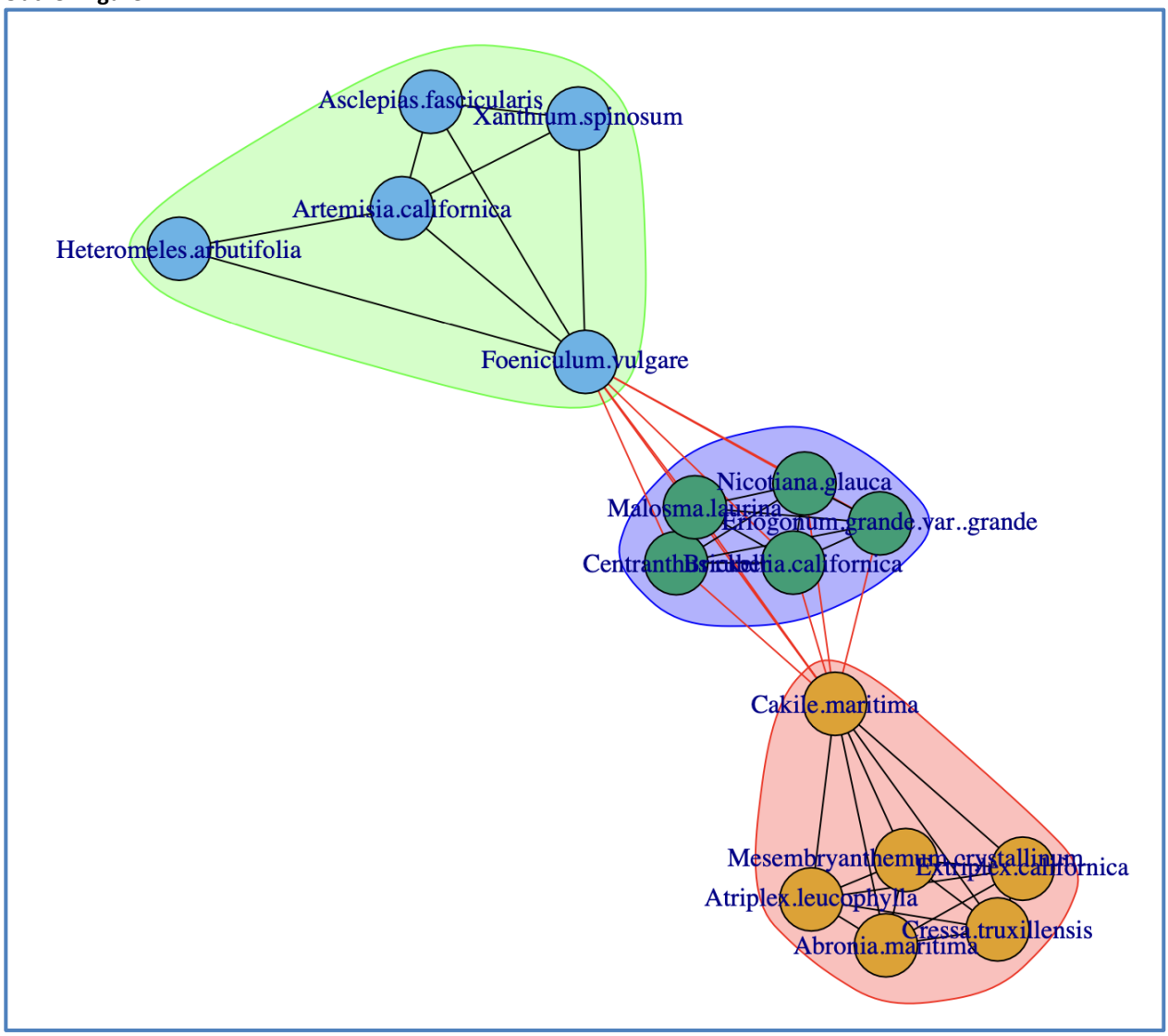
Figure 6-32. Pairwise Comparison Results

Red star indicates that the diagnostic species grouped differently between algorithms

	Complete Linkage vs Average Unweighted	Complete Linkage vs Wards	Average Unweighted vs Wards
Genista linifolia	*	*	*
Baccharis salicifolia	*	*	*
Arctostaphylos catalinae	*	*	*
Quercus pacifica	*	*	*
Abronia maritima	*	*	*
Elymus glaucus	*	*	*
Elymus triticoides	*		*
Deinandra fasciculata	*		*
Cylindropuntia prolifera	*		*
Ceanothus megacarpus var. insularis		*	*
Lepechinia fragrans		*	*
Elymus condensatus		*	*
Eriogonum grande var. grande		*	*
Encelia californica		*	*
Xylococcus bicolor	*		*
Quercus tomentella	*		*
Astragalus trichopodus var. lonchus	*	*	

Figure 6-33. Outliers - *Abronia maritima*

Outlier Figure



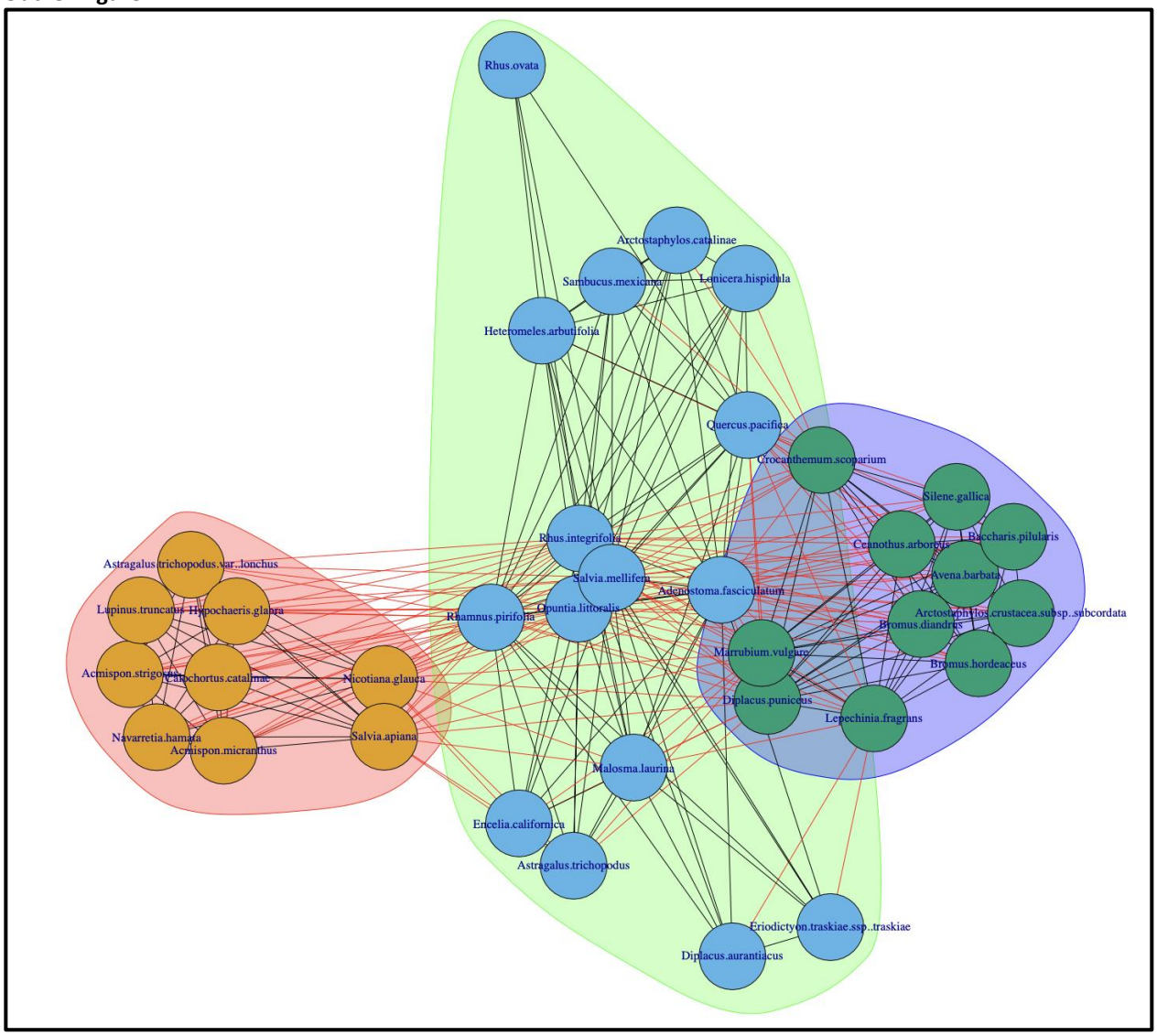
Outlier Table: *Abronia maritima*

Green Module (Blue Node)	Purple Module (Green Node)	Red Module (Orange Node)
Artemisia californica	*Brickellia californica*	***Abronia maritima***
Asclepias fascicularis	*Centranthus ruber**	*Atriplex leucophylla*
*Foeniculum vulgare**	*Eriogonum grande* var. *grande*	*Cakile maritima**
Heteromeles arbutifolia	*Malosma laurina*	*Cressa truxillensis*
*Xanthium spinosum**	*Nicotiana glauca**	*Extriplex californica*
		*Mesembryanthemum crystallinum**

** nonnative species*

Figure 6-34. Outliers - *Arctostaphylos catalinae*

Outlier Figure



Species within each module are listed on next page.

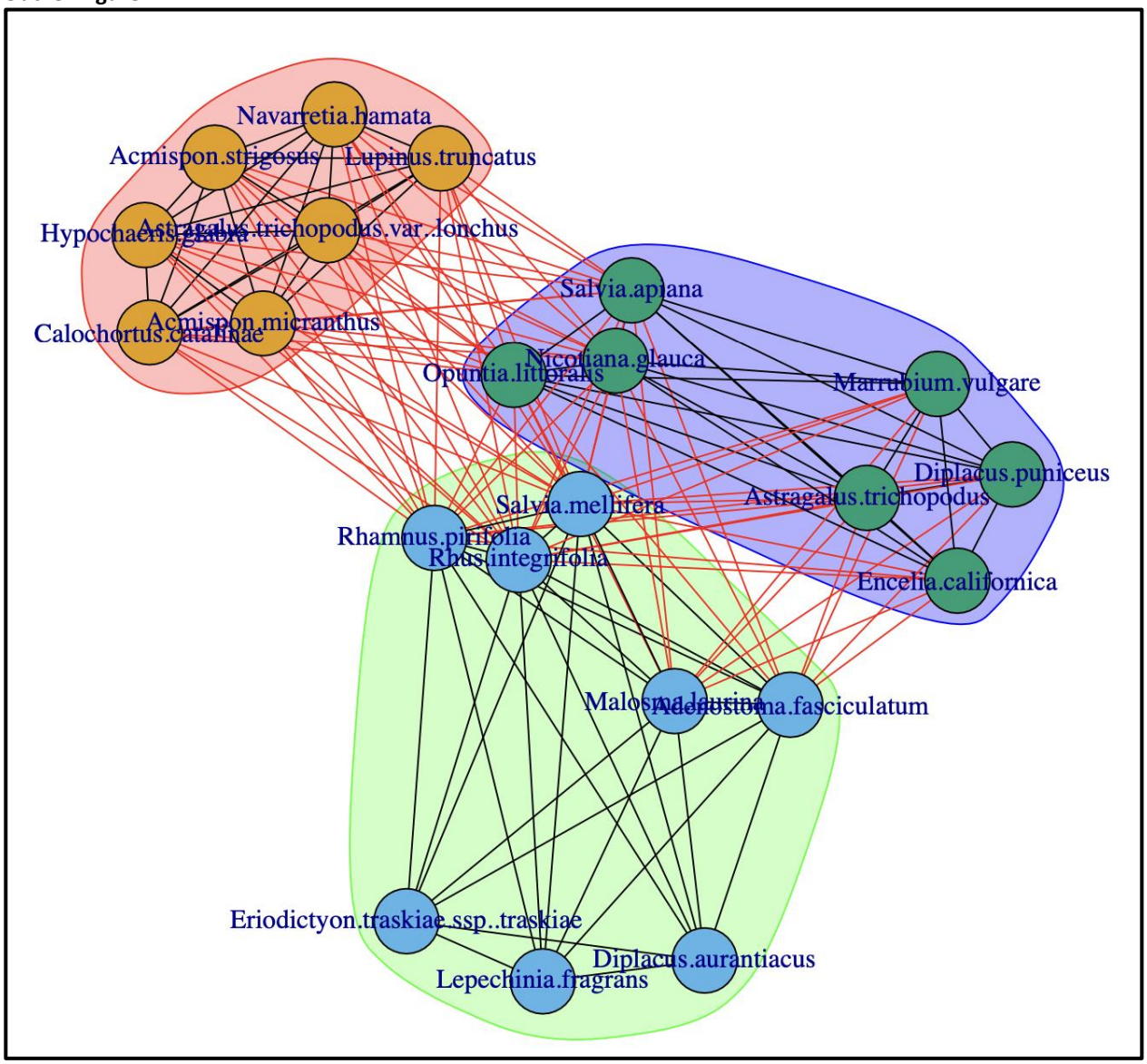
Outlier Table: *Arctostaphylos catalinae*

Red Module (Orange Node)	Green Module (Blue Node)	Purple Module (Green Node)
Acmispon micranthus	*Adenostoma fasciculatum*	*Arctostaphylos crustacea* subsp. *subcordata*
Acmispon strigosus	***Arctostaphylos catalinae***	*Avena barbata**
Astragalus trichopodus var. *lonchus*	*Astragalus trichopodus*	*Baccharis pilularis*
Calochortus catalinae	*Diplacus aurantiacus*	*Bromus diandrus**
*Hypochaeris glabra**	*Encelia californica*	*Bromus hordeaceus**
Lupinus truncatus	*Eriodictyon traskiae* subsp. *traskiae*	*Ceanothus arboreus*
Navarretia hamata	*Heteromeles arbutifolia*	*Crocanthemum scoparium*
*Nicotiana glauca**	*Lonicera hispidula*	*Diplacus puniceus*
Salvia apiana	*Malosma laurina*	*Lepechinia fragrans*
	Opuntia littoralis	*Marrubium vulgare**
	Quercus pacifica	*Silene gallica**
	Rhamnus pirifolia	
	Rhus integrifolia	
	Rhus ovata	
	Salvia mellifera	
	Sambucus mexicana	

** nonnative species*

Figure 6-35. Outliers - *Astragalus trichopodus* var. *lonchus*

Outlier Figure



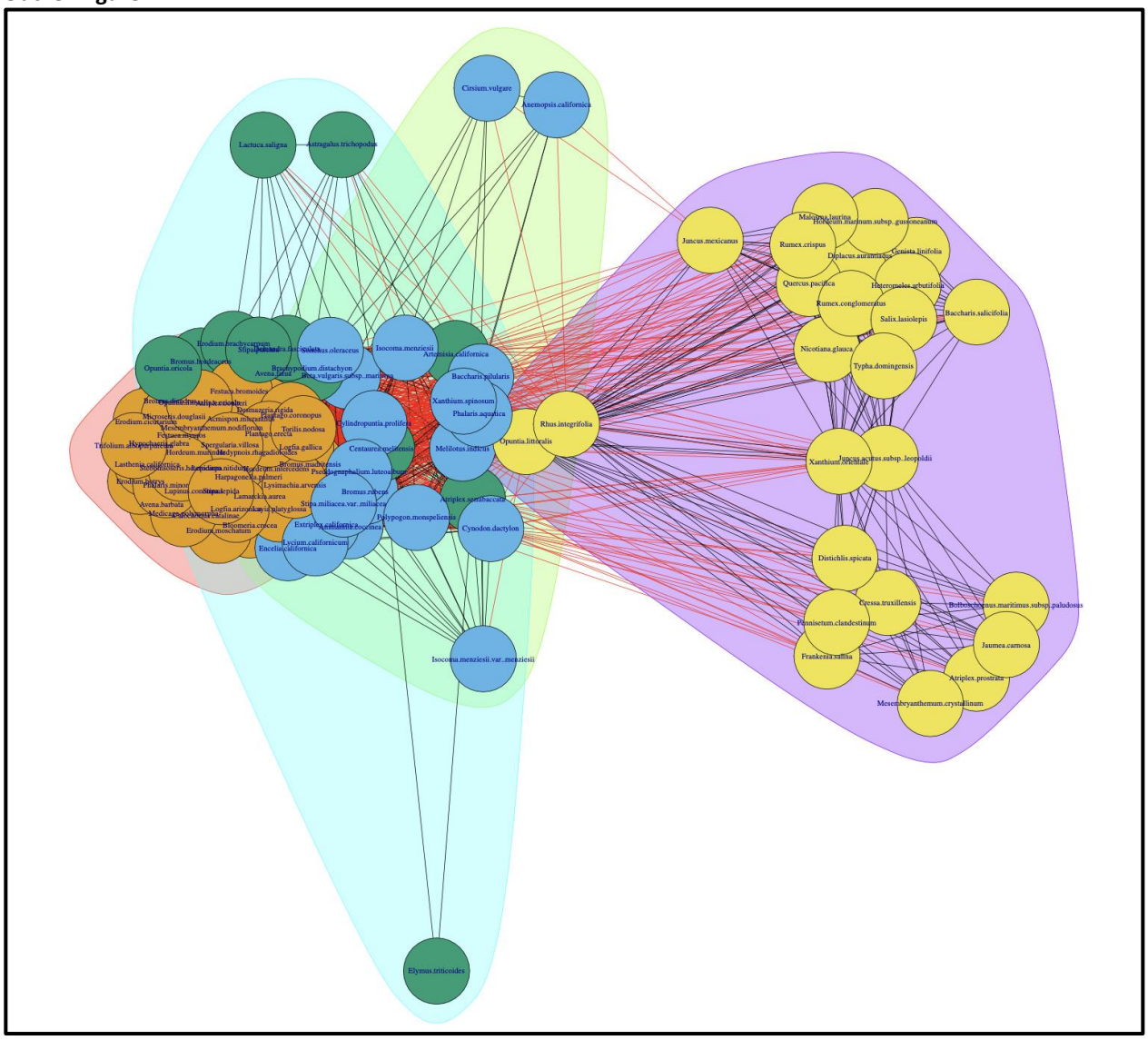
Outlier Table: *Astragalus trichopodus* var. *lonchus*

Red Module (Orange Node)	Purple Module (Green Node)	Green Module (Blue Node)
Acmispon micranthus	*Astragalus trichopodus*	*Adenostoma fasciculatum*
Acmispon strigosus	*Diplacus puniceus*	*Diplacus aurantiacus*
Astragalus trichopodus* var. *lonchus	*Encelia californica*	*Eriodictyon traskiae* subsp. *traskiae*
Calochortus catalinae	*Marrubium vulgare**	*Lepechinia fragrans*
*Hypochaeris glabra**	*Nicotiana glauca**	*Malosma laurina*
Lupinus truncatus	*Opuntia littoralis*	*Rhamnus pirifolia*
Navarretia hamata	*Salvia apiana*	*Rhus integrifolia*
		Salvia mellifera

** nonnative species*

Figure 6-36. Outliers - Baccharis salicifolia

Outlier Figure



Species within each module are listed on next page.

Outlier Table: *Baccharis salicifolia*

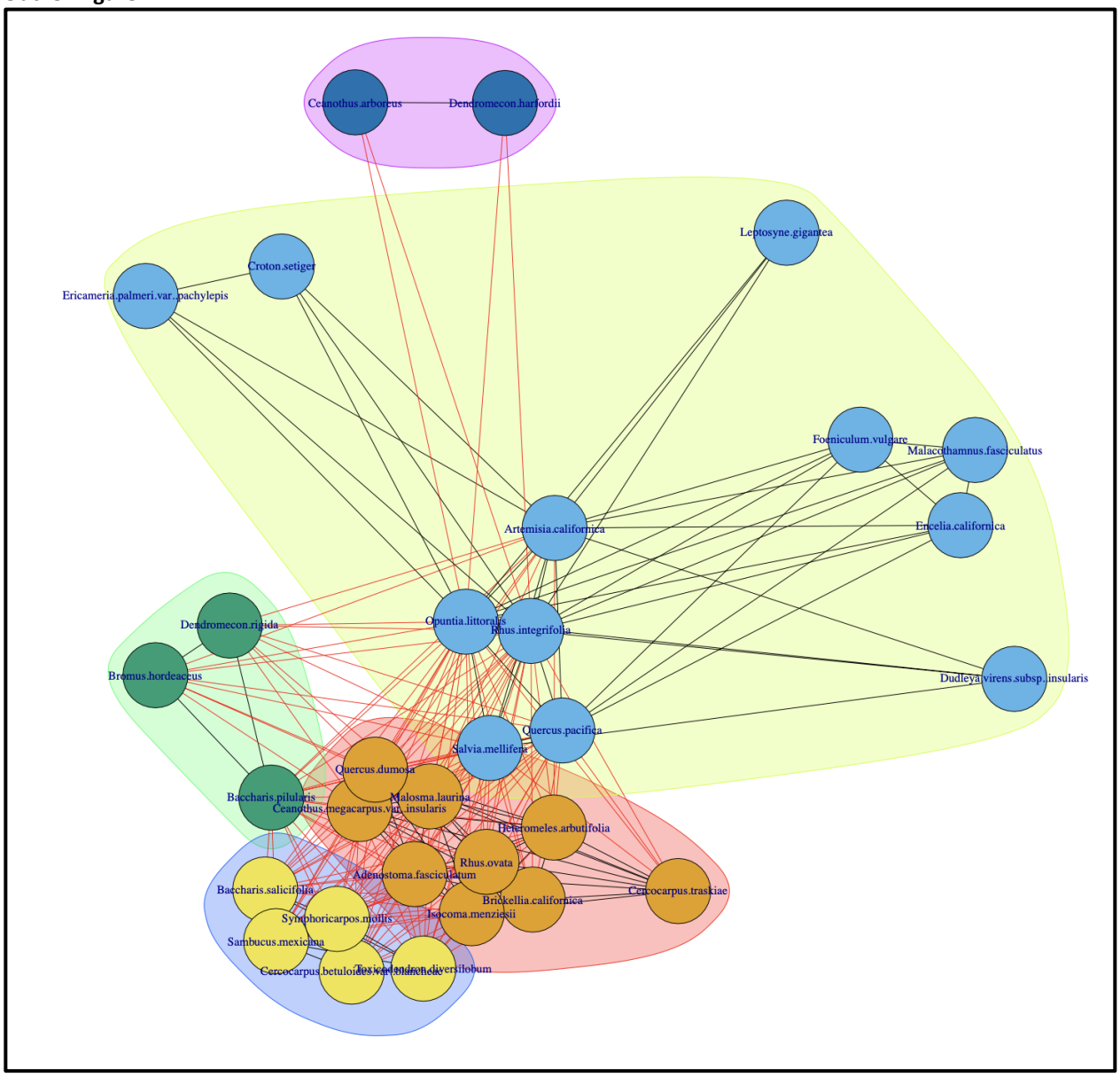
Red Module (Orange Node)	Blue Module (Green Node)	Green Module (Blue Node)	Purple Module (Yellow Node)
Acmispon micranthus	*Artemisia californica*	*Ammannia coccinea*	*Atriplex prostrata**
Atriplex coulteri	*Astragalus trichopodus*	*Anemopsis californica*	***Baccharis salicifolia***
*Avena barbata**	*Atriplex semibaccata**	*Baccharis pilularis*	*Bolboschoenus maritimus* subsp. *paludosus*
Bloomeria crocea	*Avena fatua**	*Beta vulgaris* subsp. *maritima**	*Cressa truxillensis*
*Bromus diandrus**	*Brachypodium distachyon**	*Bromus rubens**	*Diplacus aurantiacus*
*Bromus madritensis**	*Bromus hordeaceus**	*Cirsium vulgare**	*Distichlis spicata*
Calochortus catalinae	*Centaurea melitensis**	*Cylindropuntia prolifera*	*Frankenia salina*
*Desmazeria rigida**	*Deinandra fasciculata*	*Cynodon dactylon**	*Genista linifolia**
*Erodium botrys**	*Elymus triticoides*	*Encelia californica*	*Heteromeles arbutifolia*
*Erodium cicutarium**	*Erodium brachycarpum**	*Extriplex californica*	*Hordeum marinum* subsp. *gussoneanum**
*Erodium moschatum**	*Lactuca saligna**	*Isocoma menziesii*	*Jaumea carnosa*
*Festuca bromoides**	*Opuntia oricola*	*Isocoma menziesii* var. *menziesii*	*Juncus acutus* subsp. *leopoldii*
*Festuca myuros**	*Stipa pulchra*	*Lycium californicum*	*Juncus mexicanus*
Harpagonella palmeri		*Melilotus indicus**	*Malosma laurina*
*Hedypnois rhagadioloides**		*Phalaris aquatica**	*Mesembryanthemum crystallinum**
Hordeum intercedens		*Polypogon monspeliensis**	*Nicotiana glauca**
*Hordeum murinum**		*Pseudognaphalium luteoalbum**	*Opuntia littoralis*
*Hypochaeris glabra**		*Sonchus oleraceus**	*Pennisetum clandestinum**
*Lamarckia aurea**		*Stipa miliacea* var. *miliacea**	*Quercus pacifica*
Lasthenia californica		*Xanthium spinosum**	*Rhus integrifolia*
Layia platyglossa			*Rumex conglomeratus**
Lepidium nitidum			*Rumex crispus*
Logfia arizonica			*Salix lasiolepis*
*Logfia gallica**			*Typha domingensis*
Lupinus concinnus			*Xanthium orientale*
*Lysimachia arvensis**			
*Medicago polymorpha**			
*Mesembryanthemum nodiflorum**			
Microseris douglasii			
Opuntia littoralis x oricola			
*Phalaris minor**			
*Plantago coronopus**			
Plantago erecta			
*Spergularia villosa**			

Red Module (Orange Node)	**Blue Module (Green Node)**	**Green Module (Blue Node)**	**Purple Module (Yellow Node)**
Stebbinsoseris heterocarpa			
Stipa lepida			
*Torilis nodosa**			
Trifolium albopurpureum			

** nonnative species*

Figure 6-37. Outliers - *Ceanothus megacarpus* var. *insularis*

Outlier Figure



Species within each module are listed on next page.

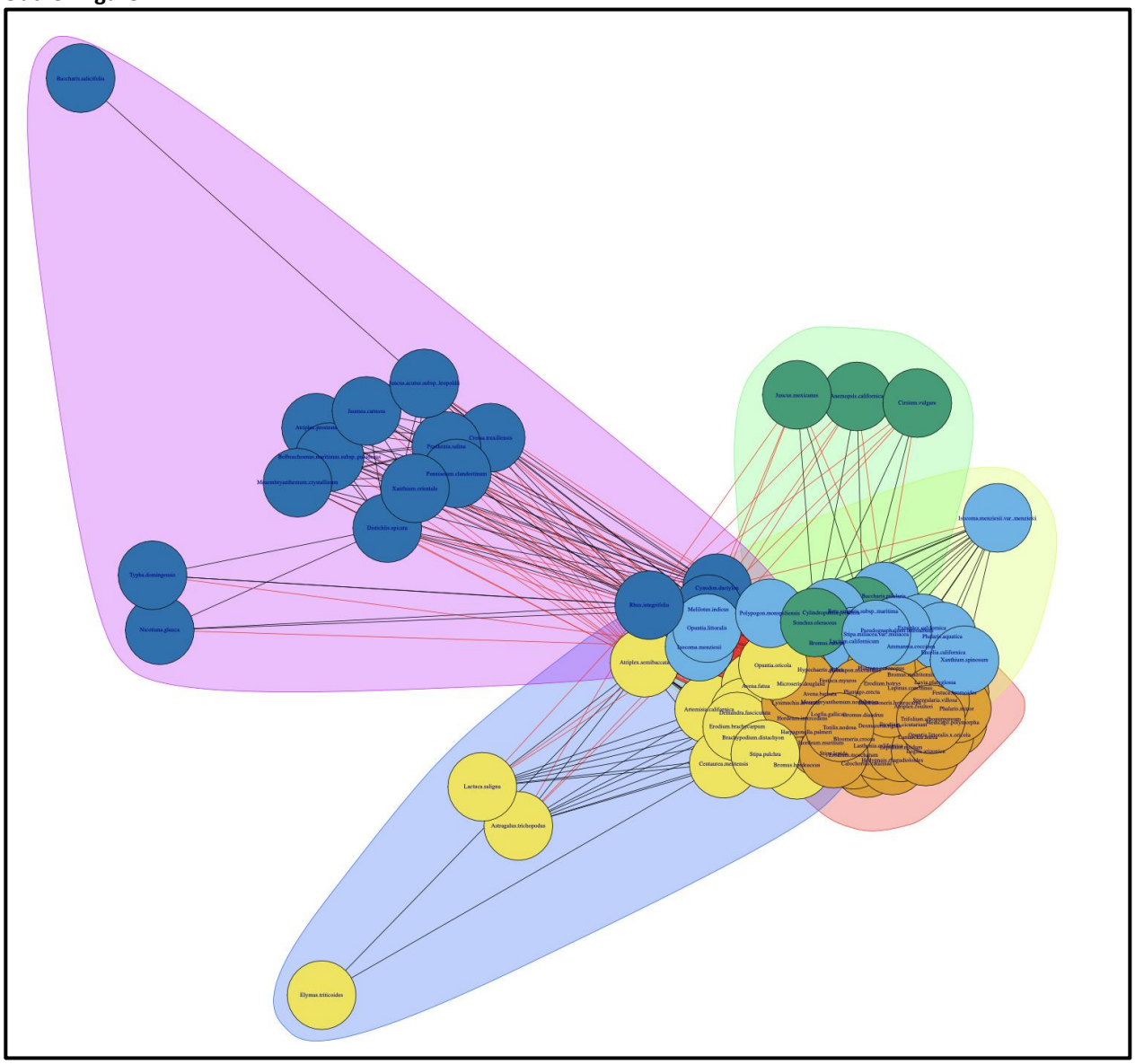
Outlier Table: *Ceanothus megacarpus* var. *insularis*

Purple Module (Dark Blue Node)	**Yellow Module (Light Blue Node)**	**Green Module (Green Node)**	**Red Module (Orange Node)**	**Blue Module (Yellow Node)**
Ceanothus arboreus	*Artemisia californica*	*Baccharis pilularis*	*Adenostoma fasciculatum*	*Baccharis salicifolia*
Dendromecon harfordii	*Croton setiger*	*Bromus hordeaceus**	*Brickellia californica*	*Cercocarpus betuloides* var. *blancheae*
	Dudleya virens subsp. *insularis*	*Dendromecon rigida*	***Ceanothus megacarpus* var. *insularis***	*Sambucus mexicana*
	Encelia californica		*Cercocarpus traskiae*	*Symphoricarpos mollis*
	Ericameria palmeri var. *pachylepis*		*Heteromeles arbutifolia*	*Toxicodendron diversilobum*
	*Foeniculum vulgare**		*Isocoma menziesii*	
	Leptosyne gigantea		*Malosma laurina*	
	Malacothamnus fasciculatus		*Quercus pacifica* (previously *Q. dumosa*)	
	Opuntia littoralis		*Rhus ovata*	
	Quercus pacifica			
	Rhus integrifolia			
	Salvia mellifera			

** nonnative species*

Figure 6-38. Outliers - *Cylindropuntia prolifera*

Outlier Figure



Species within each module are listed on next page.

Outlier Table: *Cylindropuntia prolifera*

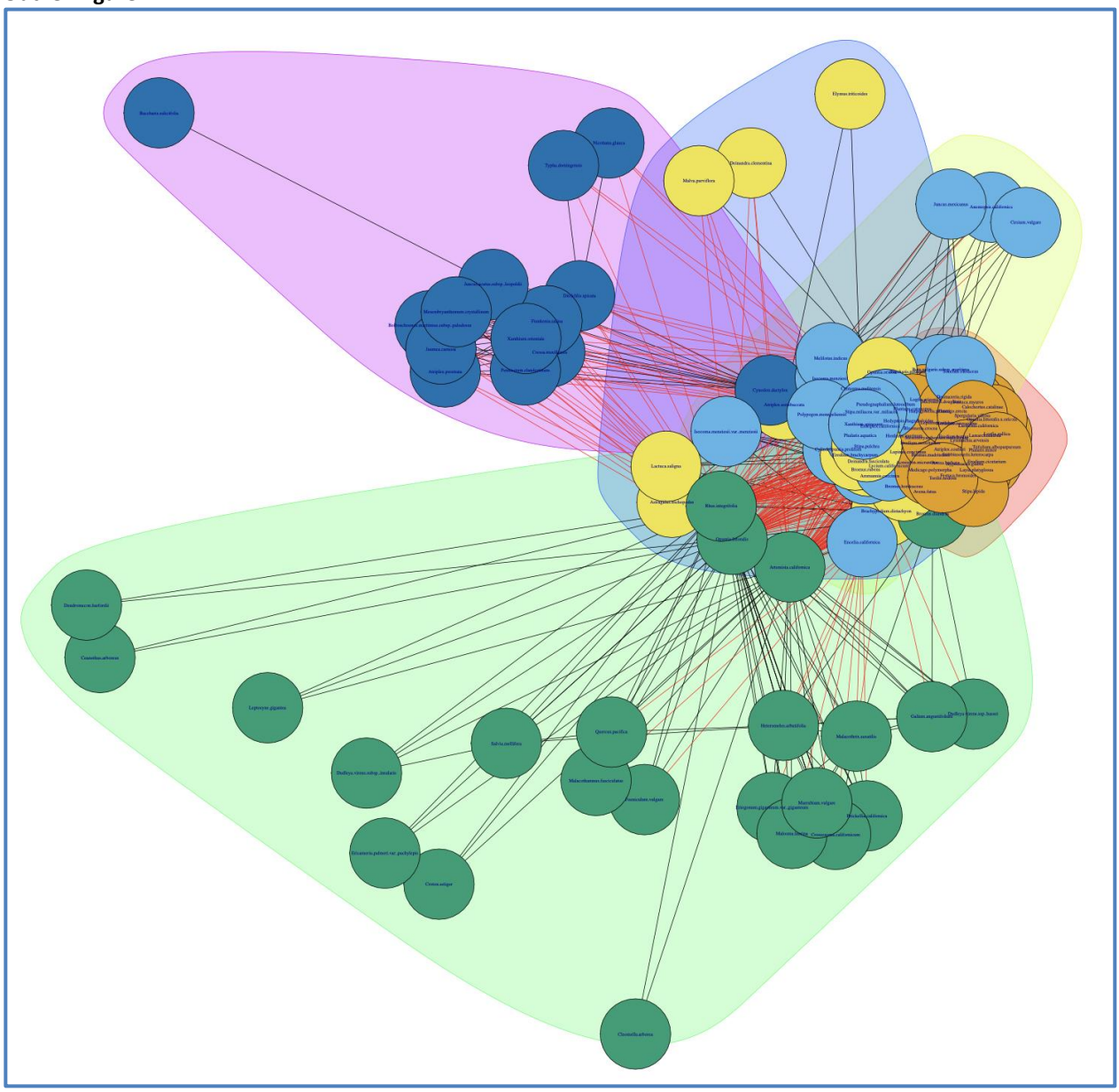
Purple Module (Dark Blue Node)	Blue Module (Yellow Node)	Red Module (Orange Node)	Yellow Module (Light Blue Node)	Green Module (Green Node)
*Atriplex prostrata**	*Artemisia californica*	*Acmispon micranthus*	*Ammannia coccinea*	*Anemopsis californica*
Baccharis salicifolia	*Astragalus trichopodus*	*Atriplex coulteri*	*Baccharis pilularis*	*Beta vulgaris* subsp. *maritima**
Bolboschoenus maritimus subsp. *paludosus*	*Atriplex semibaccata**	*Avena barbata**	*Bromus rubens**	*Cirsium vulgare**
Cressa truxillensis	*Avena fatua**	*Bloomeria crocea*	***Cylindropuntia prolifera***	*Juncus mexicanus*
*Cynodon dactylon**	*Brachypodium distachyon**	*Bromus diandrus**	*Encelia californica*	*Sonchus oleraceus**
Distichlis spicata	*Bromus hordeaceus**	*Bromus madritensis**	*Extriplex californica*	
Frankenia salina	*Centaurea melitensis**	*Calochortus catalinae*	*Isocoma menziesii*	
Jaumea carnosa	*Deinandra fasciculata*	*Desmazeria rigida**	*Isocoma menziesii* var. *menziesii*	
Juncus acutus subsp. *leopoldii*	*Elymus triticoides*	*Erodium botrys**	*Lycium californicum*	
*Melilotus indicus**	*Erodium brachycarpum**	*Erodium cicutarium**	*Opuntia littoralis*	
*Mesembryanthemum crystallinum**	*Lactuca saligna**	*Erodium moschatum**	*Phalaris aquatica**	
*Nicotiana glauca**	*Opuntia oricola*	*Festuca bromoides**	*Polypogon monspeliensis**	
*Pennisetum clandestinum**	*Stipa pulchra*	*Festuca myuros**	*Pseudognaphalium luteoalbum**	
Rhus integrifolia		*Harpagonella palmeri*	*Stipa miliacea* var. *miliacea**	
Typha domingensis		*Hedypnois rhagadioloides**	*Xanthium spinosum**	
Xanthium orientale		*Hordeum intercedens*		
		*Hordeum murinum**		
		*Hypochaeris glabra**		
		*Lamarckia aurea**		
		Lasthenia californica		
		Layia platyglossa		
		Lepidium nitidum		
		Logfia arizonica		
		*Logfia gallica**		
		Lupinus concinnus		
		*Lysimachia arvensis**		
		*Medicago polymorpha**		
		*Mesembryanthemum nodiflorum**		

Purple Module (Dark Blue Node)	**Blue Module (Yellow Node)**	**Red Module (Orange Node)**	**Yellow Module (Light Blue Node)**	**Green Module (Green Node)**
		Microseris douglasii		
		Opuntia littoralis x oricola		
		*Phalaris minor**		
		*Plantago coronopus**		
		Plantago erecta		
		*Spergularia villosa**		
		Stebbinsoseris heterocarpa		
		Stipa lepida		
		*Torilis nodosa**		
		Trifolium albopurpureum		

** nonnative species*

Figure 6-36. Outliers - *Deinandra fasciculata*

Outlier Figure



Species within each module are listed on next page.

Outlier Table: *Deinandra fasciculata*

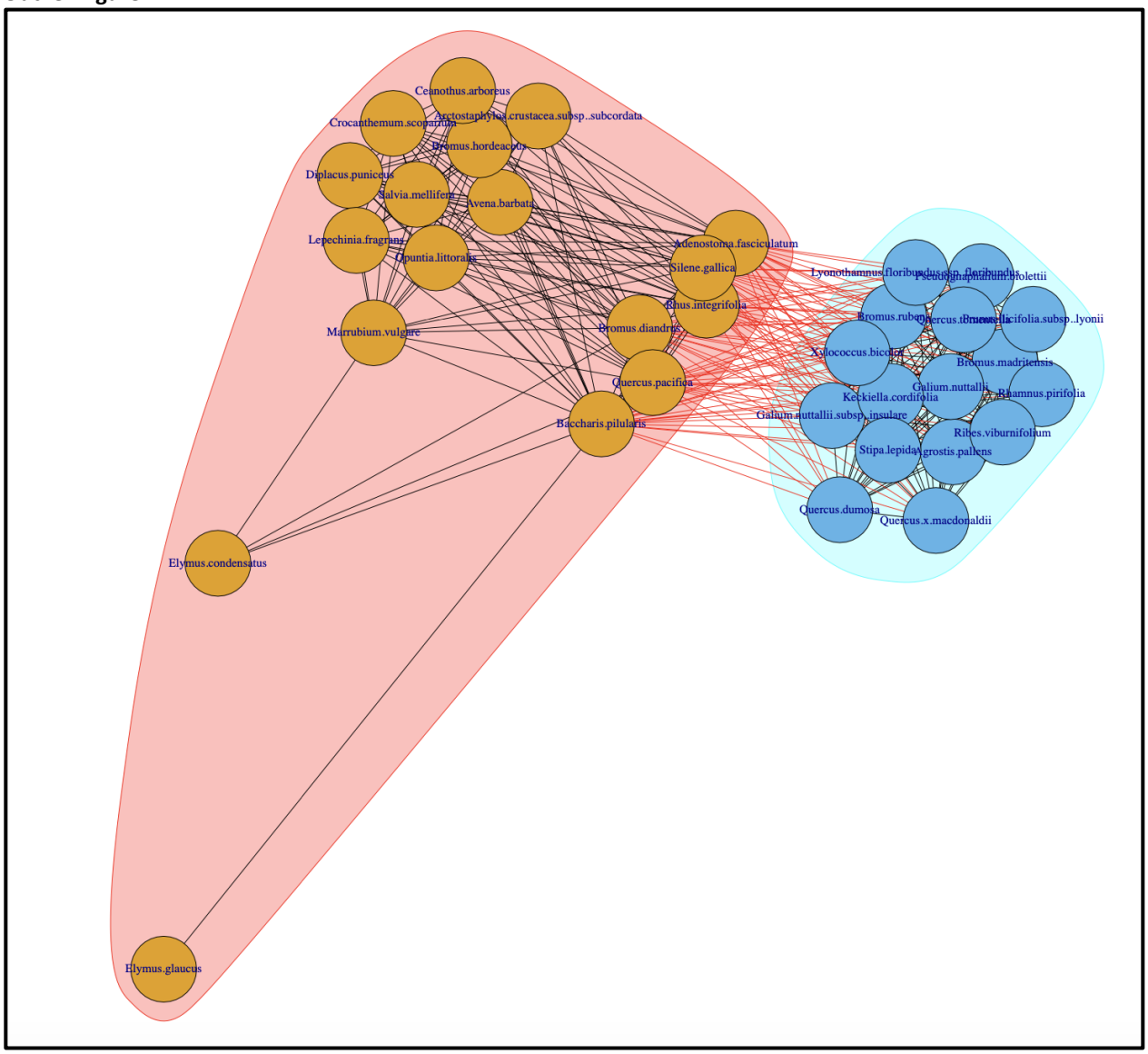
Purple Module (Dark Blue Node)	Blue Module (Yellow Node)	Yellow Module (Light Blue Node)	Red Module (Orange Node)	Green Module (Green Node)
*Atriplex prostrata**	*Astragalus trichopodus*	*Ammannia coccinea*	*Acmispon micranthus*	*Artemisia californica*
Baccharis salicifolia	*Atriplex semibaccata**	*Anemopsis californica*	*Atriplex coulteri*	*Brickellia californica*
Bolboschoenus maritimus subsp. *paludosus*	*Avena fatua**	*Baccharis pilularis*	*Avena barbata**	*Bromus diandrus**
Cressa truxillensis	*Brachypodium distachyon**	*Beta vulgaris* subsp. *maritima**	*Bloomeria crocea*	*Ceanothus arboreus*
*Cynodon dactylon**	*Bromus hordeaceus**	*Bromus rubens**	*Bromus madritensis**	*Crossosoma californicum*
Distichlis spicata	*Centaurea melitensis**	*Cirsium vulgare**	*Calochortus catalinae*	*Croton setiger*
Frankenia salina	*Deinandra clementina*	*Cylindropuntia prolifera*	*Desmazeria rigida**	*Dendromecon harfordii*
Jaumea carnosa	***Deinandra fasciculata***	*Encelia californica*	*Erodium botrys**	*Dudleya virens* subsp. *hassei*
Juncus acutus subsp. *leopoldii*	*Elymus triticoides*	*Extriplex californica*	*Erodium cicutarium**	*Dudleya virens* subsp. *insularis*
*Mesembryanthemum crystallinum**	*Erodium brachycarpum**	*Isocoma menziesii*	*Erodium moschatum**	*Ericameria palmeri* var. *pachylepis*
*Nicotiana glauca**	*Lactuca saligna**	*Isocoma menziesii* var. *menziesii*	*Festuca bromoides**	*Eriogonum giganteum* var. *giganteum*
*Pennisetum clandestinum**	*Malva parviflora**	*Juncus mexicanus*	*Festuca myuros**	*Foeniculum vulgare**
Typha domingensis	*Opuntia oricola*	*Lycium californicum*	*Harpagonella palmeri*	*Galium angustifolium*
Xanthium orientale	*Pseudognaphalium luteoalbum**	*Melilotus indicus**	*Hedypnois rhagadioloides**	*Heteromeles arbutifolia*
	Stipa miliacea var. *miliacea**	*Phalaris aquatica**	*Hordeum intercedens*	*Leptosyne gigantea*
	Stipa pulchra	*Polypogon monspeliensis**	*Hordeum murinum**	*Malacothamnus fasciculatus*
		*Sonchus oleraceus**	*Hypochaeris glabra**	*Malacothrix saxatilis*
		*Xanthium spinosum**	*Lamarckia aurea**	*Malosma laurina*
			Lasthenia californica	*Marrubium vulgare**
			Layia platyglossa	*Opuntia littoralis*
			Lepidium nitidum	*Quercus pacifica*
			Logfia arizonica	*Rhus integrifolia*
			*Logfia gallica**	*Salvia mellifera*
			Lupinus concinnus	

Purple Module (Dark Blue Node)	Blue Module (Yellow Node)	Yellow Module (Light Blue Node)	Red Module (Orange Node)	Green Module (Green Node)
			*Lysimachia arvensis**	
			*Medicago polymorpha**	
			*Mesembryanthemum nodiflorum**	
			Microseris douglasii	
			Opuntia littoralis x oricola	
			*Phalaris minor**	
			*Plantago coronopus**	
			Plantago erecta	
			*Spergularia villosa**	
			Stebbinsoseris heterocarpa	
			Stipa lepida	
			*Torilis nodosa**	
			Trifolium albopurpureum	

** nonnative species*

Figure 6-40. Outliers - *Elymus condensatus*

Outlier Figure



Species within each module are listed on next page.

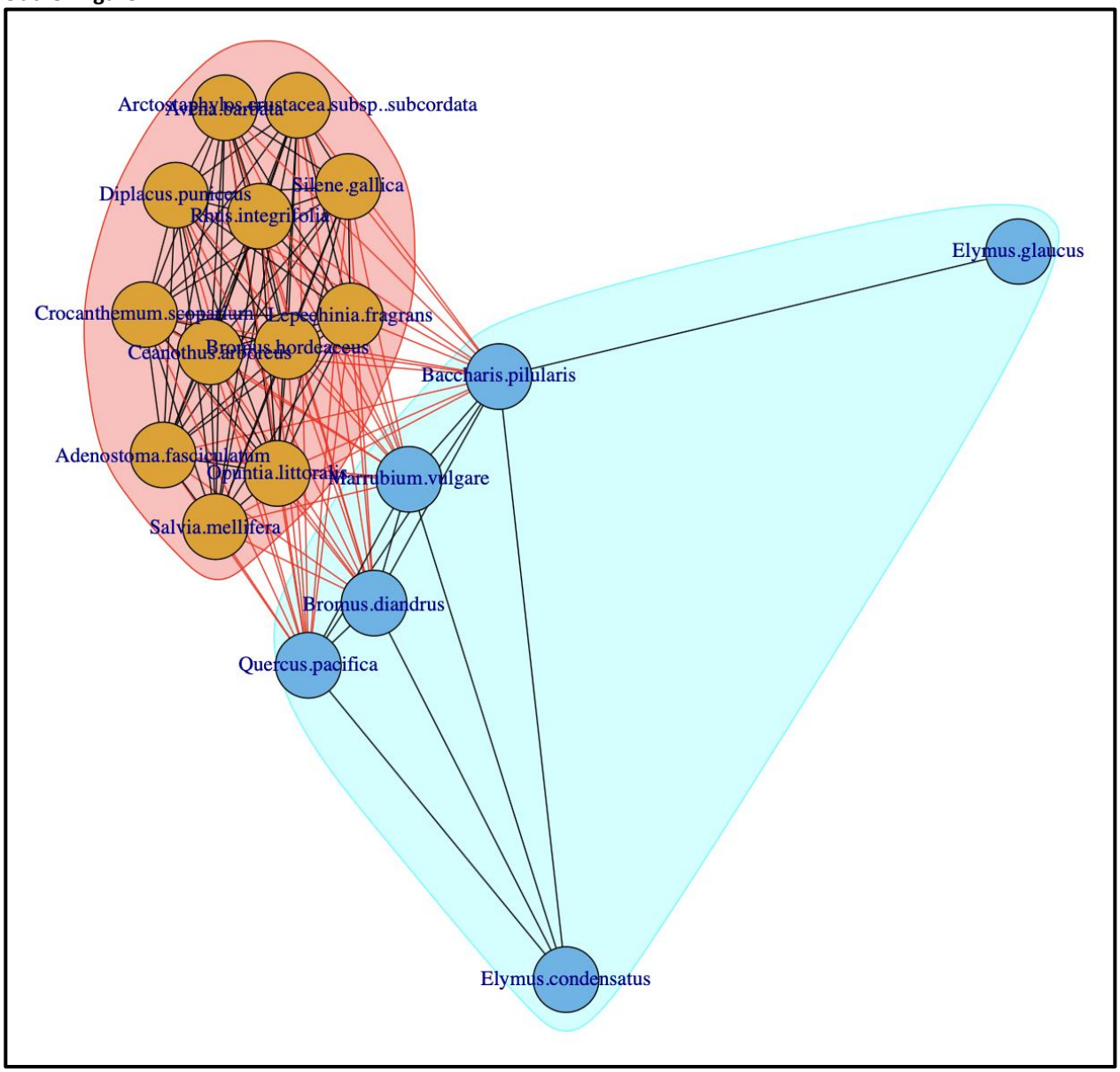
Outlier Table: *Elymus condensatus*

Red Module (Orange Node)	Blue Module (Blue Node)
Adenostoma fasciculatum	*Agrostis pallens*
Arctostaphylos crustacea subsp. *subcordata*	*Bromus madritensis**
*Avena barbata**	*Bromus rubens**
Baccharis pilularis	*Galium nuttallii*
*Bromus diandrus**	*Galium nuttallii* subsp. *insulare*
*Bromus hordeaceus**	*Keckiella cordifolia*
Ceanothus arboreus	*Lyonothamnus floribundus* subsp. *floribundus*
Crocanthemum scoparium	*Prunus ilicifolia* subsp. *lyonii*
Diplacus puniceus	*Pseudognaphalium biolettii*
Elymus condensatus	*Quercus pacifica* (previously *Q. dumosa*)
Elymus glaucus	*Quercus tomentella*
Lepechinia fragrans	*Quercus x macdonaldii*
*Marrubium vulgare**	*Rhamnus pirifolia*
Opuntia littoralis	*Ribes viburnifolium*
Quercus pacifica	*Stipa lepida*
Rhus integrifolia	*Xylococcus bicolor*
Salvia mellifera	
*Silene gallica**	

** nonnative species*

Figure 6-41. Outliers - *Elymus glaucus*

Outlier Figure



Species within each module are listed on next page.

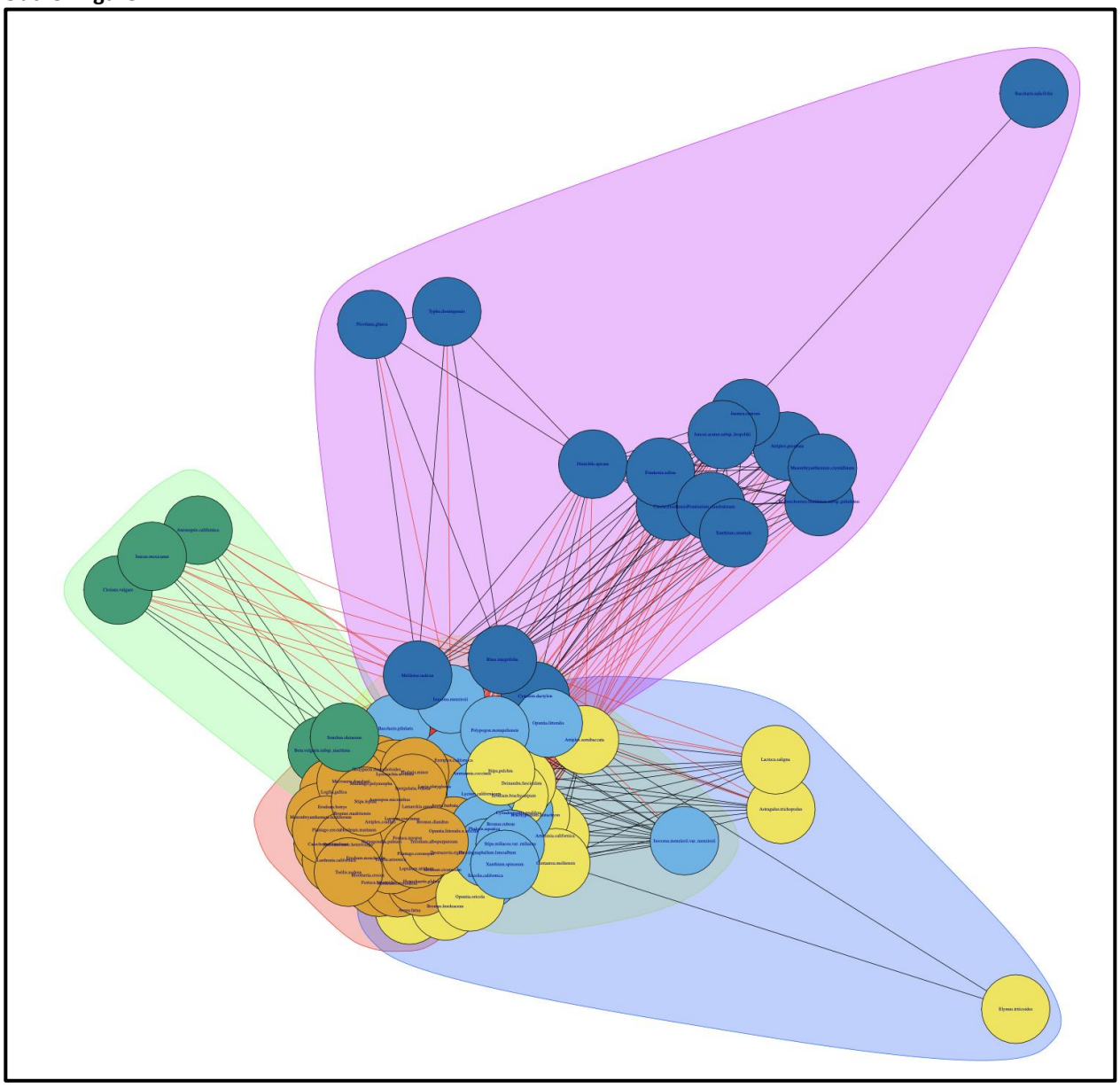
Outlier Table: *Elymus glaucus*

Red Module (Orange Node)	Blue Module (Blue Node)
Adenostoma fasciculatum	*Baccharis pilularis*
Arctostaphylos crustacea subsp. *subcordata*	*Bromus diandrus**
*Avena barbata**	*Elymus condensatus*
*Bromus hordeaceus**	***Elymus glaucus***
Ceanothus arboreus	*Marrubium vulgare**
Crocanthemum scoparium	*Quercus pacifica*
Diplacus puniceus	
Lepechinia fragrans	
Opuntia littoralis	
Rhus integrifolia	
Salvia mellifera	
*Silene gallica**	

** nonnative species*

Figure 6-42. Outliers - *Elymus triticoides*

Outlier Figure



Species within each module are listed on next page.

Outlier Table: *Elymus triticoides*

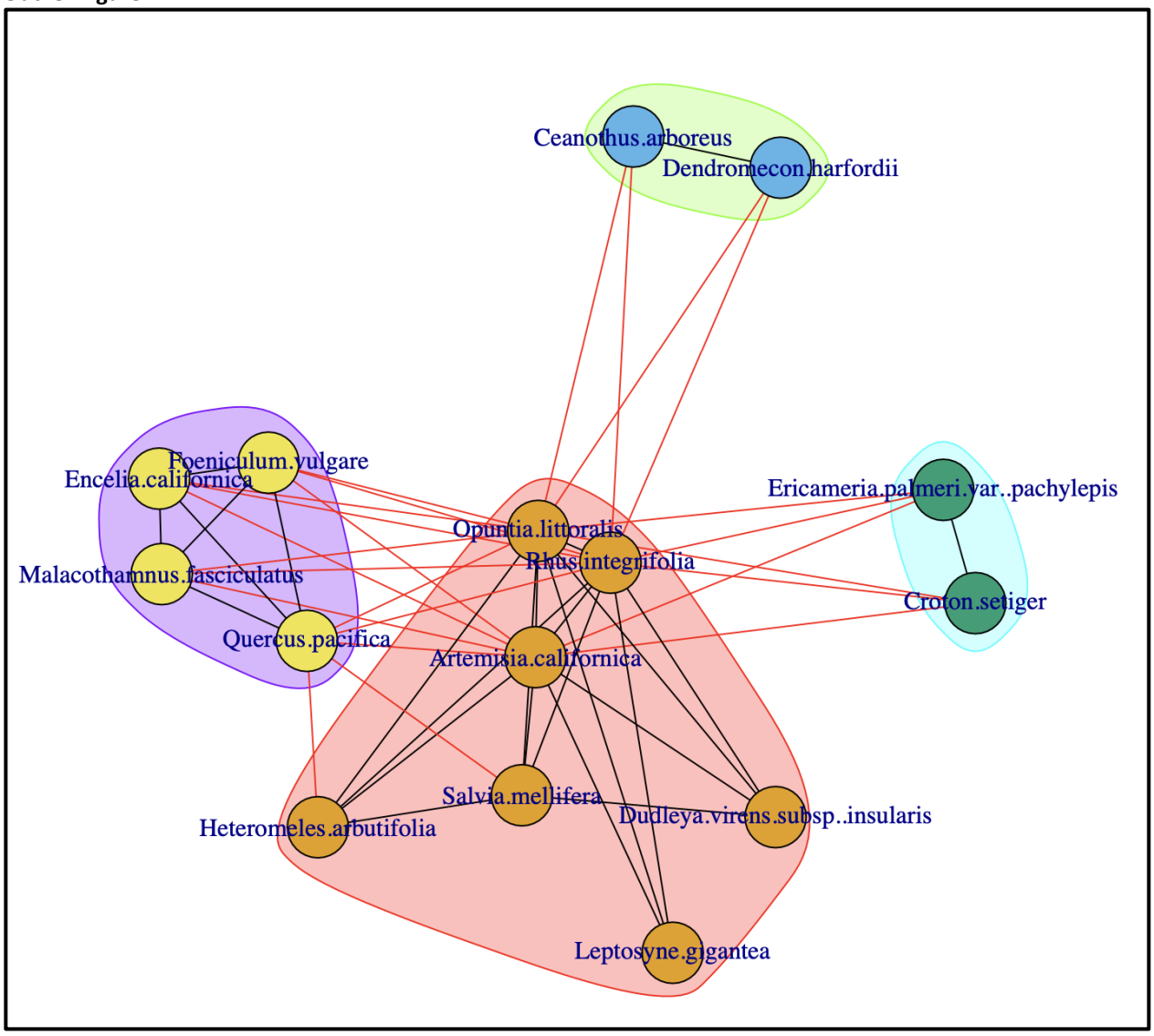
Blue Module (Yellow Node)	Red Module (Orange Node)	Green Module (Green Node)	Purple Module (Dark Blue Node)	Yellow Module (Light Blue Node)
Artemisia californica	*Acmispon micranthus*	*Anemopsis californica*	*Atriplex prostrata**	*Ammannia coccinea*
Astragalus trichopodus	*Atriplex coulteri*	*Beta vulgaris* subsp. *maritima**	*Baccharis salicifolia*	*Baccharis pilularis*
*Atriplex semibaccata**	*Avena barbata**	*Cirsium vulgare**	*Bolboschoenus maritimus* subsp. *paludosus*	*Bromus rubens**
*Avena fatua**	*Bloomeria crocea*	*Juncus mexicanus*	*Cressa truxillensis*	*Cylindropuntia prolifera*
*Brachypodium distachyon**	*Bromus diandrus**	*Sonchus oleraceus**	*Cynodon dactylon**	*Encelia californica*
*Bromus hordeaceus**	*Bromus madritensis**		*Distichlis spicata*	*Extriplex californica*
*Centaurea melitensis**	*Calochortus catalinae*		*Frankenia salina*	*Isocoma menziesii*
Deinandra fasciculata	*Desmazeria rigida**		*Jaumea carnosa*	*Isocoma menziesii* var. *menziesii*
Elymus triticoides	*Erodium botrys**		*Juncus acutus* subsp. *leopoldii*	*Lycium californicum*
*Erodium brachycarpum**	*Erodium cicutarium**		*Melilotus indicus**	*Opuntia littoralis*
*Lactuca saligna**	*Erodium moschatum**		*Mesembryanthemum crystallinum**	*Phalaris aquatica**
Opuntia oricola	*Festuca bromoides**		*Nicotiana glauca**	*Polypogon monspeliensis**
Stipa pulchra	*Festuca myuros**		*Pennisetum clandestinum**	*Stipa miliacea* var. *miliacea**
	Harpagonella palmeri		*Rhus integrifolia*	*Xanthium spinosum**
	*Hedypnois rhagadioloides**		*Typha domingensi*	
	Hordeum intercedens		*Xanthium orientale*	
	*Hordeum murinum**			
	*Hypochaeris glabra**			
	*Lamarckia aurea**			
	Lasthenia californica			
	Layia platyglossa			
	Lepidium nitidum			
	Logfia arizonica			
	*Logfia gallica**			
	Lupinus concinnus			
	*Lysimachia arvensis**			

Blue Module (Yellow Node)	Red Module (Orange Node)	Green Module (Green Node)	Purple Module (Dark Blue Node)	Yellow Module (Light Blue Node)
	*Medicago polymorpha**			
	*Mesembryanthemum nodiflorum**			
	Microseris douglasii			
	Opuntia littoralis x oricola			
	*Phalaris minor**			
	*Plantago coronopus**			
	Plantago erecta			
	*Spergularia villosa**			
	Stebbinsoseris heterocarpa			
	Stipa lepida			
	*Torilis nodosa**			
	Trifolium albopurpureum			

** nonnative species*

Figure 6-43. Outliers - *Encelia californica*

Outlier Figure



Species within each module are listed on next page.

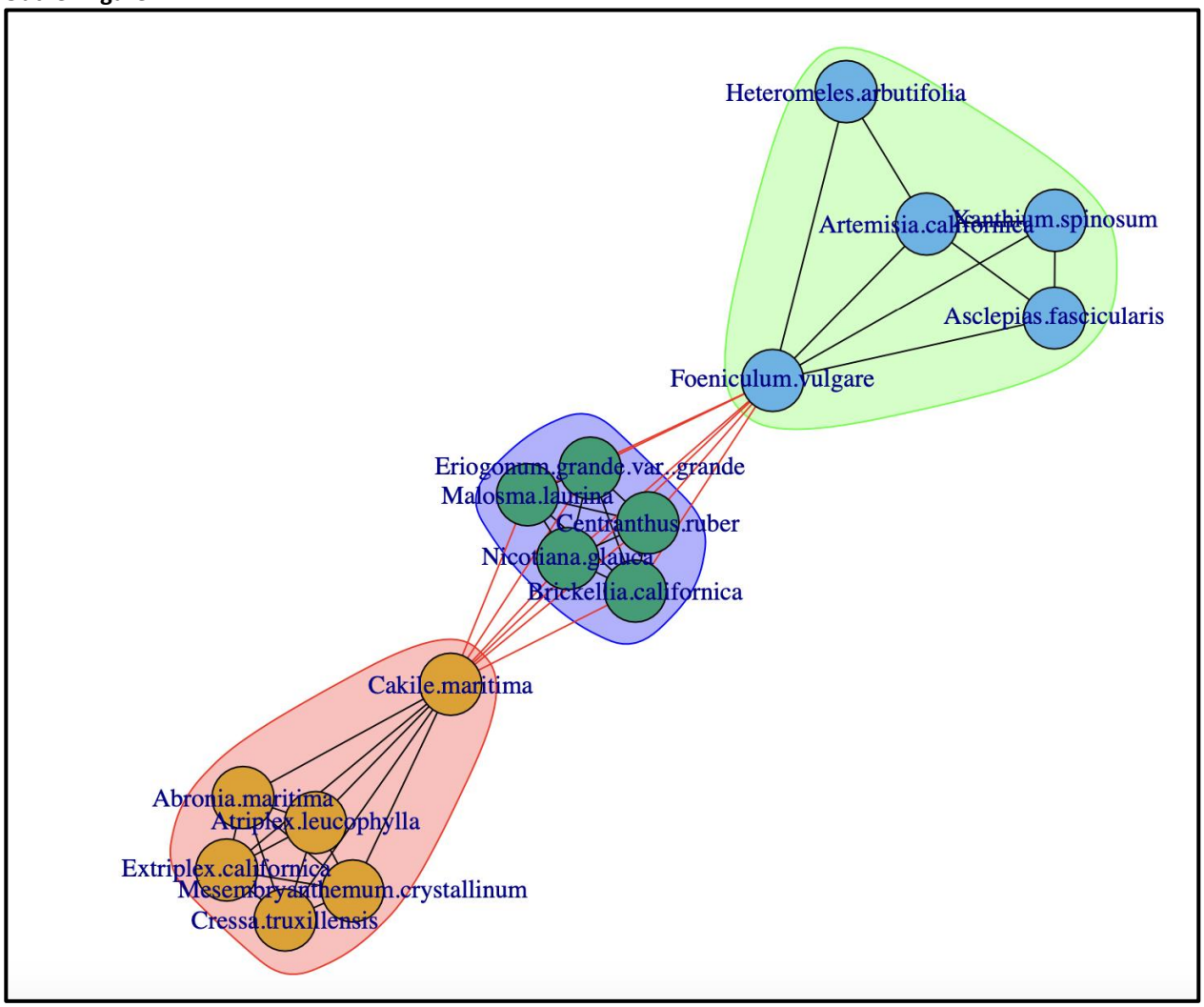
Outlier Table: *Encelia californica*

Purple Module (Yellow Node)	**Red Module (Orange Node)**	**Blue Module (Green Node)**	**Green Module (Blue Node)**
Encelia californica	*Artemisia californica*	*Croton setiger*	*Ceanothus arboreus*
*Foeniculum vulgare**	*Dudleya virens* subsp. *insularis*	*Ericameria palmeri* var. *pachylepis*	*Dendromecon harfordii*
Malacothamnus fasciculatus	*Heteromeles arbutifolia*		
Quercus pacifica	*Leptosyne gigantea*		
	*Mesembryanthemum crystallinum**		
	Opuntia littoralis		
	Rhus integrifolia		
	Salvia mellifera		

** nonnative species*

Figure 6-44. Outliers - *Eriogonum grande* var. *grande*

Outlier Figure



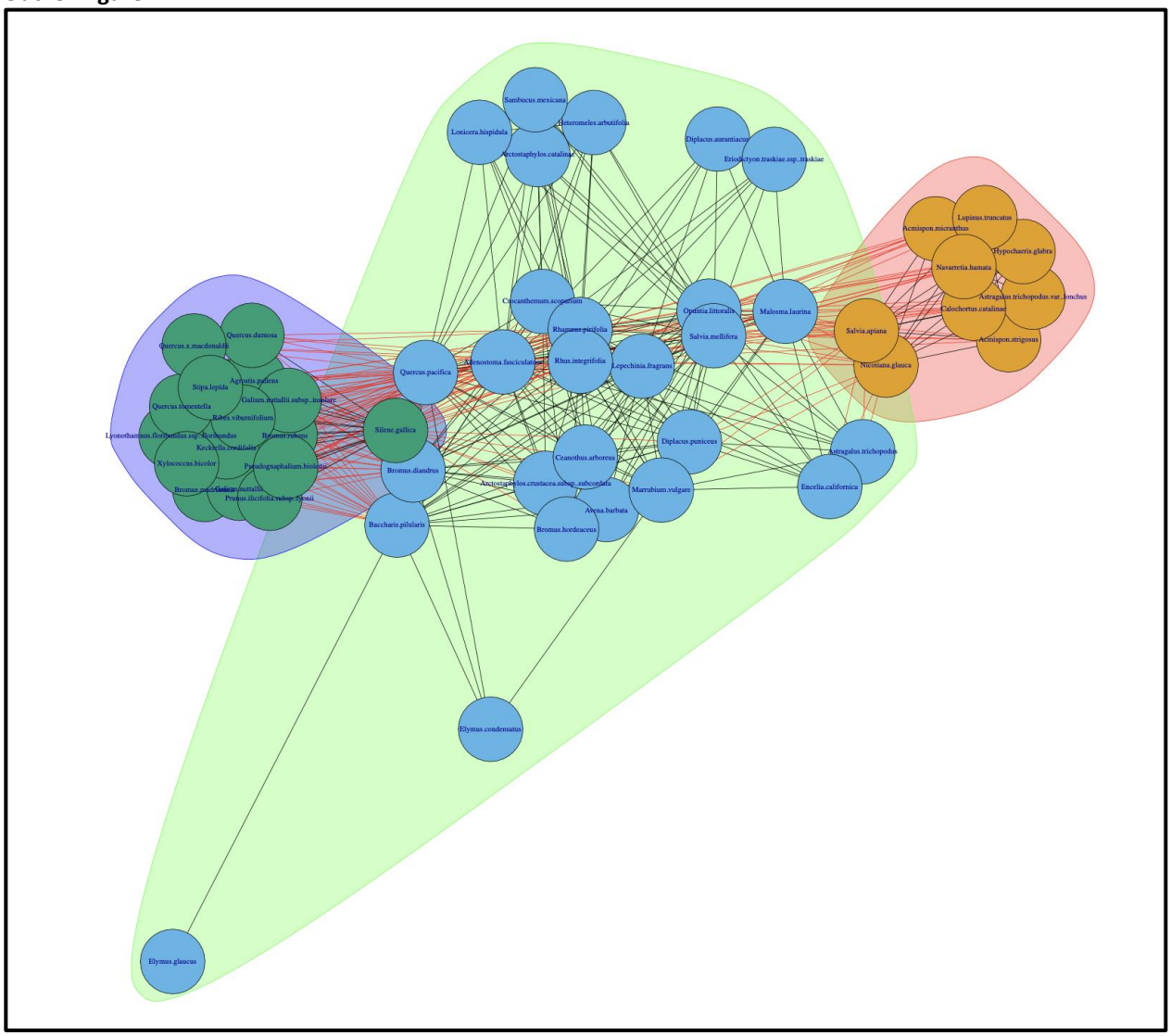
Outlier Table: *Eriogonum grande* var. *grande*

Red Module (Orange Node)	Purple Module (Green Node)	Green Module (Blue Node)
Abronia maritima	*Brickellia californica*	*Artemisia californica*
Atriplex leucophylla	*Centranthus ruber**	*Asclepias fascicularis*
*Cakile maritima**	***Eriogonum grande* var. *grande***	*Foeniculum vulgare**
Cressa truxillensis	*Malosma laurina*	*Heteromeles arbutifolia*
Extriplex californica	*Nicotiana glauca**	*Xanthium spinosum**
*Mesembryanthemum crystallinum**		

** nonnative species*

Figure 6-45. Outliers - *Lepechinia fragrans*

Outlier Figure



Species within each module are listed on next page.

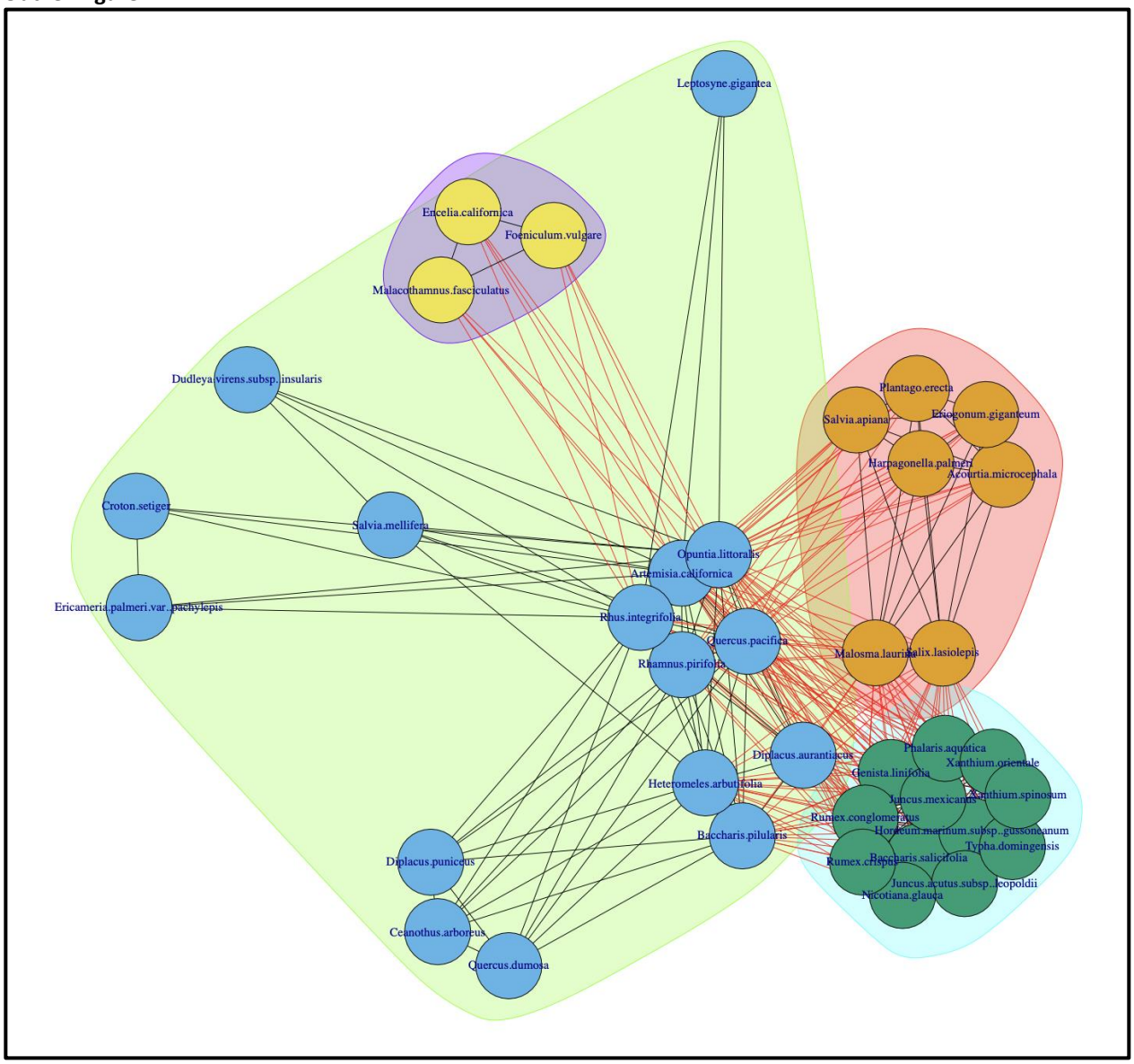
Outlier Table: *Lepechinia fragrans*

Purple Module (Green Node)	Green Module (Blue Node)	Red Module (Orange Node)
Agrostis pallens	*Adenostoma fasciculatum*	*Acmispon micranthus*
*Bromus madritensis**	*Arctostaphylos catalinae*	*Acmispon strigosus*
*Bromus rubens**	*Arctostaphylos crustacea* subsp. *subcordata*	*Astragalus trichopodus* var. *lonchus*
Galium nuttallii	*Astragalus trichopodus*	*Calochortus catalinae*
Galium nuttallii subsp. *insulare*	*Avena barbata**	*Hypochaeris glabra**
Keckiella cordifolia	*Baccharis pilularis*	*Lupinus truncatus*
Lyonothamnus floribundus subsp. *floribundus*	*Bromus diandrus**	*Navarretia hamata*
Prunus ilicifolia subsp. *lyonii*	*Bromus hordeaceus**	*Nicotiana glauca**
Pseudognaphalium biolettii	*Ceanothus arboreus*	*Salvia apiana*
Quercus pacifica (previously *Q. dumosa*)	*Crocanthemum scoparium*	
Quercus tomentella	*Diplacus aurantiacus*	
Quercus x macdonaldii	*Diplacus puniceus*	
Ribes viburnifolium	*Elymus condensatus*	
*Silene gallica**	*Elymus glaucus*	
Stipa lepida	*Encelia californica*	
Xylococcus bicolor	*Eriodictyon traskiae* subsp. *traskiae*	
	Heteromeles arbutifolia	
	Lepechinia fragrans	
	Lonicera hispidula	
	Malosma laurina	
	*Marrubium vulgare**	
	Opuntia littoralis	
	Quercus pacifica	
	Rhamnus pirifolia	
	Rhus integrifolia	
	Salvia mellifera	
	Sambucus mexicana	

** nonnative species*

Figure 6-46. Outliers - *Quercus pacifica*

Outlier Figure



Species within each module are listed on next page.

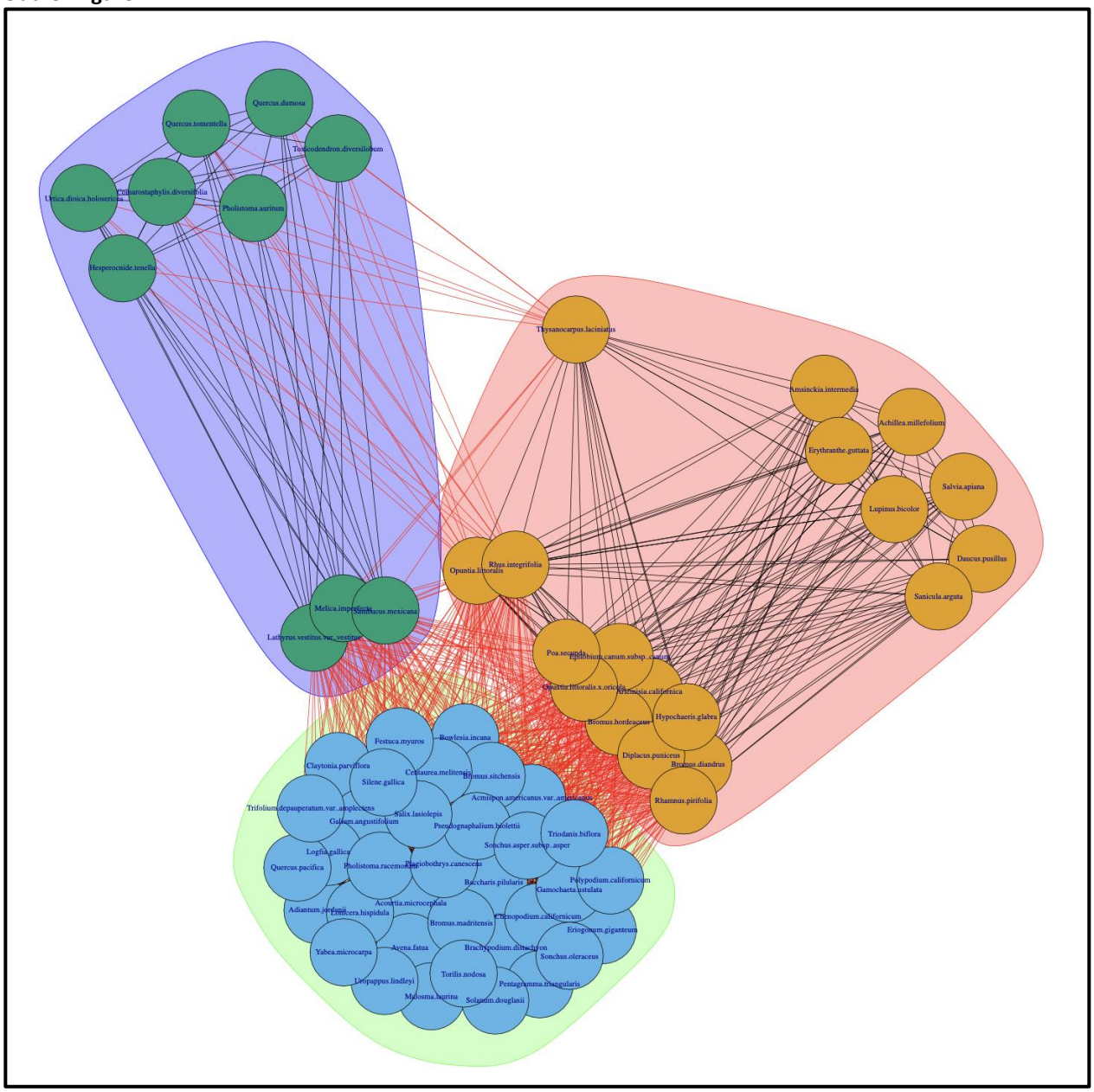
Outlier Table: *Quercus pacifica*

Purple Module (Yellow Node)	**Green Module (Blue Node)**	**Red Module (Orange Node)**	**Blue Module (Green Node)**
Encelia californica	*Quercus pacifica* (previously *Q. dumosa*)	*Acourtia microcephala*	*Baccharis salicifolia*
*Foeniculum vulgare**	*Artemisia californica*	*Eriogonum giganteum* var. *giganteum*	*Genista linifolia**
Malacothamnus fasciculatus	*Baccharis pilularis*	*Harpagonella palmeri*	*Hordeum marinum* subsp. *gussoneanum**
	Ceanothus arboreus	*Malosma laurina*	*Juncus acutus* subsp. *leopoldii*
	Croton setiger	*Plantago erecta*	*Juncus mexicanus*
	Diplacus aurantiacus	*Salix lasiolepis*	*Nicotiana glauca**
	Diplacus puniceus	*Salvia apiana*	*Phalaris aquatica**
	Dudleya virens subsp. *insularis*		*Rumex conglomeratus**
	Ericameria palmeri var. *pachylepis*		*Rumex crispus**
	Heteromeles arbutifolia		*Typha domingensis*
	Opuntia littoralis		*Xanthium orientale*
	Quercus pacifica		*Xanthium spinosum**
	Rhamnus pirifolia		
	Rhus integrifolia		

*** nonnative species***

Figure 6-47. Outliers - Quercus tomentella

Outlier Figure



Species within each module are listed on next page.

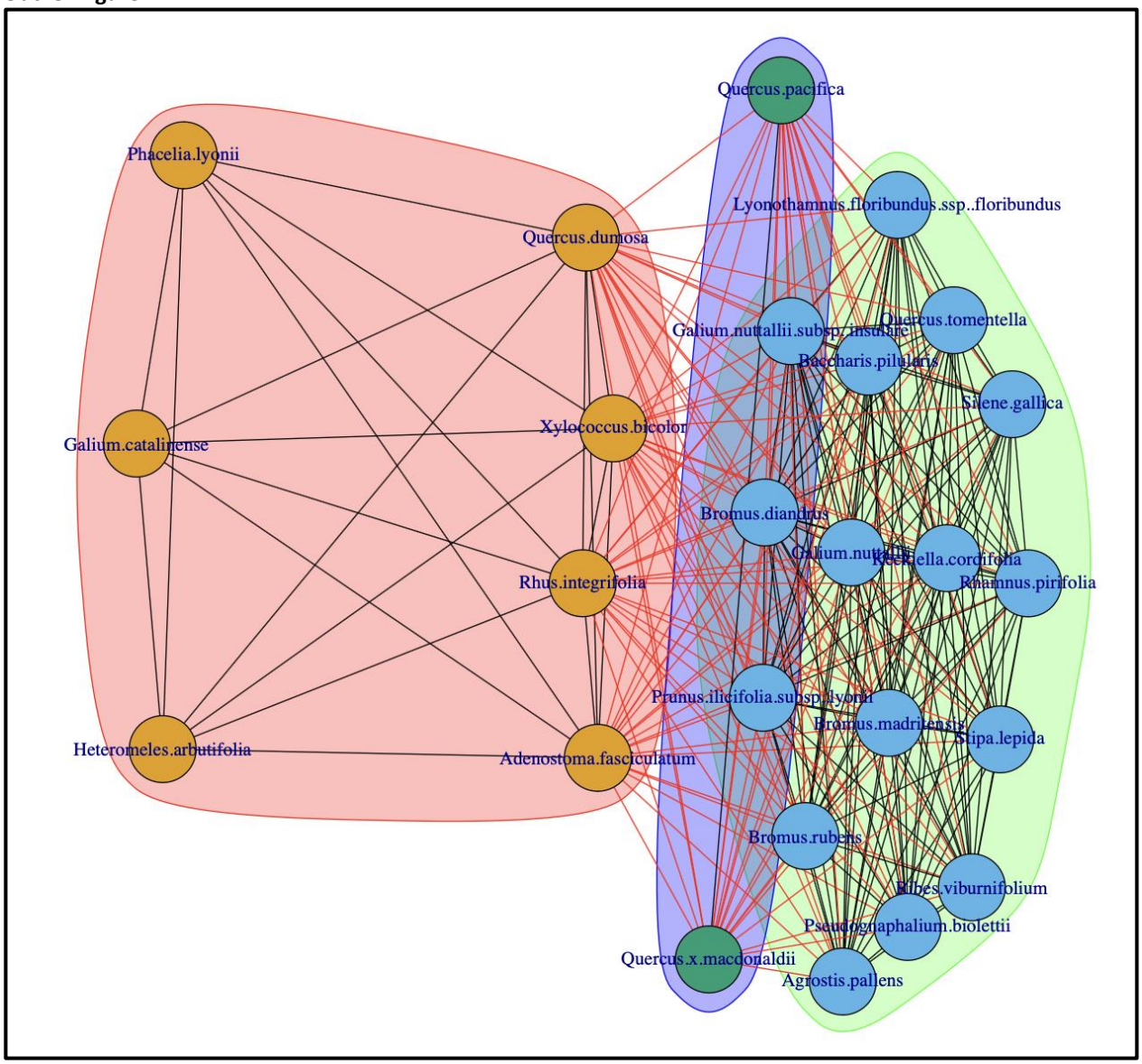
Outlier Table: *Quercus tomentella*

Purple Module (Green Node)	Red Module (Orange Node)	Green Module (Blue Node)
Comarostaphylis diversifolia	*Achillea millefolium*	*Acmispon americanus* var. *americanus*
Hesperocnide tenella	*Amsinckia intermedia*	*Acourtia microcephala*
Lathyrus vestitus var. *vestitus*	*Artemisia californica*	*Adiantum jordanii*
Melica imperfecta	*Bromus diandrus**	*Avena fatua**
Pholistoma auritum	*Bromus hordeaceus**	*Baccharis pilularis*
Quercus pacifica (previously *Q. dumosa*)	*Daucus pusillus*	*Bowlesia incana*
Quercus tomentella	*Diplacus puniceus*	*Brachypodium distachyon**
Sambucus mexicana	*Epilobium canum* subsp. *canum*	*Bromus madritensis**
Toxicodendron diversilobum	*Erythranthe guttata*	*Bromus sitchensis* (*B. carinatus*)
Urtica dioica holosericea	*Hypochaeris glabra**	*Centaurea melitensis**
	Lupinus bicolor	*Chenopodium californicum*
	Opuntia littoralis	*Claytonia parviflora*
	Opuntia littoralis x oricola	*Eriogonum giganteum* var. *giganteum*
	Poa secunda	*Festuca myuros**
	Rhamnus pirifolia	*Galium angustifolium*
	Rhus integrifolia	*Gamochaeta ustulata*
	Salvia apiana	*Logfia gallica**
	Sanicula arguta	*Lonicera hispidula*
	Thysanocarpus laciniatus	*Malosma laurina*
		Pentagramma triangularis
		Pholistoma racemosum
		Plagiobothrys canescens
		Polypodium californicum
		Pseudognaphalium biolettii
		Quercus pacifica
		Salix lasiolepis
		*Silene gallica**
		Solanum douglasii
		Sonchus asper subsp. *asper**
		*Sonchus oleraceus**
		*Torilis nodosa**
		Trifolium depauperatum var. *amplectens*
		Triodanis biflora
		Uropappus lindleyi
		Yabea microcarpa

** nonnative species*

Figure 6-48. Outliers - *Xylococcus bicolor*

Outlier Figure



Species within each module are listed on next page.

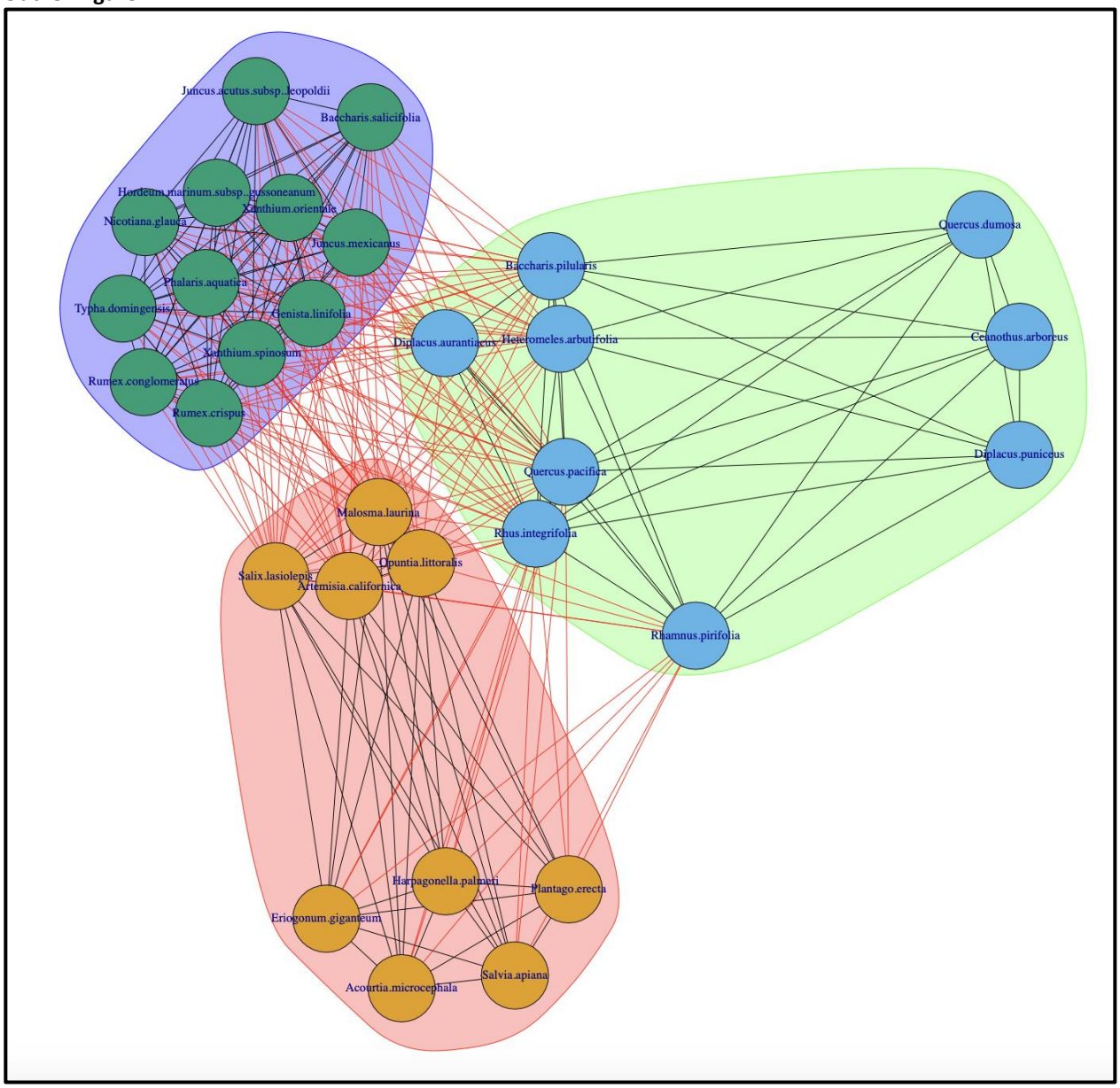
Outlier Table: *Xylococcus bicolor*

Red Module (Orange Node)	Purple Module (Green Node)	Green Module (Blue Node)
Adenostoma fasciculatum	*Quercus pacifica*	*Agrostis pallens*
Galium catalinense	*Quercus x macdonaldii*	*Baccharis pilularis*
Heteromeles arbutifolia		*Bromus diandrus**
Phacelia lyonii		*Bromus madritensis**
Quercus pacifica (previously *Q. dumosa*)		*Bromus rubens**
Rhus integrifolia		*Galium nuttallii*
Xylococcus bicolor		*Galium nuttallii* subsp. *insulare*
		Keckiella cordifolia
		Lyonothamnus floribundus subsp. *floribundus*
		Prunus ilicifolia subsp. *lyonii*
		Pseudognaphalium biolettii
		Quercus tomentella
		Rhamnus pirifolia
		Ribes viburnifolium
		*Silene gallica**
		Stipa lepida

** nonnative species*

Figure 6-49. Outliers - *Genista linifolia*

Outlier Figure



Species within each module are listed on next page.

Outlier Table: *Genista linifolia**

Purple Module (Green Node)	Red Module (Orange Node)	Green Module (Blue Node)
Baccharis salicifolia	*Acourtia microcephala*	*Baccharis pilularis*
Genista linifolia*	*Artemisia californica*	*Ceanothus arboreus*
Hordeum marinum subsp. *gussoneanum**	*Eriogonum giganteum* var. *giganteum*	*Diplacus aurantiacus*
Juncus acutus subsp. *leopoldii*	*Harpagonella palmeri*	*Diplacus puniceus*
Juncus mexicanus	*Malosma laurina*	*Heteromeles arbutifolia*
*Nicotiana glauca**	*Opuntia littoralis*	*Quercus pacifica* (previously *Q. dumosa*)
*Phalaris aquatica**	*Plantago erecta*	*Rhamnus pirifolia*
*Rumex conglomeratus**	*Salix lasiolepis*	*Rhus integrifolia*
*Rumex crispus**	*Salvia apiana*	
Typha domingensis		
Xanthium orientale		
*Xanthium spinosum**		

** nonnative species*

Appendix F

Habitat Restoration Method Guidelines

Prepared for

CATALINA ISLAND CONSERVANCY™

708 Crescent Ave.
Avalon, CA 90704

Prepared by

LAND IQ

3791 Wade Street
Los Angeles, CA 90066

FEBRUARY 2024

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1 INTRODUCTION

The following specifications are provided as a general reference to assist the Catalina Island Conservancy (Conservancy) land managers with the development of site-specific habitat enhancement and restoration plans on Catalina Island.

It is important to be mindful that the weed management and native plant material installation methods that are selected for a particular restoration project should be based on "getting to know your site" from field observations, review of existing documentation, and the goals of the project. There may be methods other than those presented in this document that are more appropriate for a particular project or site. The selection of habitat restoration methods will initially be made during the planning phase of the project, but they may change adaptively during implementation of the project after consideration of monitoring observations made during implementation of the project.

2 WEED MANAGEMENT

For most habitat enhancement and restoration efforts in southern California, it is recommended to manage the existing weed seed bank of the degraded area prior to installation of native plant material. Adequately controlling the weed seed bank first allows for the use of more cost-effective weed management methods and increases the likelihood that the native plant material added in the form of seed, cuttings, or nursery container transplants will successfully establish.

Adequate management of the nonnative seed bank may take several years to achieve, depending on the size of the nonnative seed population and the number of "grow-and-kill" events that occur each year. The grow-and-kill method is used to treat (kill) nonnative seedlings and new growth prior to seed set, to deplete the existing weed seed bank and prevent new weed seed from entering the seed bank.

Generally, it is more cost-effective and feasible for the management of large areas to rely solely on natural rainfall-driven grow-and-kill; however, project implementation is at the mercy of unpredictable weather patterns from year-to-year. This necessitates an adaptive weed management approach, which allows for flexibility in the timing and intensity of grow-and-kill events each year. Adaptive weed management is also a necessity because it is difficult and impractical to quantify the size of the nonnative seed bank in the project site during the planning phase; and rather the amount of weed management effort can only be estimated based on prior biological monitoring and experience with similar habitat restoration efforts.

In circumstances where it is important to reduce the amount of time necessary to implement the habitat restoration project, the years needed to manage the nonnative seed bank can be reduced with supplemental irrigation. Supplemental water from a temporary irrigation system can "force" more grow-and-kill events than can be achieved

with natural rainfall alone. For example, if three or four grow-and-kill events can be achieved throughout the year with supplemental irrigation instead of only one or two with natural rainfall alone, then weed management can be completed in two to three years in a project site that ultimately needs eight grow-and-kill cycles completed prior to seed addition, instead of four to five years with natural rainfall alone. However, the use of a temporary irrigation system to reduce the number of years of pre-seeding weed management, also commonly referred to as "site preparation" in habitat restoration projects, must be feasible (e.g., a water source is accessible to the project site) and justified by need given the significant cost for the purchase of water and installation of the temporary irrigation system (Brooks et al. 2019).

While most degraded areas targeted for habitat enhancement and restoration on Catalina Island have long histories of disturbance by long-term grazing, browsing, and occupation by nonnative plant populations, there are circumstances where there is little to no nonnative seed bank in the soil prior to native plant material addition (e.g., revegetation of a newly cut slope where virgin soil has been exposed). In these cases, weed management prior to native material addition may not be necessary.

Often coinciding with a history of disturbance (e.g., agriculture or unnatural fire frequency) and nonnative plant introduction, many degraded areas on Catalina are also native seed-limited, meaning that even with adequate weed management there is not sufficient viable native seed populations and/or diversity to restore sustainable native habitat. Therefore, native plant material addition is a necessary second phase in habitat restoration projects, following adequate management of the nonnative plant population.

Even in habitat restoration projects where natural recruitment from existing native seed banks and/or adjacent natural areas is sufficient—adequate weed management remains critical to the successful establishment of native habitat. While it is invaluable to have existing native material and successful natural recruitment on site, the budget for the weed management program must incorporate the additional labor and expertise required to weed around desirable native vegetation. Working around natives in a project site often requires more hand methods (e.g., hand cutting or pulling) and has fewer opportunities for time efficiencies afforded using mechanized equipment, like mowers.

The initial step in weed management typically begins in the fall with a dethatching event, as necessary for an individual site, to allow good germination of the weed seed bank with the first winter rains. The number of years required for weed management will be site-specific and depend on weed density, the type of weed species to control, annual weather patterns, and site-specific variables such as landscape position and soil type. At minimum, for most sites without supplemental irrigation, three consecutive years of site preparation activities should be planned to manage the weed population prior to installing native plant material.

The selection of weed management methods will depend on the type and density of weed species present, the density of native species, and accessibility. Control methods can include the following, as appropriate:

- Mowing/Cutting – mechanical equipment or hand tools
- Raking/Windrowing – mechanical equipment or hand tools for removal of cut material
- Hand pulling/cutting seedlings/saplings where feasible
- Herbicide application

Each weed control method has advantages and disadvantages, with considerations for the timing of application, the availability of equipment and trained staff, and limitations to site access for equipment. Nonnative seedlings and flowering plants should be controlled prior to the production of viable weed seeds to reduce contributions back to the weed seed bank. If weeding is delayed until after seed development has already occurred, seed material should be cut, bagged, and removed from the site.

Soil disruption should be kept to a minimum to reduce the germination of new weed individuals, injury to native species, and disturbance to biological soil crusts. However, during the weed management phase (i.e., site preparation), in areas with no biological crusts and low native cover, the limited disturbance of the topsoil that occurs from mechanical equipment, such as mowers, can accelerate the germination of weed seed and increase weed control efficiency. Care should be taken to not disturb deep soil layers that would bring up buried weed seed that would not otherwise express itself in the absence of disturbance.

Careful weeding needs to be done by trained crews to avoid damage to native species in areas with significant native cover or sensitive species. Adaptive management is key to success and includes regular monitoring to guide the scheduling and selection of weed control methods.

2.1 PHYSICAL CONTROL METHODS

2.1.1 MOWING/LINE TRIMMING

Mowing with mechanical equipment, such as a rotary mower, flail mower, or mulcher attached to a tractor or skid steer, or hand-operated motorized cutting tools such as line trimmers are generally the most efficient and least disruptive site preparation methods to use in areas dominated by annual grasses and weedy herbaceous species. Mowing is appropriate in larger areas that are flat to moderately sloped. Careful mowing should be implemented to limit injury to native species when cutting. In areas with a steeper slope or with a higher density of natives, walk behind, hand-operated mowers or line trimmers should be used. Line trimming can be accomplished with a gas-powered, hand-operated line trimmer fitted with a string, brush blade, or similar instrument in areas inaccessible to larger equipment.

Like line trimming, a gas-powered, hand-operate, shafted hedge trimmer with an articulating blade can be used to trim weeds above the soil surface from a standing position. Shafted hedge trimmers can be effective for cutting denser patches of broadleaf weeds after they have flowered, such as nonnative filaree (*Erodium* spp.). Line trimmers are more effective for control of nonnative annual grasses than hedge trimmers. Hedge trimmers are most effective in areas that are inaccessible to larger equipment, or when working around dense, existing native vegetation that excludes the use of larger equipment.

Fire prevention measures must also be taken to avoid accidental fires from sparks during machinery operation or line trimming with blades. These measures may include always having a water truck on site near the mowing activity, shovels carried on the mower and water truck, and water fire extinguishers. The weed material should be cut as close to the ground as possible to limit re-sprouting of herbaceous species and ensure removal of bolting crowns of grasses. Care should be taken to not damage biological soil crusts where present.

2.1.2 HAND/MECHANICAL PULLING OR CUTTING

Hand-pulling or cutting of weeds is also one of the least disruptive methods of site preparation but is an inefficient method of weed control in dense stands of weed species. Hand-pulling or cutting should be reserved for controlling isolated individuals, targeted control of high priority invasive species, controlling small infestations in areas that are inaccessible to equipment, or where high densities of native or sensitive species are present. Hand-pulling is a very useful manual technique to use on young plants and small patches of weeds.

Hand-cutting can be used to remove the flowering stalks of weeds prior to seed development with tools such as sickles or vinyl knives. The cut material can be left in place if it does not build a significant layer of thatch or placed in a mulch pile. If cut material contains viable seed, then it should be disposed of off-site or placed in a mulch pile that is actively managed for germinating weed species. Target invasive species seed material should always be removed from the site and not left in mulch piles to stop the spread into new areas.

When hand-pulling weeds, the plants should be grasped near the base pulling in the direction the plant is growing to be able to better pull most of the roots out of the ground. Short tugs work better than one long pull to prevent breaking the plant before the main roots are removed. For larger plants, it may be helpful for multiple people to hand-pull simultaneously.

Isolated individuals of select invasive species can be pulled by hand or with a tool such as the Weed Wrench™. Using hand garden tools such as picks, cultivators, weeders, specialized hoes, mattocks, and trowels, can help to loosen the soil around the roots. After loosening the soil, pull vertically from the ground to remove as much of the root system as possible, especially weed species with a long tap root. When using a weed wrench, the clamp should be placed on the lowest point on the trunk as much as

possible. The base of the weed wrench should be on the ground, but if it is not touching, rocks or branches can be placed underneath to improve leverage. Using your weight the weed wrench should be pulled toward you and not pushed away or injury could occur.

2.1.3 CUT-AND-DIG

Larger mature invasive species such as pampas grass (*Cortaderia selloana*) can be controlled by cutting the upper foliage of the plant and digging out the root system. Plant foliage can be cut with a handsaw, loppers, axe, or similar tools and removed to allow for better access to the roots. The root material can be dug out and removed with a shovel, mattock, Pulaski, or similar tool. As much of the root material should be removed as possible for effective control. Many plants can readily resprout from remaining roots. Removed root material should be properly disposed of to prevent resprouting. For example, the removed roots of tamarisk or pampas grass can resprout if the roots are touching wet soil. If the plant roots cannot be removed and disposed of offsite, the weeded root material should be placed root-upward on a dry rock or hillside or hung from trees to ensure it does not come in contact with wet soil.

2.1.4 MECHANICAL RAKING/WINDROWING

Following the initial mowing and clearing event of a site, the site should be dethatched by raking the cut material and removing it from the site. Raking and removal of cut material is not necessary in subsequent mowing events unless a significant amount of the weed species has set seed, or it is determined the thickness of the thatch will prevent germination of the next crop of weeds. Additionally, a final removal of thatch material may be necessary prior to seeding activities to ensure good seed-to-soil contact, depending on the seeding method used. For instance, drill seeding and hand-broadcast seeding can be accomplished over mowed plant stubble if the thatch is not too thick. For hydroseeding, it is best to have minimal thatch present on the ground.

Material should be mechanically raked into windrows and the placed into mulch piles within the restoration area, placed in adjacent buffer areas, or removed from the site if necessary. After the dethatching event, there may be a significant amount of weed seed present, in which case, it would be preferable to remove the thatch from the restoration area, either off-site or in buffer areas where it can be further managed during implementation of the restoration project.

An exception to leaving cut biomass in place is when an herbicide that retains the active ingredient in the dead plant material (e.g., clopyralid or imazapyr) is used. In this case, collect and mulch the biomass in a buffer area or remove and properly dispose of the material from the site since this could inadvertently damage native species present.

2.2 PRESCRIBED FIRE

Prescribed fire can be used for weed control and to promote desired vegetation and species, especially fire adapted habitat types such as chaparral with fire obligate seeders, e.g., certain manzanita (*Arctostaphylos* spp.). The purpose of the prescribed

fire needs to be clearly defined which will be used as guidance for the temperature and intensity of the fire that is needed. Factors to incorporate into determination of the temperature and intensity of a prescribed fire includes weather, topography, and available fuel of the site. If the fire is to be used primarily for the control of invasive species, the timing of the fire for most effective control is usually prior to seed set or during the earlier stages of development. However, prescribed fire can promote invasive species if the species are also adapted to fire for germination of seed or they are vigorous resprouters after fire or disturbance. The area where a prescribed fire is to occur should be assessed for the presence of invasive species and it should be determined if these types of invasive species are in the prescribed burn area. If possible, treatment of these invasive species should occur prior to the fire (Tu et al. 2001).

To conduct a prescribed burn, since Catalina island is within the State Responsibility Area (SRA) it is subject to obtaining a California Department of Forestry and Fire Protection (CAL Fire) burn permit and air quality permits from the local Air Quality Control District, both of which are necessary all year round in Southern California. A Project Type Burn Permit from CAL Fire allows landowners to do prescribed burns on allowable burn days determined by the Air District. The prescribed fire would also be subject to CEQA compliance if the project could have an impact on the environment. CEQA compliance can take the form of a Notice of Exemption (NOE), Negative Declaration (ND), Mitigated Negative Declaration (MND), or an Environmental Impact Report (EIR). The Conservancy would be fully liable if anything goes wrong with the fire.

A Prescribed Burn Plan should be developed that includes specifications for each burn area describing the burn treatment and project area. The Burn Plan needs to include a description of the project, the objectives for the prescribed burn, the acceptable conditions for doing the burn, e.g., wind speed and relative humidity, equipment lists, emergency assistance sources, and checklists for burn preparation. Within the document an ignition plan, holding plan, and a contingency plan should be fully developed. All necessary approvals for the Burn Plan should be obtained before conducting the burn.

The timing of the burn can affect the outcomes with weed control or target species recovery controlled by warm season versus winter burns. In general, burns will be best done during the warm season when weeds are actively growing and can be controlled and when desirable native species are actively growing. Fire intensity will impact the outcome with fires that are too hot can kill existing plants, and if temperatures are too hot can kill beneficial soil organisms along with native seed (Tu et al. 2001).

General guidelines for prescribed fires are the following: (UCANR Accessed 2023)

- Burn in the early part of the day when temperatures are generally cooler and relative humidity is higher
- Burn when there are no to very light winds

- Establish "check lines" or fire breaks in fuel continuity that will stop or check a fire. This can be accomplished by separating the fuels, e.g., raking a bare area, or by making a "wet line" by wetting with sufficient water (if available)
- Reduce velocity of a fire or Rate of Spread (ROS) by backing the fire down a steep slope (starting at the top of the slope), and backing the fire into the wind
- Make sure fire safety equipment is readily available for all staff participating in the prescribed burn, e.g., water fire extinguishers, long handled shovels, etc.

An alternative to conducting a prescribed burn themselves, the Conservancy could as an option participate in the CAL Fire Vegetation Management Program. In this case, the Conservancy would need to enter into contract with CALF Fire, and CAL Fire would be responsible for planning and implementing the prescribed burn on the Conservancy's land. Most or all the funding would be provided by CAL Fire, and they would assume liability for the burn. Vegetation Management projects that are in brushlands generally achieve CEQA compliance under the existing Chaparral Management Program EIR through the filling out of the Vegetation Management Program environmental checklist, which is essentially an "Initial Study", and if the checklist reveals no significant adverse impacts, then the project complies with the Chaparral Management Program Environmental Impact Report (PEIR). If there are significant adverse impacts then a supplemental environmental analysis, generally an ND or MND, is required (CAL FIRE 2019). A potential drawback to the Vegetation Management Program option is the lead time that is necessary for the planning and the availability of CAL Fire to implement the project.

2.3 CHEMICAL CONTROL METHODS

The following guidelines for chemical control methods follow the Conservancy's Catalina Habitat Improvement and Restoration Program (CHIRP) control techniques that has been implemented since 2003 for target invasive species. The core mission of CHIRP is to ensure that native plant species continue to dominate the ecosystem for the immediate and long-term future. General guidelines for herbicide control of other nonnative weed species are also provided in the following subsections.

Herbicide treatment is specified mainly for dense weed areas with low densities of native species and for control of high priority invasive species that are perennial or may re-sprout from taproots and rhizomes. For effective control of weed populations, these weeds must be controlled before they produce viable seed. Most herbicides are not selective for weeds only (i.e., these herbicides must be applied with the least harmful effect to non-target native species). In general, post-emergent herbicides, which kill plants after they have germinated and are actively growing, are recommended.

Only herbicides registered for use in California and in wildlands should be used judiciously within restoration or enhancement areas. Herbicides that are registered for use in California natural areas are recommended for particular weed species at rates specified on the herbicide labels. The recommended herbicides registered for use in California that are proposed in these guidelines are glyphosate, a non-specific herbicide

registered for use on almost all weed species, fluazifop-p-butyl to control weedy grasses, clopyralid for the treatment of thistles in the rosette stage, triclopyr for invasive woody and forb species, aminopyralid for the control of thistles, and imazapyr for highly invasive perennial grass species and tamarisk (*Tamarix ramosissima*).

Either a state licensed Pest Control Advisor (PCA) or those exempt from state pesticide licensing requirements (e.g., landowners such as the Conservancy, and the University of California Cooperative Extension Advisors) can make written herbicide recommendations for Catalina Island. In the case of the former, the herbicide applicator must have a pest control business license that requires at least one individual employed by the business be in possession of a Qualified Applicator's License (QAL). All licenses must be issued by the State of California and be currently registered in the county of work. If a qualified applicator is not present during the herbicide treatment, all applicators must have undergone documented herbicide training.

Personnel must wear all Personal Protective Equipment (PPE) required by law and follow all herbicide label directions and precautions. PPE includes but is not limited to chemical-resistant nitrile gloves, eye protection, chemical protective suits, e.g., Tyvek®, and protective footwear. All re-entry times specified on an herbicide label must be observed and posted. Herbicide preparation must be conducted only in approved staging areas more than 100 feet from a stream course or any body of water. Only herbicides and surfactants approved for aquatic use should be used within 100 feet of a stream course or any body of water.

A colorant or marking dye is recommended to ensure even coverage of herbicide. The material should be a non-toxic material such as Blazon®, Turf Mark®, or equivalent. The dye should be mixed with the herbicide at no more than half the rate specified on the label as it can reduce product performance, especially at lower herbicide application rates.

Herbicide treatment should be conducted only when weather conditions are conducive to effective uptake of the herbicide by target species when plants are at the specified growth stage. Optimal weather includes sunny and dry conditions with ambient temperatures of at least 65 degrees Fahrenheit. Wind conditions should be seven miles per hour or less for herbicide applications that can be subject to drift, e.g., foliar spray methods, to minimize herbicide drift for worker protection and to prevent damage to desirable vegetation.

2.3.1 FOLIAR SPRAY TREATMENT

Foliar spray treatment involves applying a select herbicide at a specified concentration directly to the exposed foliage of the plant to thoroughly wet all leaves. For the foliar spray treatment to be effective, the exposed foliage needs a thorough coating of herbicide, and the plant should be actively growing. The green or photosynthesizing parts of the plant should be sprayed for uptake of the herbicide by the plant. Typically, the foliar spray treatment is best used on smaller plants to ensure adequate cover of the herbicide.

The disadvantage of the foliar spray treatment is the damage that may be caused to desirable species in the localized area where spraying occurs, especially if a non-selective herbicide like glyphosate is being used. Additionally, the foliar application method is generally ineffective on invasive plants with thick waxy cuticles.

Foliar spray treatment can be implemented either by broadcast application or hand-operated sprayers. Broadcast application can be accomplished using a boom spray attached to a tractor or smaller utility vehicle. This is a highly efficient and cost-effective method but should only be done in areas with a low density of natives to reduce damage to desirable species, especially if a non-selective herbicide such as glyphosate is used. Truck-mounted sprayers with a wand and pressurized line can be used, which will allow for more directed spray to target weed species, while still being efficient.

Backpack sprayers or spray bottles are appropriate in areas with less dense weed species and higher native cover or to spot treat high priority invasive species. However, backpack or bottle spray application is the least efficient and most labor-intensive herbicide control method. For backpack or hand-held application of herbicide, use a low-pressure regulated sprayer with a coarse droplet size and single-nozzle wand. For this type of application use either spray-to-wet applications, or low volume directed spray.

For any type of hand-held applicator, make sure it is fully functional and does not have any leaks. The cap should be securely screwed on and not-cross threaded. For backpack sprayers, the rubber gasket and nipple in the sprayer lid should be regularly lubricated for proper functioning. The applicator should not bend over or lean too far forward. Prior to use, prime the backpack sprayer with 10 to 20 pumps. When traveling between spraying points, be sure to keep your hand off the lever to avoid any inadvertent spraying of herbicide.

To decrease the chances of spraying nontarget plants, preparation before spraying may be needed in areas where weeds are mixed in with native plants. The target plant for control should be separated from natives and if the plant is tall, the plant should be carefully bent downward, away from natives, and the herbicide solution applied. After spraying, the plant should be released slowly and carefully to avoid any herbicide drips or runoff. Be sure to observe what is behind and around the target species and be mindful of wind speed and direction. Nozzle adjustments may be necessary to get the mist pattern for best coverage of the target plant. Larger plants should be sprayed from multiple angles to be sure to cover them completely.

For application to small weeds (e.g., seedling stage) amongst dense native plants, if herbicide application is deemed necessary, the herbicide can be applied by backpack sprayer with a low-pressure regulated wand with the nozzle directed to the weed foliage, thereby avoiding overspray. However, nozzle-to-plant application is time intensive and requires highly trained applicators that can differentiate between native and nonnative plants at the seedling stage; and therefore, it is typically not the most cost-effective weed management method.

2.3.2 STUMP CUT AND HERBICIDE TREATMENT

Treatment of larger and well-established individuals, including high priority invasive species that may re-sprout from taproots or rhizomes, is best accomplished by using the stump cut and herbicide application method. Advantages of the stump-cut treatment compared with foliar application for larger individuals, includes the following:

- Lower quantity of herbicides required to treat the invasive species; and
- Localized application of the herbicides reduces the likelihood of herbicide contact with non-target native species, during application.

Typically, the stump cut and herbicide treatment is used in late summer and early fall when plants are translocating energy reserves to the rootstock and when seed dispersal is not enhanced by weeding activities optimal timing though is dependent on the weed species being treated.

The stump cut treatment method process involves cutting the stump of an invasive species flat at about 8 to 10 inches in height, then **immediately** (within 2 minutes or less) treating the exposed cambium of the cut stump with a select herbicide at a specified concentration. The stump cut treatment should be implemented in the following steps:

Step 1. Plants will be cleanly cut, horizontally, close to the ground (using a saw, rotary brush cutter or similar tool).

- The cut vegetation will be removed from the project area the same day it is cut and properly disposed of off-site or in a designated buffer area.
- Mulching Option: To reduce the cost of disposal, cut material that does not contain significant amounts of viable seed may be stockpiled in-place in compost piles in areas that are devoid of native species and that were previously occupied by the same treated invasive weed species. Do not locate mulch piles in areas that may negatively impact the recruitment or growth of native species (e.g., areas immediately adjacent to existing native habitat).

Step 2. The stumps or stems will be re-cut, cleared of sawdust and immediately painted with the specified herbicide within two minutes of cutting, before the cut surface begins to congeal, to ensure penetration of the herbicide. The herbicide should be applied to the cambium in 60 seconds or less after cutting.

- Apply the herbicide on the cut stump (the percent solution will be dependent on the weed species treated and herbicide used). Apply carefully to avoid any drips or damage to surrounding native species.

Plants generally should be checked about one month after application to determine the success of the herbicide treatment. Any re-growth from the treated stumps should be treated with the foliar herbicide application method in the same growing season or as re-growth appears in the next growing season. Any new seedlings and small saplings

observed during follow-up treatments can be hand-pulled, ensuring that the root system is removed. The pulled material should be removed from the project area or chipped and stockpiled for composting, as some species can regenerate when moisture is available.

2.3.3 DRILL AND FILL

For larger nonnative woody plants or trees, the drill and fill technique can be used in areas that are inaccessible with large cutting equipment, are on steep slopes, or are in remote areas. This can be a benefit to wildlife as the dead material can remain as a snag that could serve as a potential nesting opportunity or a perch for raptors for hunting. Dead trees should not be left in areas where they can become a safety hazard if they were to fall over or lose large limbs. The drill and fill method involves drilling a series of small holes in the bark and injecting a concentration of herbicide in the drilled holes to reach the cambium. The number and size of the holes as well as the concentration of herbicide will depend on the species being controlled and the herbicide being used.

In general, the guidelines for drill and fill should be implemented in the following steps:

Step 1. Drill holes, ideally one inch apart, below the first branches or leaves to a depth of two or three inches.

- The number of holes will depend on the size of the tree and size of the drill bit will depend on the species being controlled. The holes can be staggered "Charlie Brown" style to avoid running into each other. Up to two rows of holes can be drilled for larger trees.
- The holes should be drilled to a depth of two to three inches angled slightly downward to prevent herbicide from spilling out of the hole when applied.

Step 2. Fill each hole with the specified herbicide at the specified rate on the label.

- The holes should be filled with herbicide within 60 seconds of drilling before the hole begins to congeal.
- A spray bottle should be used to fill the holes slowly with the specified herbicide.

2.3.4 BASAL BARK TREATMENT

The basal bark treatment is for use on nonnative woody and tree species. The specified herbicide should be applied at the specified rate per the herbicide label in a band completely encircling the main trunk, suckers, or branches of the plant. When applied to the main trunk the herbicide should be applied in at least a two-foot band around the main trunk. When applied to suckers or branches, the bands should completely cover the smaller branches and suckers up to the leaves. Enough herbicide should be applied so that it glistens on the bark. Application should be slowly in drops or small squirts, starting from the top to the bottom, allowing the herbicide to roll down the bark. Using a mist for application should only be done as a last resort.

Since esters can pass more readily through tree bark compared to salts, ester formulations are usually more effective for basal bark treatments. However, because of

the high volatility of esters, basal bark treatments should be applied when the weather is cooler on calm days. Basal bark treatments are usually more effective on small younger trees with smooth bark and can be noneffective on older trees with thick corky bark (Tu et al. 2001).

BASAL BARK GLOVE OF DEATH

A variation of the basal bark treatment is the "Glove of Death" that was developed by The Nature Conservancy (TNC) land stewards (Tu et al. 2001) is a control method that is used by the Conservancy for certain highly invasive species. The intention is for more direct herbicide application with minimal to no runoff in areas with a high density of native species. The method involves wearing a cotton glove over a protective rubber or nitrile glove and spraying herbicide on the cotton glove. Herbicide should be sprayed slowly onto the glove to wet it, avoiding drips. The target weed species should be grabbed by the stem and herbicide applied by squeezing, slowly moving your hand down the stem trying to apply as much herbicide as possible to the stem without allowing for dripping. Gloves can be sprayed with herbicide prior to application and stored in a Ziploc bag with a label to transport it to the treatment location. This limits the need to bring additional spray equipment and the chance for herbicide drift when applying the herbicide to the glove in the field.

2.3.5 RECOMMENDED HERBICIDES FOR THE CONTROL OF NONNATIVE SPECIES

The following subsections provide information and application rates for specific herbicides recommended for use in the restoration and enhancement areas.

Categories of herbicides include pre-emergent and post-emergent. Pre-emergent herbicides are applied to the soil and work by either disrupting plant germination or kill newly germinated weed species and do not harm established plants. Post-emergent herbicides work on established and actively growing weed species. Only post-emergent herbicides are recommended for use in the restoration and enhancement areas. Pre-emergent herbicides should not be used for habitat restoration since they may also affect newly germinated native species preventing natural recruitment or establishment of an applied seed mix. The soil residual life of herbicides, or the amount of time it remains active in the soil, varies by herbicide and can be anywhere from several months to several years before breaking down into inert compounds.

Post-emergent herbicides are either selective (kills specific types of weeds such as grasses or broadleaves) or non-selective (works on all plants). Grass-selective herbicides include Fusilade® DX and Envoy®. Broadleaf-selective herbicides include Clopyralid. Non-selective herbicides include glyphosate, triclopyr, and imazapyr.

Post-emergent herbicides can be broadcast sprayed in areas with a low density of native species or applied with backpack sprayers in areas with a higher density of native species. Selective herbicides can be broadcast sprayed to control the desired weed type with little to no impact on natives of a different plant type. Non-selective herbicides can be more efficient in areas with a mix of grass and broadleaf weed species since they can

treat all the weed species present at the site. However, non-selective herbicides can cause the most harm to desirable native species and should only be broadcast sprayed in areas with a low density of natives.

Caution should be taken to prevent overspray and herbicide drift onto the foliage of native species as they can damage or kill the plant(s). Prior to selection and use, the label of each herbicide should be read to determine if the active ingredient can translocate through the soil and cause potential damage to the root system of native species. For example, imazapyr translocates through the soil and its use should be primarily limited to the stump cut treatment method or used sparingly for foliar treatment of hard to treat highly invasive species to reduce the amount of herbicide introduced into the soil and limit herbicide drift.

Fluazifop (Fluazifop-p-butyl Fusilade® DX)

The active ingredient in Fusilade® DX is fluazifop-p-butyl. Fusilade® DX is a selective post-emergent herbicide used for the control of annual and perennial weed grasses. The herbicide is systemic i.e., it is absorbed and moves from the foliage to the roots, rhizomes, stolons, shoots, and meristematic regions of the grasses.

Application Rate

Fusilade® DX application rates for annual and perennial grasses are 16-24 ounces (oz) per acre (4 to 6 oz of active ingredient [a.i.] per acre). For control of seedlings the rate is 8 oz per acre (2 oz a.i. per acre). Add the following spray additives to the herbicide mixture for optimum effectiveness:

- Crop oil concentrate containing 15-20% approved emulsifier at 0.5-1% volume/volume (v/v) (0.5-1 gallon [gal]/100 gal)
- Nonionic surfactant containing at least 75% surface-active agent at 0.25-0.5% v/v (1-2 quarts/100 gal)
- A non-toxic colorant or marking dye to insure even coverage of herbicide. The dye should be mixed with the herbicide at no more than half the rate specified on the label of the dye as it can reduce product performance, especially at lower herbicide application rates.

Weedy grass species should be treated at the appropriate growth stage for optimum effectiveness. Grasses that have tillered (sprouted a shoot from its base), formed seed heads, or exceeded the growth stages listed on the label should not be treated. Target weed grasses should not be under stress (e.g., from moisture, temperature, low soil fertility) for optimum control.

If the treatment area has a mix of weedy grasses, Fusilade application should be implemented when the first grass reaches the specified growth stage for treatment using the highest application rate for the grasses in the mixed population. The optimum growth stage for treatment of annual grasses is when grasses are 2–8 inches tall, but prior to tillering and/or seed head formation. It is important to note that in drought

years when available water is limited, nonnative grasses can flower early when plants are less than 8 inches tall. Monitoring of flower production is critical to determine the optimum time for weed control. Thoroughly coat the foliage with herbicide during foliar application, but not to the point of runoff of the herbicide.

No more than 72 fluid ounces of Fusilade per acre a year should be applied to a treatment area. It should not be applied if rainfall is expected within 1 hour of application. Fusilade should not be applied directly to water, where surface water is present, or where runoff into water bodies could occur. To reduce herbicide runoff, avoid applications of herbicide within 48 hours of rainfall. Restrict entry into treated areas as specified on the label.

Visual observations of control can be seen within one week of treatment; however, it is dependent on the grass species and environmental conditions. Growth of treated grasses typically stops soon after application. Signs of herbicide control include loss of vigor, yellowing, reddening, and eventual death.

Glyphosate

Glyphosate (e.g., Roundup Pro® Concentrate or Roundup Pro® Max or Roundup Custom® for aquatic use) is a broad-spectrum post-emergence herbicide for the control of annual, perennial, and woody weed species. The herbicide is systemic and moves from the treated foliage to the root system.

Foliar application should be implemented when the target species are at the appropriate growth stage for optimum effectiveness. Target annual and perennial species should be actively growing. Application to annual species should be prior to seed head formation of grasses and before bud formation in broadleaf weeds. Perennial weeds should be treated after they reach the reproductive stage of growth, seed head formation in grasses and bud formation for broadleaf species. If treatment is necessary prior to perennials reaching the reproductive stage, the higher label application rate should be used.

Application Rate

Most annual and perennial weed species can be effectively treated with a 2% solution of glyphosate when applied during the appropriate growth stage. Follow label directions of the glyphosate product used to mix a 2% solution. Add colorant or marking dyes to the spray solution to aid the applicator in achieving good coverage of target species. The dye should be mixed with the herbicide at no more than half the rate specified on the label as the amount of dye can reduce product performance, especially at lower herbicide application rates. Most glyphosate products contain a surfactant, and no additional surfactant is needed or recommended to add to the mix except for glyphosate products registered for aquatic use. Aquatic glyphosate formulations do not contain a surfactant in the herbicide product. If using an aquatic formulation and a surfactant is added to the mix, follow the directions on the herbicide label. A surfactant approved for aquatic use should be used such as Liberate®. However, it should be noted

that in some cases, specific project permits and conditions may not allow use of a surfactant for aquatic applications.

For spray to wet applications, spray coverage should be uniform and complete without spraying to the point of runoff using a 2% solution of glyphosate.

For low volume directed spray applications use a 4 to 8% solution of the glyphosate product for control of annual and perennial weeds. Refer to the herbicide label for species to determine the appropriate application rate. Spray coverage should be uniform with at least 50 to 75% of the foliage treated. For best results the top one half of the plant should be sprayed.

Except where specified on the label, no more than 8 pounds (lbs) of glyphosate acid per acre per year should be applied to a treatment area in California. The total glyphosate acid amount is additive for all glyphosate products used in a given area, so it is important to keep a record of the amount of all glyphosate acid used in a given area per year. Glyphosate products have different acid concentrations and acid equivalents are provided on all product labels.

Herbicide application should not occur if heavy rainfall is expected soon after application. Herbicide should not be applied directly to water or to areas where surface water is present. Restrict entry into treated areas as specified on the label.

Visual observations of control on annual weeds can be seen within 2 to 4 days and 7 days or more for perennial weeds. Signs of herbicide control include wilting and yellowing of foliage advancing to complete browning of above-ground growth and deterioration of root material.

Glyphosate can also be used for the stump cut and drill and frill methods. For the stump cut method, generally a 50% solution is used for treatment and for the drill and frill method a 100% solution. Label directions should be followed for each method and for the species targeted for control.

Clopyralid

Clopyralid is a post-emergence selective broadleaf herbicide. It is particularly effective for the control of thistle and clover species and is considered safe to use with established native grass species. However, immature native grasses prior to tillering and development of a secondary root system may be negatively affected by clopyralid. Clopyralid is the active ingredient in the herbicide Transline®.

Application Rate

Clopyralid should be applied at ¼ to ⅔ pint per acre, depending on the weed species being treated and associated growth stage. Add the following spray additives to the herbicide mixture for optimum effectiveness:

- A non-ionic surfactant at a rate of 1 to 2 gal/100 gal of herbicide mixture.

- A non-toxic colorant or marking dye to insure even coverage of herbicide. The dye should be mixed with the herbicide at no more than half the rate specified on the label of the dye as it can reduce product performance, especially at lower herbicide application rates.

In general, the herbicide is most effective when weeds are small and actively growing. The lower rate should be used only during highly favorable growing conditions and when plants are 3 to 6 inches tall. The higher rates should be used if the plants are stressed or in areas with high weed density. The foliage should be thoroughly coated for effective control.

Application during extreme growing conditions such as drought, freezing conditions, or wet foliage at the time of application may reduce the effectiveness of the herbicide. Herbicide is rainfast within 2 hours of application. Avoid injury to non-target plants by avoiding spray drift. Non-target plants can be affected by direct spray on plant foliage or indirectly by root uptake through the soil. The maximum application rate per year in California during the growing season is ⅔ pint per acre.

Clopyralid should not be applied directly to water, where surface water is present or where runoff into water bodies could occur. Clopyralid should not be used in areas where movement through the soil could contaminate ground water, such as loamy sand, sandy soils or in areas with a shallow water table.

Sprayed material should not be used for composting or mulch as clopyralid may remain for long periods in dead plant tissue and negatively affect future growth and development of non-target species in treated areas.

Triclopyr

Triclopyr (e.g., Garlon 3A, Garlon 4, or Pathfinder® II) is a systemic herbicide used for the control of broadleaf species and grasses. Triclopyr can be used at any time during the growing season and is most effective when used to treat actively growing plants.

Application Rate

For the control of broadleaf species triclopyr should be applied at 1 to 4.5 lbs acid equivalent (a.e.) per acre in a total volume of 20 to 100 gallons of water. The herbicide mixture can be applied at any time of the growing season. Add the following spray additives to the herbicide mixture for optimum effectiveness:

- A non-ionic surfactant at the rate specified on the label of the surfactant. Use the higher recommended concentrations of surfactant when applying lower spray volumes per acre.
- A non-toxic colorant or marking dye to insure even coverage of herbicide. The dye should be mixed with the herbicide at no more than half the rate specified on the label of the dye as it can reduce product performance, especially at lower herbicide application rates.

The maximum application rate of triclopyr is 9 lbs a.e. per acre per year for Garlon 4 and 8 lbs a.e. per year for Pathfinder® II.

Triclopyr can also be used for the stump cut method and is generally applied with a 20 or 50% solution depending on the target weed species when using Garlon 4. Pathfinder® II is used for the control of woody species using stump cut or basal bark methods. Product label directions should be followed for each method for the life stage of the species targeted for control.

Aminopyralid

Aminopyralid (e.g., Milestone®) is a systemic herbicide used for the control of broadleaf species. It is particularly effective for the control of thistle species and can be used at multiple life stages of target plants. In general, grasses are highly tolerant of aminopyralid and aren't affected by application. Aminopyralid can be used as a preemergent so care should be taken to use it primarily for selective spot treatment of target invasive species and not be used for broadcast application which could inhibit native recruitment.

Application Rate

The maximum application rate of aminopyralid is 0.11 lbs a.e. per acre per year as a result of broadcast, spot, or repeat applications.

Aminopyralid will generally be used for spot foliar spray applications for target invasive species with a 0.3% solution. For certain target species, a 2% solution of glyphosate will be added to the mix for more effective control.

Imazapyr

Imazapyr (e.g., Habitat®) is a non-selective systemic herbicide that is used to treat a wide range of broadleaf and grass species. It can be used at any time of the year and has a formulation that is approved for aquatic use (Habitat®). Care should be taken when using imazapyr products since it can translocate in the soil and harm desirable native species. Imazapyr is best used for direct application, such as the stump cut method, or for spot treatment only for foliar applications. Avoid spraying the ground with imazapyr especially over the rooting zone of native plants. Plant material that has been treated with imazapyr should not be left on site or used as mulch as the active ingredient is retained in the plant material and can pass through into the soil or onto the foliage of plants it is in contact with.

Application Rate

The maximum application rate of Habitat® is 1.5 lbs a.e. imazapyr per acre per year. For foliar treatments, the solution will range from 1 to 2% depending on the target species and life stage. For stump cut use a 10% solution and for drill and frill methods a 100% solution. All product labels should be followed for application rates depending on the method, target species, and growth stage.

Add the following spray additives to the herbicide mixture for optimum effectiveness when using Habitat®:

- Add a nonionic surfactant at the rate of 0.25% volume/volume or higher (see manufacturer's label) of the spray solution. Best results are obtained from using a nonionic surfactant with hydrophilic to lipophilic balance rate between 12 and 17 with at least 70% surfactant in the formulated product.
- Instead of a surfactant, a methylated seed oil or vegetable-based seed oil concentrate may be used at a rate of 1.5 to 2 pints per acre. Uptake of Habitat by plants under moisture or temperature stress may be aided by the use of oils as indicated by research.

2.3.6 Herbicides Approved for Aquatic Use

Only herbicides and surfactants approved for aquatic use should be used in riparian habitats or within 100 feet of a stream course or body of water for treatment of weed species. It is important to note that permits may not allow the use of a surfactant in riparian habitats. The purpose of a surfactant is to provide more uniform coverage and improve penetration of the herbicide into the plant. Approved aquatic herbicides include Round-up® Custom (active ingredient glyphosate), Habitat® (active ingredient imazapyr), and Renovate® 3 (active ingredient triclopyr). Only non-ionic surfactants should be used that are approved for aquatic use. Non-ionic surfactants approved for aquatic use include Liberate® and Rainier®.

2.4 Weed Seed Handling, Resprout Reduction, and Plant Matter Disposal

While the physical removal and chemical treatment of invasive species is a key part of weed management, care must also be taken to reduce the chances of seed spreading, resprouting, and other undesirable consequences of weed control. Preventing the future propagation of weeds will increase the effectiveness of current practices and reduce the severity of later infestation.

Though it is recommended to control weeds before seeds mature, there may be situations where this is not possible. For example, if the weed can seed year-round and monitoring each individual's life stage is too difficult. It is important then to be mindful of the presence of seeds during control events. While the plant itself may be removed, seeds left behind at the site or stuck to clothing or equipment can reduce the effect of management and spread the infestation to other areas.

To reduce the spread of seed, remove any flowering parts or seeds found on plants before cutting, hand-pulling, or herbicide application and place the material in appropriate containers for disposal. Pick up all seeds that remain on the ground and place in containers. After each treatment, ensure that all seeds are removed from clothing and equipment and placed in the disposal containers before leaving the area.

Any storage bin or vehicle used during treatment and for transport of weeded material shall be inspected and all seeds, flower, and root material removed.

In many cases it is possible to leave treated plant matter on site to dry out and decompose. If no flowers or seeds are present, pull the plant and place it on the ground to dry out only if the species is not rhizomatous and there is no potential for re-sprouting. In such cases, it will be important to completely remove all root matter through digging out the roots when mechanical methods are being used, and properly removing and disposing of cut matter off-site. Thatch of plants treated with herbicides that remain in the dead plant material, such as clopyralid and imazapyr should not be used as mulch and if treating large areas, the material should be removed from the site.

If the plant thatch material is to be removed from the site and the conditions are met where there is not seed material present and weeded material is not able to resprout from root material, the thatch can be left to dry out on site for a few days to a week, making it easier for removal since the material will be lighter and easier to work with.

2.5 MANAGEMENT METHODS FOR TARGET INVASIVE SPECIES ON CATALINA ISLAND

The Conservancy's CHIRP program has prescribed treatment methods for select invasive species present on the island. Methods include physical control methods and chemical control methods. Preferred and secondary methods are given and are selected based on time of year, plant life stage, etc. The methods are reviewed and updated annually as needed based on new research and through monitoring control effects in treated populations.

While use of the weed management methods presented above are effective for most nonnative plants, some invasive plant species may require more focused control effort within a habitat restoration area. Many of these invasive species are naturalized, with established populations in the areas under weed management. The goal for a typical habitat restoration project is to control their spread and to reduce their population size to the point where self-sustaining native vegetation communities can be restored. Absolute control is often not feasible or necessary in all cases. The control methods for target invasive species used by the Conservancy are presented in Appendix A.

Separate consideration should be made for control of those invasive plant species that have yet to become common on Catalina Island. These less common invasive plant populations should be managed with an early detection and rapid response (EDRR) management approach, as advocated by the California Invasive Plant Council (Cal-IPC). An EDRR plan for natural areas associated with a habitat restoration project is outside of the scope of this plan but should be considered as a complementary land management activity to habitat restoration efforts.

Table 2-1 shows the selected invasive species and their relative threat to California's natural areas as ranked by Cal-IPC. The Cal-IPC ranking is for the statewide threat; however, keep in mind that on Catalina Island, some of these species may pose a

greater or lesser threat. The table also presents species deemed invasive on Catalina that are not ranked by Cal-IPC and are actively controlled.

Table 2-1. Invasive Plant Species on Catalina Island

Scientific Name	Common Name	Cal-IPC Rank
Arctotheca calendula	Capeweed	Moderate
Arundo donax	Giant cane	High
Asparagus asparagoides	Bridal creeper	Moderate
Asphodelus fistulosus	Onionweed	Moderate
Brassica tournefortii	Saharan mustard	High
Caesalpinia spinosa	Tara	None
Cakile maritima	Sea rocket	Limited
Carduus pycnocephalus	Italian thistle	Moderate
Carpobrotus species	Iceplant	Moderate, High
Centaurea solstitialis	Yellow starthistle	High
Centranthus ruber	Jupiter's beard	None
Cirsium vulgare	Bull thistle	Moderate
Cortaderia selloana	Pampas grass	High
Cotoneaster species	Cotoneaster	Moderate
Cynara cardunculus	Artichoke thistle	Moderate
Cytisus scoparius,	Scotch	High
Cytisus striatus	Portuguese broom	Moderate
Delairea odorata	Cape Ivy	High
Eriogonum fasciculatum	California buckwheat	None
Eucalyptus species	Eucalyptus	Watch, Limited
Euphorbia regis-jubae	Milky spurge	None
Euphorbia terracina	Carnation spurge	Limited
Ficus carica	Common fig	Moderate
Foeniculum vulgare	Fennel	Moderate
Genista linifolia	Flax leaf broom	Watch
Genista monspessulana	French broom	High
Genista stenopetala	Sweet broom	None
Hedera helix	English ivy	High
Hypercium androsaemum	Sweet amber	Watch
Lathyrus latifolius, L. odoratus	Everlasting, Sweet pea	Watch
Lepidium draba	Whitetop	Moderate
Malephora crocea	Coppery mesembryanthemum	Watch
Marrubium vulgare	Horehound	Limited
Mesembryanthemum species	Crystalline iceplant	Limited, Moderate

Scientific Name	Common Name	Cal-IPC Rank
Nicotiana glauca	Tree tobacco	Moderate
Oenothera xenogaura	Dummond's gaura	None
Osteospermum calendulaceum	Stinking Roger	None
Paspalum vaginatum	Seashore Paspalum	Watch
Pennisetum setaceum	Fountain grass	Moderate
Phalaris aquatica	Harding grass	Moderate
Phoenix canariensis	Canary Island Date Palm	Limited
Pinus halepensis	Aleppo pine	None
Pittosporum undulatum	Victorian box	Watch
Ricinus communis	Castorbean	Limited
Salsola tragus	Russian thistle	Limited
Silybum marianum	Milk thistle	Limited
Spartium junceum	Spanish broom	High
Stipa tenuissima	Mexican feathergrass	Watch
Tamarix ramosissima	Tamarisk	High
*Tribulus terrestris**	Puncture Vine	Limited
Vinca major	Periwinkle	Moderate
Washingtonia species	Fan palm	Moderate
Yucca species	Yucca	None

3 EROSION CONTROL

Erosion control measures may be needed for restoration areas on steep slopes or next to roadways or facilities. Erosion control measures include biodegradable straw wattles, erosion control fiber mats, check dams with hay bales, hydraulically applied soil binders, etc.

In the cases where construction activities will trigger the need for a Construction General Permit for Stormwater Discharges that requires the development of a Storm Water Pollution Prevention Plan (SWPPP), in California the SWPPP must be prepared by a certified Qualified SWPPP Developer (QSD) to ensure compliance with the National Discharge Elimination System Permit (NPDES). The SWPPP will provide detailed information on Best Management Practices (BMPs) that will be used in specific instances for erosion control and provides a monitoring plan to track compliance with permit conditions to be conducted under the supervision of a Qualified SWPPP Practitioner (QSP). A Construction general permit is required when there will be ground disturbance totaling one or more acres in size.

In instances where erosion control is needed but not subject to permit conditions, the following presents general guidelines for erosion control BMPs that could be used for

the restoration and enhancement areas presented in this HRMP. For optimum erosion control, a combination of the following erosion control measures may be needed.

3.1 STRAW WATTLES

Straw wattles are an effective erosion control measure to use on steep slopes that are lacking vegetation that will prevent erosion of bare soil surfaces. The wattles interrupt and slow down water flow on steep slopes and capture sediment that may be within the sheet flow. Biodegradable natural wattles of straw or coir rolls, if needed, should be used, and the netting of the wattles should be of non-plastic, biodegradable material that will break down in the environment over time, such as burlap wrap. Plastic netting can be an entanglement hazard for wildlife. General guidelines for straw wattle spacing are as follows:

- 50-feet apart on slopes flatter than 10:1
- 20 feet apart on slopes that are between 4:1 to 10:1
- 15 feet apart for slopes from 2:1 to 4:1
- 10 feet apart for slopes steeper than 2:1

The wattles should be trenched into the ground at a depth of 2 to 4 inches deep and aligned with slope contours. No daylight should be seen under the wattle if installed properly. Ends of the wattles shall be overlapped by 12 inches and not butted end to end to prevent rilling. Wood stakes that are at least 18 inches long and at least one inch in diameter should be placed at each end and every 4 feet on center, driven in the center of the wattle to anchor the wattle to the slope. Two to three inches of the stake should be left protruding above the wattle. Stakes should be driven perpendicular to the slope.

Straw wattles should be inspected regularly after significant rain events and maintained as needed to ensure adequate sediment holding capacity. Generally, removal of accumulated sediment should occur when the accumulated sediment reaches ¾ of the barrier height. Any damaged or missing wattles should be replaced.

3.2 FIBER MAT

A fiber mat, or rolled erosion control netting, is an erosion control measure to use on bare steep slopes to prevent topsoil and sediment movement until vegetation can establish for slope stabilization. It might be best used with other erosion control measures such as straw wattles on steep slopes. If seeding is planned in areas where the fiber mats are placed, the mat should have an open area percentage of 65 percent so that seed may be applied after the netting is put in place. If a product with less open area must be used (e.g., for increased erosion control protection) then a netting with no less than 50 percent open area should be used.

The fiber mat should be made of 100 percent natural biodegradable fiber woven into a matrix (no synthetic materials), a minimum roll width of 6 feet, and weight of about 11.8 ounces per square yard (e.g., BioD-Mat® 40 or Coir Mat 480). The open area

percentage of the mat to use will depend on the amount of erosion protection needed with the less open space providing increased erosion control protection.

Fiber mats work best in areas with bare soil that have been graded. The mats need to fit snug to the ground surface to be most effective. If application of seed is to occur in combination with the fiber mat, the seed bed should be prepared which might include loosening the upper couple of inches prior to installation if the soil is compacted. Seeding should occur before installation of the netting. Reseeding in areas that were disturbed during installation may need to occur.

Installation of the fiber mat should begin at the top of the slope and the mat anchored into a 12-inch anchor trench. The mat should be placed in the trench and the trench backfilled and the soil tamped down firmly. The mat should then be rolled down the slope. Adjacent parallel rolls should overlap by 6 inches and anchored with 6-inch-long staples that are degradable (e.g., 11-guage steel wire staple). When the mat must be spliced, the rolls should be placed end over end (shingle style) with 12 inches overlapping. The overlapped area should be secured with two staggard rows of staples 6 inches on center. For slopes that are 2:1 and steeper, a minimum of 2 staples per every square yard is recommended. The end of the mat at the downslope end should be anchored into the ground in a 12 by 6-inch anchor trench. The mat should be placed in the trench, backfilled with soil, and tamped into the ground.

3.3 SILT FENCES

A silt fence is a temporary erosion control measure that is used for capture of sediment on site by intercepting and slowing down the flow of sheet flow runoff. It is made of permeable fabric that captures sediment behind the fence. Silt fences should be placed below areas where sheet flows discharge from the site. Silt fences are most applicable around the perimeter of the project, below the toe of or downslope of exposed and erodible soils, along streams, or around temporary spoil or stockpiles. Silt fences are not appropriate for protection against concentrated flows and are only applicable for sheet flow.

For most effective erosion control silt fences should be used in combination with other erosion control devices, such as straw wattles on steep slopes. The silt fence should be installed offset 3 feet from the toe of slope to be most effective. A trench should be excavated approximately 6 inches wide and 6 inches deep along a level contour. The bottom of the silt fence should be keyed in a minimum of 12 inches, 6 inches deep and 6 inches horizontally in the bottom of the trench. After placing the silt fence fabric material in the trench, it should be backfilled with soil and tamped into the ground.

The silt fence should be secured with posts that are a minimum of 12 to 18 inches below the bottom of the trench and placed a maximum of 6 feet apart. The stakes should be placed on the downslope side of the trench. When fence lengths need to be joined together, the silt fence fabric should be spliced together only at a support post with a minimum of 6 inches of overlap and both ends secured to the post. The fabric should be folded around the stake one full turn for each section and the two stakes placed

together and driven tightly together to prevent potential flow through of sediment at the joint. The tops of the stakes should be secured with wire. The fence material should be stapled to the posts and with staples that are 1.75 inches long and be 0.6 inch or heavier wire. The staples used for joining two sections of fence together should be 0.12 inches or heavier wire. A minimum of 4 staples should be used to secure the fabric to the stakes. The end stake should have two stakes and the fabric folded around one full turn and secured with 4 staples. The last 8 feet of the fence should be turned upslope to prevent stormwater from flowing around the fence.

Inspection of silt fences should occur before and after rain events. Repairs should be done as needed, e.g., torn, or weathered fabric should be replaced, and broken posts should be replaced. Inspection after rains should be done to see if sediment removal is necessary to continue to provide adequate sediment holding capacity of the fence. Sediment removal should occur when sediment reaches 1/3 of the barrier height.

3.4 STRAW HAY BALE CHECK DAM

Check dams can be a useful temporary erosion control tool in smaller drainages or deep erosion gullies. They should not be used in flowing channels or streams and are not intended for protection against large storm events. They are designed to reduce debris flow, scour, and erosion. The check dam can prevent undercutting from occurring if installed correctly and can slow down the velocity of water flow in the channel or gully. The general guidelines for design limits of the straw hay bale check dam are the following:

- Slopes 0 to 15% - the maximum drainage area between check dams is 1 acre and maximum slope length is 200 feet
- Slope 15 to 20% - the maximum drainage area between check dams is ½ acre and maximum slope length is 100 feet
- Slope >20% - not recommended

The hay bales should be made of natural material that is certified weed-free that meet the State requirements for noxious and invasive weeds. For more durable straw hay bales, the bale should be bound with either wire or nylon string. Twine binding will break down quicker thereby reducing the integrity of the hay bale. The bales should be placed in rows with the bale ends tightly abutting the adjacent bales. Depending on the size of the erosion control area, multiple straw check dams may be necessary. The number needed will depend on the size of the drainage or gully.

Two rows of hay bales should be installed with the downstream hay bales trenched into the ground so that the top of the row of bales placed on their long, wide side are level with the ground. The top of the bales across the center of the drainage or gully should all be level and set at the same elevation. A trench should be dug immediately upstream of this row so at least 6 inches of each bale is below ground and wide enough to accommodate a row of bales set vertically on their long edge. The trench and the tops of the bales across the center of the channel should be as level as possible so that water

will evenly flow across the top. This trench should be continued up slope on either side of the channel so that the last bales are higher than the top of the bales in the center of the channel (USDA 2012).

The hay bales should be anchored in with wooden stakes or #4 rebar that are driven through the bales and into the ground 1 ½ to 2 feet into the ground. The stakes should be angled to drive towards the adjacent previously laid bale, so they are driven towards each other.

For further protection, an energy dissipater of rocks and/or logs can be constructed at the base of the spillway bales. Logs can be anchored in front of the hay bales with bent rebar or rocks can be piled at least two deep against the bales. The energy dissipator should be large enough to receive all the flowing water over the hay bale check dam (USFS 2006).

Monitoring of the check dams should occur before and after rain events and maintenance conducted as needed. The check dam can quickly fill up with sediment after a storm and if the sediment accumulation is one-third of the bale height, it should be cleaned out. Straw hay bales will degrade quickly and may need to be replaced every 3 months, depending on the site conditions and weather. The buildup of sediment over time behind the check dam can allow for establishment of desirable native habitats that can further provide erosion stabilization.

Alternative materials can be used for the construction of check dams that may be preferred, provide greater stabilization and last longer. Other materials include fiber rolls, gravel filled bags, rocks, or logs. The advantage of using alternative materials are they will last longer in the environment since hay bales can quickly degrade and last less than 3 months, especially in areas with high rainfall.

3.5 HYDRAULICALLY APPLIED SOIL STABILIZERS

Hydromulch with soil stabilizers can be an effective erosion control measure on bare erodible slopes, including steep slopes that are between 25 to 50%. It can be used as a temporary measure until vegetation can reestablish on the bare slopes and can be used in combination with seed application to jump start the vegetation recovery process. The mulch will protect the slope from rain drop impact and can reduce sheet flow that might otherwise occur on steep, bare slopes. The mulch can provide favorable conditions for seed germination and establishment by trapping moisture and providing temperature regulation.

Erosion control effectiveness of hydromulch appears to be mainly during the first few months after application and erosion control protection is diminished by higher rainfall amounts and or/intensity (Hubbert et al. 2011). Hydromulch is most effective on slopes with a shorter run length such as road cuts where concentrated flow is diminished (USFS 2006). When using hydromulch, it is recommended to have erosion control measures in place at the toe of the slope such as silt fence.

There are currently products on the market that can be applied that includes the hydromulch and soil stabilizers all into one, e.g., EarthGuard® Pellets or EarthGuard® Fiber Matrix. If seeding is to be done with hydromulch application, it is recommended to use the Fiber Matrix material. In general, the recommended application rate of the hydromulch is 2,000 pounds per acre. Depending on the steepness of the slope, the manufacturer recommended application rates should be used which depends on slope steepness and annual average rainfall amounts.

4 PLANT MATERIALS

The goal of the Project is to maintain the genetic biodiversity of the plant populations on Catalina Island, so to the extent possible, all plant material collected for seed application and container plant production for restoration projects should be obtained from native plant communities growing on the island. Seed for restoration projects will either be specially collected on the island or obtained from the Conservancy's seed farm facility to ensure genetic integrity of the seed and container plant material. Using sources from the island will also reduce the risk of contamination with unintended genetics and reduce the risk of the introduction of nonnative species that are currently not present on the island that may be inadvertently included in seed purchased from seed vendors/companies.

In some instances, there may not be enough seed available from island sources for projects that require large quantities of seed. For those species that function as erosion control or nurse crop species, do not exist in large enough quantities on the island, or are not being produced at the island seed farm facility, it will be necessary to either (a) use seed stock from a seed collector/supplier that can be verified as collected within Los Angeles County and of similar microclimate regime, or (b) extend the collection area on a species-by-species basis from appropriate sources within Los Angeles County or other appropriate microclimatic regions in Southern California. The seed collection firm shall certify all seed collection locations. Sources for all species and any adjustments to the seeding rate should be approved by the project restoration ecologist/biologist.

When special collection off island is required, the seed material should be collected by a qualified native seed collection firm that has a minimum of five years of experience and holds all the necessary licenses and permits through the term of the project. The selected firm must be approved by the project restoration ecologist/biologist and the Conservancy.

4.1 SEED MATERIALS

Active restoration for the restoration projects will consist mainly of the addition of seed material for restoring native habitats in areas with reduced native seed banks. Seed can either be specially collected from wild populations or grown on seed farms for seed bulking of commonly used native species in the restoration process. Either method will

include seed collection activities, seed processing and storage, and seed testing for pure live seed determination.

4.1.1 SEED COLLECTION

Standard industry collection procedures and best practices for seed collection should be followed to maintain genetic integrity, diversity, and variability, which are crucial for project success. This will also ensure the adaptive capacity of the planting material and provide climate change resilience. Planning should begin early for seed collection or seed farm production to allow enough time to be able to obtain the needed seed quantities.

Seed scouting should occur prior to seed collection to make sure the seed is ripe and ready for collection. Seed is ripe when they shake from the pod or seed casing, can be easily removed from the plant, and/or are turning dark in color. Populations should be frequently checked after blooming starts to determine when the seeds will be ready for harvest. In general, once the seeds have turned hard and cannot be punctured with a thumbnail, then it is mature and ready for collection. In general, ripe seed should be collected from the plant and not from material that has already fallen to the ground.

Seed collected in the wild should follow the best practices that includes collecting at the appropriate time of year for each species, collecting a maximum of 5% of the current season seed either on a population or on a per plant basis, and collecting from at least 30 to 50 different plants in a collection area from multiple separate populations in a collection area, e.g., same elevation band or watershed. Separate populations should be at least ¼ mile distance from each other. These practices will ensure genetic variation is collected. Seed collection should be from plants in good condition and not ones with disease, insect infestations, etc. (USFS 1993).

For the collection of species that are federally- or state-listed as rare, threatened, endangered or candidate species, a permit may be needed from either United States Fish and Wildlife Service (USFWS) and/or California Department of Fish and Wildlife (CDFW). A permit is not required for non-listed native species or plants that have a California Native Plant Society (CNPS) CNPS Rare Plant Rank of 1B, 2B, 3 and 4.

A similar amount of seed should be collected from each individual plant, regardless of seed production of the individual plant. In other words, don't collect more seed from a high seed-bearing plant versus a low seed-bearing plant. If practical the seed collection should be randomly and evenly collected throughout a population (CNPS 2015). Areas with a high density of weeds, in particular invasive weed species, should be avoided for collection to decrease the chances of inadvertently spreading invasive species either through collection or transfer from clothing and equipment.

Seed bags should be clearly labeled with the following information, plant species name, date collected, location, and the name of the collector. A log should be created each day to keep track of all collected seed. The seed log should include the same bag information and include the number of bags of seed for each species collected on that

day. Dry seeds should be collected in paper bags and moist fruits collected in plastic bags or containers (CNPS 2015). Seeds that are fleshy should be kept in a cool shady place while collecting since overheating can kill the seed. Fleshy seeds should also be dried in the same day of collection, if possible, by being spread to dry or the seed should be refrigerated if drying is not immediately possible.

Since site preparation weed management will occur for multiple years, ideally seed collection should begin as soon as possible so it can occur for multiple years to be able to collect the quantity of seed needed for a restoration project. Seed production is highly dependent on annual weather conditions with seed produced in each year depending on rainfall timing/amounts and temperature conditions that cue germination. In severe drought years, seed production may be extremely low or viable seed may not be produced. If it seems that seed may not be available for certain species or enough seed might not be able to be collected prior to installation, the seed collectors should be directed to opportunistically collect additional species that may be suitable substitutes or additions for the range of restoration targets for the restoration project.

4.1.2 Seed Processing, Cleaning, and Storage

The collected seed should be dried, cleaned, and placed in proper storage to maintain viability and vigor of the seed to increase seed longevity. Germination declines over time for all seed, but proper storage will slow down the rate of decline.

Seed should be dried well before cleaning and storage to ensure optimal quality. Ideally seeds should be dried immediately after harvesting to prevent any fungal growth or rotting and decomposition of the seed. In general, seed should be dried down to 8 to 10% moisture prior to storage. Drying can be done by laying out the seed in a thin layer on a tarp, screen, cardboard, or anything moveable allowing for good air flow for the seed to dry out. Drying can take several days to a few weeks (Houseal 2007). It is best to dry the seed in a sunny area where it will be protected from insect, bird, or rodent predation with temperatures below 90 degrees F because high temperatures can kill the seed. If nights are going to be cool or wet, the seed should be brought inside to a safe place to prevent it from getting wet, which could start to mildew or rot (USFS 1993).

Cleaning the seed of inert material reduces the chances of rotting or molding of the seed. The amount of seed cleaning that is needed will depend on the harvesting method for the seed, how much inert material is present, the desired purity of the seed, and the seeding method to be used with some methods requiring a higher degree of cleaned seed. For optimal cleaning, a seed cleaning machine should be used.

The first step for cleaning is threshing to dethatch the seed from any flower stalks or seed heads. Many different tools can be used for this process such as mechanical threshers or hammer mills or can also be done by hand methods for smaller quantities of seeds using creatively produced, handheld implements that can remove the seed from stalks. The second step is winnowing or sieving the seed through a series of screens to remove chaff, other plant material, weed seed, and empty seed hulls.

Stored seed should be kept free of pests and predation and in conditions to prevent rot and molding. Seed should be stored in a cool dry place with little to no variation in the temperature and humidity. In general, seed stored in a cool, dry place can remain viable for 1 to 3 years. Seed storage can be longer in climate controlled, (temperature and humidity), storage units and seed can remain viable for 3 to 5 years or longer, depending on the species being stored. For the longest seed storage, if properly dried seeds can be stored in freezer conditions and can last as long as 20 years. However, seed longevity for some seed decreases with cold temperature. Removing seed from freezer storage should be avoided, but if it is necessary, care should be taken when removing seed from freezer storage to prevent any moisture from entering the seed storage container. In some cases, seed longevity is only a matter of months regardless of storage such as for willow species (*Salix* spp.) and certain oak species (*Quercus* spp.) and these seeds need to be planted in the same season as collection.

4.1.3 Seed Testing

Prior to use, the seed should be tested for germination and purity to assure the pure live seed (PLS) pounds (lbs) for each species. Individual seed lots (seed collection in one location or in different years) must be tested for seed viability and purity by a registered seed technologist (RST) or similar qualification from the Society of Commercial Seed Technologists (SCST) or by an independent seed-testing laboratory certified by the Association of Official Seed Analysis (AOSA) and tested according to the rules and procedures of the AOSA.

The seed tests should include the following information for each species: botanical name, seed lot number, percent purity, percent germination, percent total viable seed, percent by weight of inert matter, percent by weight other crop seed (not to exceed 1.5 percent), and percent weight weed seed (not to exceed 1.0 percent and 0.0 percent Noxious or Restricted weed allowed). Seed tests shall not contain any weed species listed as noxious or restricted in the State of California. For more information regarding laws and regulations for invasive species, see the following CDFW website: www.wildlife.ca.gov/Conservation/Invasives/Regulations.

Seed tests should be available to the land manager upon request. Seed tests should be performed no more than 12 months before seed application. Retesting for germination may be required if the seeding schedule is delayed and the latest available test date is beyond 12 months.

A sample seed test result is shown in Figure 4-1 for a seed lot of purple needlegrass. The observed germination rate is 82% and the purity rate is 97.43%, and the calculated target PLS is 79.89% excluding the contribution of dormant seed to viability.

It should be noted that in this case testing determined 10% of the seed was dormant. The PLS in the seed report was 89.64% when calculated based on total viability, 92% (82% germination + 10% dormant), and purity, 97.43%.

Report Of Seed Analysis

Account No.	Date Received	Date Completed	Lab Number
	10/27/14	11/20/14	14-14107

Sender's Information*

Kind	**STIPA PULCHRA**
Variety	**--**
Lot Number	**8/20/14**
Other	**(NASSELLA)**

*The information above is provided by the sender.

Purity Analysis		Viability Analysis				
Pure Seed Components	**Purity**	**Days Tested**	**Germination %**	**Dormant %**	**Hard %**	**Total Viable**
STIPA PULCHRA	**97.43%**	**21**	**82**	**10**	**-N-**	**92**
Crop Seed	**0.08%**					
Inert Matter	**2.40%**					
Weed Seed	**0.09%**					

Other Crop Seeds: In 100 grams	**# per lb**
BROMUS CARINATUS	68

Noxious Weed Seeds: In 100 grams **None Found**
(C) California Noxious, (O) Other Noxious

Other Weed Seeds: In 100 grams	**# per lb**
BROMUS CATHARTICUS	41
HORDEUM SP.	9
VULPIA MYUROS	9
CHENOPODIUM SP.	5
MELICA SP.	5

Other Determinations:

Live Seed Per Pound	84,651
P.L.S.	89.64 %

Germination Remarks
DORMANT SEED: 10% GERMINATED WHEN PRECHILLED AND GA3 ADDED
Purity Remarks
INERT MATTER: BROKEN SEED, PLANT MATERIAL, SOIL

Tests Requested Purity, Germination, P.L.S., Live Seed Per Pound. No other tests requested.

WARRANTY: We warrant that the purity and germination test results reported on this form have been carried out in accordance with Association of Official Seed Analysts (AOSA) rules unless otherwise specified. Test results reflect the condition of the submitted sample and may not reflect the condition of the seed lot from which the sample was taken.
DISCLAIMER OF WARRANTIES: WE MAKE NO OTHER WARRANTIES OF ANY KIND, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Signature:

SOCIETY OF COMMERCIAL SEED TECHNOLOGISTS AUTHORIZED REGISTERED SEED TECHNOLOGIST 067 *1922*

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Aleta Meyr, RST; Michael Aberle, RST

Figure 4-1 Sample Seed Test Report for Purple Needlegrass (*Stipa pulchra*)

5 SEED ADDITION

Native plant material will be primarily added to the habitat restoration area by seed after it has achieved weed management thresholds. Restoration success is in large part dependent upon proper site preparation during the weed management step. It is very important to gain adequate control of nonnative species prior to installation. Weed management should continue until the weed management threshold is achieved rather than installing plant material too soon.

Seed installation can be achieved by several methods, including drill seeding, imprint seeding, broadcast seeding, hydroseeding, and the seed ball technique. The

determination of seeding method will be dependent upon site conditions and accessibility. Larger sites that are accessible by equipment can be efficiently seeded mechanically with a drill seeder, imprint seeder, hydroseeder, or broadcast seeder. Smaller sites, sites with a high density of native species, or with unavoidable populations of sensitive species can be seeded (optimally during the fall season) by hand broadcast or the seed ball technique.

An effective method for seed application on very steep slopes (≥1.5:1) is the hydroseed method as the mulch provides an erosion control blanket when using materials such as Flexterra® FGM™ or EarthGuard® Fiber Matrix™.

5.1 SEED MIX DESIGN

A well-designed seed mix is essential to the establishment of a diverse and sustainable native vegetation community. Seed species should be selected to include the appropriate level of diversity for the target vegetation community and based on the site conditions (e.g., soil type, hydrology, slope, aspect, landscape position). Seed mixes can also be augmented with additional species that are typical of the vegetation communities predicted to be suitable in the future (e.g., Riordan et al. 2018), which will help facilitate potential future shifts in plant assembly.

5.1.1 PLANT FUNCTIONAL GROUPS

Seed mixes can be developed by first identifying the key plant functional groups that are ecologically relevant for the target vegetation community, which may include some of the following:

- Early establishment nurse crop
- Erosion control annuals
- Early successional shrub species
- Mid-story mature shrub canopy species
- Native grasses
- Native herbaceous species (annuals and perennials)
- Native trees

It is important to include species that may not be common in the mature, established vegetation community (such as those observed in reference stands) but are common in the community following a natural disturbance, such as wildfire. These species may be found in any of the plant functional groups but are particularly represented in the early establishment nurse crop and early successional shrub species groups. Including these species not only fortifies the seed bank with components necessary for post-disturbance recovery, but they also provide the same function in the habitat restoration seed mix. In the case of restoration from seed, the disturbance is artificially created by the weed management efforts, which allows the seeded natives to establish from a low thatch, higher bare ground cover condition.

Fast germinating erosion control annuals are often included, especially on slopes to provide a cover crop that will help stabilize erodible soils, compete with annual weeds during the early establishment period, and provide time for the native seed mix to germinate and establish. Erosion control annuals may be selected that are not locally native, but native to California or the western United States, because they readily germinate and quickly mature. However, care must be taken to select species that will not compete with the rest of the native seed mix. Erosion control annuals should be selected that will eventually diminish from the restoration area by year two or three, due to their life history traits.

Native annuals, such as California plantain (*Plantago erecta*) and small fescue *(Festuca microstachys)*, can be effective erosion control species, but factors of site (e.g., soil substrate) and year (e.g., rainfall amounts) will influence germination rates, density, and plant size of species (e.g., Espeland and Rice 2007) and, consequently their relative effectiveness for early erosion control. *Plantago erecta* is a widespread and common species in California, but it can be difficult to make sufficient local wild collections for restoration projects; however, *P. erecta* is available from seed suppliers with commercially bulked seed production fields at reasonable costs. We recommend consulting with species experts to determine if the use of any commercially bulked seed is a threat to local wildlife—and if so, identify a suitable alternative species to perform a similar function in the seed mix.

5.1.2 CRITERIA FOR SPECIES SELECTION

Consider the following factors when selecting the appropriate species to include in the seed mix for each relevant plant functional group:

- Site conditions
- Species traits
- Seed sources
- Seed availability from wild collection, seed farm, or commercial sources
- Seed cost for production or purchase from seed vendor

Site conditions to consider include the following: soil type, soil moisture conditions, hydrology, slope, aspect, landscape position and microclimate of the site. Every plant species has a set of unique traits that determine the environmental conditions needed for survival (i.e., species ecological niche). Selecting species that have suitable traits for the range of environmental conditions at the site will help ensure successful establishment. For example, soil type, including soil texture and organic matter content, are important in determining the available rooting depth, capacity of soil to hold water that is available to plants (i.e., available water capacity), the rate at which water drains through the soil profile (i.e., infiltration rate), and soil chemistry (e.g., pH, nutrient availability, salinity). Depending on soil type and other site conditions (e.g., landscape position, hydrology, slope, aspect, and rainfall), the soil moisture of a site may be classified as hydric (wet), mesic (moderate moisture) or xeric (dry). Hydric soils are

poorly drained with standing water for at least part of the growing season and are usually associated with wetland plant species.

The aspect of a slope (i.e., direction it faces) and its slope (i.e., how steep it is) affect the soil moisture as well by influencing how well drained a soil is and the amount of solar radiation it receives. The upper part of a slope is typically drier than the lower part of the slope. South and west facing aspects are relatively more xeric than north and east facing aspects at the same elevation (for the Northern Hemisphere). Consequently, aspect and slope form soil moisture gradients that influence species distribution and assemblages. These differences can often result in striking transitions in vegetation communities, as seen on Catalina island where a north-facing slope with more mesic conditions may be dominated by chaparral plant species with sclerophyllous leaves (i.e., typically evergreen, hard, thick, leathery, small leaves) that form a closed shrub/tree canopy—and on an opposing south-facing slope, the more xeric conditions may support Californian coastal scrub that is dominated by drought-deciduous shrubs with an open canopy.

Species traits to consider after characterizing the site conditions may include the following: geographic range and the population distribution within that range, seed dormancy, life span, growth form, plant height, root morphology, resprouting capacity after disturbance, nutrient requirements (e.g., phosphorus, lime [calcium carbonate]), pH and salinity tolerance, light requirements, and phenology, such as the seasonal timing of seedling emergence and flowering.

Phenology of the species is important to consider. Some plants germinate, grow and flower in fall and spring (i.e., cool-season plants), while others germinate in spring, grow and later flower in summer (i.e., warm-season plants). The lifespan of a plant can be classified as annual, biennial, or perennial. Many of the annuals in a seed mix will be common in the first few years after seed addition, which will provide cover, reduce weed abundance by competing for resources and make contributions to the native seed bank to help facilitate recovery following a future disturbance (e.g., wildfire). As the perennial species germinate and grow, there will be a shift in dominance to perennial species that will provide longer-term structural stability and persistence in the vegetation community. Components from both annuals/biennials and perennials are essential to sustainable habitat restoration, which is why life span is included in the classification of plant functional groups used to design seed mixes (see above).

Identifying appropriate seed sources is an on-going challenge for land managers and restoration specialists. In general, seed from local wild populations in the same bioclimatic region as the restoration site is preferred. In addition to local wildland collection, seed can be obtained from the following sources: a wildland collection from a broader geographic range within a similar bioclimatic profile, first- (F1) or second-generation (F2) nursery bulked seed from special local collections, or commercial seed production fields. Special collections of seed from local wildland can take multiple years, depending on the availability of the specified species each year; therefore, once the seed mix is designed, the seed collection program should start concurrently with the

first years of weed management of a restoration site, to ensure that the seed collection is ready and a sufficient amount has been collected (especially for the key target species) by the time installation is planned (e.g., in the fall of year 3 of a project). For seeds produced at the Conservancy seed facility, production should be timed to begin as needed for the seed to be ready at the anticipated time for seed installation.

Sources of seed for rare, sensitive, or protected species, or such species that have critical ecological relationships with wildlife (e.g., food plant species for butterflies) must be selected carefully to maintain the fitness of the plant population based on best available information. Species experts and wildlife agencies should be consulted for guidance on appropriate seed sources in these circumstances.

In general, it is advisable to maximize the diversity of seed mixes within each plant functional group included in the seed mix design to increase the resiliency of the restored habitat to future uncertainties, such as climate change. However, seed availability ultimately controls the number of species that can be included in a seed mix. If commercial seed is to be used, the cost of seed will also be a factor. The commercial price of seed varies based on its annual availability and difficulty to collect, effort to clean and test, viability in storage (e.g., some species lose most of their viability after less than one year in storage) and demand in the marketplace. Deciding on which species to include depends on the goals of the habitat restoration project, planned native vegetation communities, and the balance of seed mix diversity with target seed application rates.

If the restoration area to be seeded has a high probability of developing into more than one different vegetation alliances (e.g., based on habitat suitability model outputs from Appendix D of the HRMP and/or field assessments), consider increasing the diversity of the seed mix and allowing the microsite conditions in the restoration area to determine the appropriate assemblage of species. In this way, we can leverage nature to establish ecologically appropriate vegetation communities.

5.1.3 PURE LIVE SEED (PLS) SEEDING RATES

After species have been selected to represent each plant functional group in the seed mix, then seeding rates for each species need to be specified. The amount of pure live seed (PLS) must take into account seed loss to predators and various time for germination of types of seed. An example of seed mix design is presented in Table 5-1 for the Californian coastal scrub vegetation type. Five plant functional groups have been selected, with a range of species diversity (i.e., number of species) recommended for each plant functional group. For each species, the desired abundance in the area to be seeded (e.g., common, occasional) can be stated to guide seeding rates, which will be specified as PLS per unit area. PLS is the viable seed in a seed collection lot that will readily germinate, excluding inert matter, other crop seed species, weed seed species, and non-viable seed. In the following example, square feet (sqft) is the area used for designing the seed mix, because it is easier to imagine than a larger area, such as an acre of land. It is helpful to determine the amount of seed that will germinate in the first

season or two by excluding dormant seed and hard seed from the live seed total for PLS determination. Table 5-1 shows the amount of PLS per sqft using the two different calculations.

Table 5-1 Example of Californian Coastal Scrub Seed Mix Design Target Ranges

Plant Functional Groups	Number of Species	Abundance[1]	PLS/sqft[2]	PLS/sqft[3] +dormant seed
1. Early Establishment Nurse Crop & Erosion Control Annuals	2 or more	Common in First Year, Occasional in Future Years	75–125	75–150
2. Early Successional Shrub Species	1-2 or more	Common in Second Year, Occasional in Future Years	5–10	5–25
3. Mid-story Mature Shrub Canopy	5 or more	Common	10–25	10–50
4. Native Grasses	3 or more	Occasional to Common	10–25	10–35
5. Native Herbaceous Species (Annuals and Perennials)	4 or more	Common in Two Years, Occasional in Future Years	50–75	50–100
TOTAL[4]	**15–20 or more**		**150–260**	**150–350**

1. *Target abundance in the habitat restoration site.*
2. *PLS = Pure Live Seed, as determined by seed testing of purity and germination rate of collected seed species. sqft = square feet*
3. *Includes the contribution of dormant and hard seed, as determined by seed testing.*
4. *Final seed mix amount depends on factors such as species availability, collection cost, seed germination rates, site conditions and weather during the collection period. Poor seed collections can increase costs significantly.*

The seeding rate, expressed as PLS/sqft, is the number of seeds determined to achieve a desired plant density. It is important to note that not all the seed will necessarily germinate in the same season or in the same year. The recommended seeding rate range (PLS/sqft) shown by plant functional group for Californian coastal scrub in Table 5-1 is the sum of the seeding rates for each species selected for that group. The sum of seeding rates (PLS/sqft) for individual species by plant functional group and the sum of seeding rates for all the plant functional groups is the total seeding rate for the seed mix. In Table 5-1 the total recommended seeding rate is a range of 150 to 260 PLS/sqft which will achieve the desired plant density. Establishing the appropriate plant density is important. Excessively high plant densities could cause some species to suffer from higher competition for essential nutrients and water; and, conversely, if plant densities are very low, then there may be insufficient plant densities to compete with weeds and create adequate wildlife habitat. Additionally, if planting densities are high, then overseeding occurred which is a “wasting” of valuable limited seed resources.

Seeding rate recommendations are also provided in Table 5-1 that include the contribution from dormant and hard seeds. Some species will only germinate with specific environmental cues, in which case, they will require some pretreatment (e.g., cold stratification, gibberellic acid application) to intentionally "break" the dormancy before they are seeded—unless these environmental cues are known to exist or can be found in the area to be seeded. Most other seeds readily germinate under typical conditions, assuming the seed is ecologically suitable for the site; however, it is common for a small fraction of the total seed (e.g., 5–10%) to have a higher dormancy. The amount of dormant seed in a seed lot can be quantified by the germination seed test. Dormant seed may need more physical scarification of the seed coat or a more extreme cold stratification to break dormancy, in which case, it may germinate in the future, but it may take more time or unique conditions to occur before doing so. Depending on the species and its role in the seed mix, consider planning for the contribution of dormant seed.

PLS seeding rates can be converted into PLS/acres for each species by multiplying the seeding rate in PLS/sqft by the conversion for acres (43,560 sqft in 1 acre).

$$\frac{Target\ Species\ \#\ of\ PLS}{sqft} \times \frac{43{,}560\ sqft}{1\ acre} = PLS\ per\ acre$$

Total PLS quantities for the restoration area can be calculated by the product of the seeding rate in PLS/acre and the size of the area to be seeded in acres.

$$\frac{Target\ Species\ \#\ of\ PLS}{acre} \times\ Size\ of\ Area\ to\ be\ seeded\ (acre) = Total\ \#\ of\ PLS\ Required$$

To calculate the seeding rate in weight (lbs) of PLS per acre, the number of seeds per pound must be known from previously published information. The number of seeds in one pound will vary significantly by species. For example, there are 5,500,000 seeds of California sagebrush in one pound, compared with 450,000 seeds of California buckwheat (*Eriogonum fasciculatum*) in one pound.

$$\frac{Target\ Species\ \#\ of\ PLS}{sqft} \times \frac{43{,}560\ sqft}{1\ acre} \times \frac{1\ lbs}{Known\ \#\ of\ seeds\ per\ lbs} = lbs\ PLS\ per\ acre$$

For example, based on previously reported data, the average number of purple needlegrass seeds per pound is 110,000. If the target seeding rate is 17 PLS per sqft, then the pounds of PLS per acre would be 6.7, as shown here:

$$\frac{17\ PLS\ of\ Stipa\ pulchra}{sqft} \times \frac{43{,}560\ sqft}{1\ acre} \times \frac{1\ lbs}{110{,}000\ seeds\ per\ lbs} = 6.7\ lbs\ PLS\ per\ acre$$

5.1.4 BULK SEEDING RATES

Actual seed collection lots, even after they have been processed and cleaned, are not entirely composed of live seed. Therefore, we need to be able to calculate bulk seed amounts and bulk seed rates. Bulk seed is composed of the seed collected and cleaned, with a small fraction of crop seed (other, non-weed species), weed seed, and inert matter. And the seed collected is not entirely viable, as some of it will not germinate. These amounts are determined from a seed test. Note that the amount of seed material collected in the field, prior to processing and cleaning, will be greater than the cleaned bulk seed amount.

When we need to determine the amount of cleaned bulk seed to be collected for a project, estimates can be made based on the specified PLS seeding rates and past published values for the seed for the following:

- Purity rate (%)
- Germination rate (%)
- Average known number of seeds per bulk pound

For example, based on past seed collection records of purple needlegrass, the typical minimum purity rate is 80% and the minimum germination rate is 90%. PLS is a product of purity and germination (as determined from seed test results) divided by 100.

$$\frac{Purity\ (\%)\ \times\ Germination\ (\%)}{100}\ =\ PLS\ (\%)$$

Therefore, the minimum PLS of a purple needlegrass collection is estimated to be 72% or 0.72 in fraction form, as shown here:

$$\frac{80\%\ Purity\ \times\ 90\%\ Germination}{100}\ =\ 72\%\ PLS\ =\ 0.72\ PLS$$

To calculate the bulk seeding rate, divide the PLS seeding rate in pounds per acre by the PLS percent.

$$\frac{lbs\ PLS\ per\ acre}{PLS\ Fraction}\ =\ Bulk\ seeding\ rate\ per\ acre$$

If the specified seeding rate for purple needlegrass is 6.7 PLS pounds per acre and an estimated PLS of 72%, then the bulk seeding rate would be calculated as follows:

$$\frac{6.7\ lbs\ PLS\ per\ acre}{0.72}\ =\ 9.3\ lbs\ of\ bulk\ seed\ per\ acre$$

The total bulk seed quantities required after cleaning can be calculated by the product of the bulk seeding rate in PLS/acre and the size of the area to be seeded in acres.

$$\frac{lbs\ bulk\ seed}{acre}\times\ Size\ of\ Area\ to\ be\ seeded\ (acre)\ =\ Total\ lbs\ of\ bulk\ seed\ required$$

For the example of purple needlegrass seeded at a bulk rate of 9.3 lbs per acre for a 10-acre site, the total cleaned bulk seed required is estimated to be 93.0 lbs, as shown here:

$$\frac{9.3\ lbs\ bulk\ seed}{acre} \times\ 10\ acres = 93.0\ lbs\ of\ bulk\ seed\ required$$

These calculations should be repeated for each species in the seed mix to determine the total amount of seed to be collected. However, these values are estimates based on past seed collection lots, and the actual germination rate for new seed collection rates can vary significantly. Variance in seed viability (changes in germination rate) from year-to-year is most often seen in wildland collections, as many semi-arid plants exhibit plasticity in reproductive effort in response to rainfall variations (e.g., Ruiru et al. 2015). Commercially farmed seed tends to have consistent germination rates because the plants are grown under a more controlled environment. Therefore, seed should be tested for seed viability and purity to determine the actual percent PLS.

5.1.5 MONITORING FOR SEED MIX DESIGN

After the habitat restoration plan has been prepared, implementation of the project will begin. Concurrent with the seed collection and production process, weeds will be treated in the restoration area for multiple years as part of the adaptive weed management step. During biological and horticultural monitoring activity that is being conducted to inform the timing and method of weed treatment, the restoration specialist and/or field biologist should take note of conditions at the site, updating observations made during the planning stage that informed seed mix design, as discussed above.

These new observations will provide updated site information to help inform final seed mix specifications for installation at the end of weed management. The information collected during the planning stage may have been limited to field visits during one season prior to manipulation of the vegetation cover therefore, the extended weed management period, which may last three or more years, provides the opportunity to better “know-your-site”. The response of the seed bank and existing perennial species to weed treatments, weather and other dynamic site conditions will better inform our understanding of the ecologically appropriate targets for restoration, including the suitable distribution and diversity of vegetation communities and plant species.

Observations of the emergence of any existing native seed bank can both further inform appropriate restoration targets and be used to adjust seed mix diversity and seeding rates. For example, if during thatch removal and weed management, a restoration area seed bank expresses a sufficient density of an early successional annual herb, such as clustered tarplant (*Deinandra fasciculata*), which was previously specified in the restoration seed mix, then it may be dropped from the mix. Removing the species from the seed mix may reduce seed supply costs, make that seed available for use in another area, and/or provide the opportunity to add another complementary annual

herb to increase biodiversity (if the adjustment allows enough lead time to collect or grow the additional species).

This is a significant advantage of implementing longer weed management periods and seed-based restoration because it provides the flexibility to adjust and optimize seed mixes for the restoration area based on observations made over multiple seasons and years.

5.1.6 SEED MIX ADJUSTMENTS

Seed mix species and/or application rates can be adjusted based on the results of seed testing and/or seed availability, as appropriate, to achieve the desired seed mix performance.

Adjustments to the seed mix and the seed collection/production program can be made, as necessary, throughout the weed management implementation period to best match the conditions in the restoration area. This information comes from the monitoring program that is conducted as part of the feedback loop in the adaptive management process. Other adjustments that will need to be made to the seed mix will be based on the following:

- Seed test results, which indicate the actual percent PLS of the seed lots, versus the estimated PLS rates from the initial planned seed mix; and,
- Seed availability.

Using the sample seed test result for purple needlegrass Figure 4-1 it was determined that the percent PLS of this seed lot is 79.89% (excluding the contribution of dormant seed) based on actual, tested purity and germination rates. This is different than the estimate of a minimum of purple needlegrass collection of 72% PLS calculated during seed mix design using published purity and germination rates (see above). Therefore, to achieve the same design goal of 17 PLS per sqft in the seeded area, less bulk seed will be required. An estimated rate of 9.3 lbs of bulk seed per acre was based on the estimated minimum PLS of 72%.

With an actual PLS of 79.89%, the bulk seeding rate should be adjusted to 8.4 bulk lbs per acre, as shown here:

(6.7 lbs PLS per acre)/0.7989 = 8.4 lbs of bulk seed per acre

This adjustment based on actual PLS from seed test results should be made for each species in the seed mix.

Typically, however, not all the specified seed material is available, and adjustments must be made with available seed. The seed collector may have collected additional suitable seed material that was not included in the specified seed mix that can be used to replace or augment shortfalls in the required seed amounts. Or, for species that are in the same plant functional group in the seed mix design, it may be appropriate to increase the rate of one species to supplement shortfalls in the collection of another species.

5.1.7 TIMING OF SEED INSTALLATION

Seed installation should occur in the fall after sites have met the appropriate focal weed thresholds (as discussed in Section 4 of the HRMP) to take advantage of the entire rainy season which is particularly important for non-irrigated restoration sites and at the beginning of the active growing season for vegetation communities in Southern California, except for riparian plant communities. For non-irrigated restoration sites, if seed installation cannot occur by the end of December, then it is recommended to postpone seeding until the following fall. While the applied seed mix can remain viable in the soil for several years for most species, it is important to time seeding to capture most of the rainfall in the first season to allow for germination of the seed mix and a sufficient establishment period prior to dry hot summer conditions.

Sites that are ready to be seeded should have little to no thatch. If significant thatch is present, land managers should rake, collect, and remove it prior to seeding because it will inhibit seed-to-soil contact, required for optimal germination rates.

The installation of native plant material will generally be accomplished by seeding the habitat restoration area following adequate control of weed populations through the weed management phase (i.e., site preparation). Restoration success is, in large part, dependent on adequate weed management prior to the addition of native plant material. Weed management should continue until the weed management threshold is achieved rather than installing plant material too soon because weed management after the addition of seed is much more difficult and labor intensive.

6 SEEDING METHODS

The installation of native plant material will be accomplished by seeding the habitat restoration area following adequate control of weed populations during the weed management phase (i.e., site preparation). Restoration success is, in large part, dependent on adequate weed management prior to the addition of native plant material. Additional weed management events should be conducted as necessary, even if it delays seeding to a subsequent year, because weed management after the addition of seed is much more difficult and labor intensive.

For restoration of native habitats, the following seeding methods are options for installation:

- Drill seeding
- Hydroseeding
- Mechanical broadcast seeding
- Hand broadcast seeding
- Imprint seeding
- Seed ball broadcast seeding

Determination of the appropriate seeding method will depend on site conditions and accessibility. Larger sites that are accessible by equipment can be mechanically seeded with a drill seeder or broadcast seeder. Smaller sites, sites with a high density of native species or sensitive species present can be seeded by hand broadcast or the seed ball broadcast method.

Other seeding methods may be appropriate for a particular habitat restoration project, including hydroseeding and imprint seeding. Hydroseeding requires a water source and is a significantly more expensive method than drill seeding. Imprint seeding is best used in areas where few to no native species are already present. Steep topography, areas of shallow soil and the presence of medium size rocks will limit the use of imprinting. Imprint seeding generally requires the soil to be cleared of thatch and disked prior to imprinting to allow the imprinter to make the specified imprints in the soil. Disking the soil will encourage the germination of weed seed that would not otherwise have germinated. Disking is more appropriate in a condition where there is not a significant weed seed bank, whereas drill seeding is less disruptive to the soil.

6.1 DRILL SEEDING

Range drill seeding is the optimum seeding method for many restoration areas. Drill seeding is efficient, has the highest reliability for applying the seed mix at the desired rate with proper calibration of the equipment and provides good seed-to-soil contact. With a range drill seeder, seed material can be installed with minimal soil disturbance and implemented over mowed plant thatch and equipment can be maneuvered around existing native species to avoid impacts.

Drill seeding is better than broadcast seeding in several ways. Drill seeding provides better seed to soil contact, as the seeds are sown directly into the ground and covered with soil more efficiently than with broadcast seeding methods. Drill seeding applies seed at a more consistently uniform seeding rate and reduces seed loss due to predation and wind scatter. Less seed per acre is required compared to hand-seeding methods thus reducing seed costs and resulting in less “waste” of seed.

However, drill seeding may not be practical in all habitat restoration sites because of the presence of a higher density of native or sensitive species, access limitations for equipment, and incompatible site conditions. For example, if a restoration site has many large rocks on the soil surface, it may not be possible to maneuver the drill seed equipment within the site to seed at a uniform rate. When the drill seeder runs over rocks, it can bounce and not properly create the planting furrows or evenly apply seed.

6.1.1 DRILL SEEDING IMPLEMENTATION

Drill seeding can be used in many habitat restoration projects, where the equipment is able to maneuver based on the slope and where the occurrence of woody native species is relatively low. Range drill seeding can be accomplished over mowed stubble if the thatch is not too thick. In some cases, the thatch may be broken down with light disking

prior to drill seeding. A thick thatch may need to be removed prior to seeding (e.g., by mechanical raking and windrowing Section 2.1.4).

One- or Two-Way Drill Seeding

Depending on the terrain of the restoration area, drill seeding can be accomplished in two passes or in a single pass. For drill seeding in two passes, divide the seed mix into two equal parts and apply each half of the seed mix in perpendicular passes across the site forming a grid pattern. Drill seeding with two passes is generally used on flat to very gentle slopes. For steeper slopes, the one pass method should be used and seeding direction is along the contour of the slope such that erosion rills are not encouraged to form following seed application. Seeds should be planted at a depth of not less than ¼ inch and no greater than ½ inch. Drill seeding equipment should be maneuvered around groups of dense native or sensitive species.

Drill seeding will apply the specified seed mix at the same time through separate seed boxes, with light seeds and heavy seeds divided into separate seed boxes. Wheat bran will be added to facilitate seeding. The bran helps to keep the seeds evenly dispersed in the seed box and produce uniform seeding of different sized seeds (St. John et al. 2012).

Materials to be applied during drill seeding include:

- Specified seed mixes.
- Bran at ¼ the weight of the specified bulk seed.
- Soil Amendments, e.g., arbuscular mycorrhiza (AM) fungi

The seed mixes should be supplied in pre-mixed bulk amounts in 50-pound bags and contain the appropriate amount of wheat bran. All bags should have seed tags declaring each species' bulk weight, pure live seed weight, purity and germination, weight of wheat bran, and total weight of contents.

Drill seeding can also incorporate specified AM fungi amendments, if appropriate and specified at the same time through a separate seed box.

MODIFIED DESIMONE METHOD

When seed is limited and it is preferable to distribute seed across the maximum area possible, while maintaining the specified seeding rates for the seeded areas, use of the "modified DeSimone strip method" should be considered. With this method, seeded strips are installed at the width of the drill seeding equipment (e.g., 6 feet wide) and are alternated with an unseeded strip wide enough for access to conduct remedial weed management but also narrow enough to facilitate natural recruitment from adjacent seeded strips as the native vegetation grows and reaches reproductive maturity.

This method would be most appropriate for sites without a significant source of upwind or adjacent, nonnative propagules that would make the additional on-going weed maintenance required in the unseeded strips cost prohibitive. Weed maintenance would need to continue until the plants in the seeded strips reach reproductive maturity and

successfully recruit into the unseeded strip. Otherwise, it is usually more efficient to seed the entire habitat restoration area under weed management, and if seed sources are limited, collect seed from the mature restored habitat (no more than 15 percent of the seed of any one plant) to install in a second phase of the project later.

6.1.2 DRILL SEEDING EQUIPMENT

Range drill seeders come in a variety of widths ranging from 6 to 15 feet. Planting row spacing can vary between 8 to 12 inches. Drill seeding equipment consists of seed boxes, seed metering devices, drill tubes that drop the seed and a type of soil opening device such as disk openers followed by an implement such as drag chains or press wheels that covers the seed in the furrow with soil. The press wheels also serve to firm and press the soil over the seed (USDA 2009). Range drill seeders can be mounted to many types of equipment like a crawler type dozer or rubber-tired tractor with all-wheel drive.

Drill Seeder Calibration

Seeding equipment requires calibration prior to applying the seed mix to ensure that the seed mix is applied uniformly across the site per the specified seeding rate. All equipment should be checked to ensure everything is in proper working order and any maintenance performed as necessary. Also check the seeding equipment for any impediments to the openers that could inhibit seed flow, clogged tubes, and make sure the tire pressure is adequate. The recommended air pressure of the tires should be set and maintained at the same pressure during calibration and seeding operations. Improper tire inflation will cause inaccuracies in the calibration of the equipment and subsequent inaccuracies in the seeding rates (USDA 2010).

Depending on the type of drill seed equipment, multiple methods are available for calibrating the drill seeder. Refer to the equipment manual for specific guidelines on calibration and how to perform adjustments to the seeder. The following describes general guidelines for drill seeder calibration.

If the specified seed mix is presented in pure live seed (PLS) rates, the rates must be converted to bulk lbs per acre for calibration. Use the following formula for calculating bulk seeding rate per acre.

$$\frac{PLS\ lbs\ per\ acre}{Percent\ PLS} = Bulk\ seeding\ rate\ per\ acre$$

To begin the calibration process, the drill gates should be checked for proper positioning for the type and size of seeds being planted. Calibration of the equipment should start at the widest open position based on the seed sizes in the mix and then closing the drill gates to the proper position. Two commonly used methods for calibration are the seed weight-distance method and the wheel circumference method (USDA 2010).

Some drill seeders have a third seed box for fluffy seed material. If fluffy seeds are incorporated in the seed mix, it is very important to calibrate the drill seeder accordingly. The fluffy seed mix with the carrier should be placed in the fluffy seed box

and the drill seeder should be run to calibrate the specified seeding rate. A carrier such as wheat bran or rice hulls, is used to ensure that different sized seeds stay evenly mixed and to improve seed flow. Approximately 1 acre of seed with the carrier should be sufficient for calibration. If the target seeding rate cannot be achieved, then adjust the amount of carrier accordingly until calibration is set (St. John et al. 2008).

Note: When calibrating the equipment, be sure to calibrate the drill seeder accordingly if applying the seed in two separate passes. The seeding rate for calibration should then be divided in half.

Seed Weight-Distance Calibration Method

Step 1. Compute the area of a 100-foot test run that is based on the drill seeder width.

$$\frac{Drill\ width\ (feet) \times\ 100\ foot\ test\ run}{43{,}560\ square\ feet/acre} = Acreage\ of\ test\ run$$

Step 2. Calculate the amount of seed mix needed for test run.

$$Bulk\ pounds\ of\ seed\ per\ acre\ \times\ acreage\ of\ test\ run = Pounds\ of\ seed\ mix\ needed\ for\ test\ run$$

Then calculate:

$$\frac{Pounds\ of\ seed\ mix\ for\ test\ run}{Number\ of\ seeding\ tubes\ on\ drill} = Pounds\ of\ seed\ mix\ per\ seed\ tube$$

Step 3. Mark the 100-foot test run in the field. The drill seeder should be run for at least 6 feet before starting the test run to make sure the seed is dropping uniformly to prime the drill tubes. The drill tubes should be removed from the disk openers and a collecting implement placed under the tube spout to collect the dropped seed. Drive at a constant speed during the test run. Weigh the dropped seed from a minimum of 2 tubes on either side of the drill and compare it to the calculated seed amount. If necessary, adjust the drill openings. This step should be repeated until the weight of the dropped seed is within 10 percent of the calculated amount. Once the calibration is set, repeat the procedure again at least twice to insure proper calibration (USDA 2010).

Wheel Circumference Calibration Method

The wheel circumference calibration method involves measuring the circumference of the drill drive wheel in feet and then determining the number of revolutions the wheel is required to turn for a predetermined length. To use this calibration method, the drive wheel must be able to be turned by hand without the need for pulling the drill.

Step 1. Calculate the area covered for the determined seeding run length.

$$\frac{Drill\ width\ (feet) \times\ 100\ foot\ test\ run}{43{,}560\ square\ feet/acre} = Acreage\ of\ test\ run$$

Step 2. Calculate the number of drive wheel revolutions. Measure the circumference (perimeter) of the drive wheel to determine the number of revolutions.

$$\frac{Distance\ of\ test\ run\ (feet)}{Wheel\ circumference\ (feet)} = Number\ of\ drive\ wheel\ rotations\ for\ test\ run$$

It is important to note that the measurements in Step 1 and Step 2 should be to the nearest tenth of a foot for accuracy.

Step 3. Calculate the amount of seed mix that would be delivered from each tube for the determined test run acreage.

$$Bulk\ pounds\ of\ seed\ per\ acre\ \times\ acreage\ of\ test\ run = Pounds\ of\ seed\ mix\ needed\ for\ test\ run$$

Then calculate:

$$\frac{Pounds\ of\ seed\ mix\ for\ test\ run}{Number\ of\ seeding\ tubes\ on\ drill} = Pounds\ of\ seed\ mix\ per\ seed\ tube$$

Step 4. The drill tubes should be removed from the disk openers. The drive wheel should be turned until seed is dropping uniformly to prime the drop tubes. A collection implement should be placed under the tube spout to collect the dropped seed. Weigh the dropped seed from a minimum of 2 tubes on either side of the drill and compare it to the calculated seed amount. If necessary, adjust the drill openings. This step should be repeated until the weight of the dropped seed is within 10 percent of the calculated amount. Once the calibration is set, repeat the procedure again at least twice to insure proper calibration (USDA 2010).

Drill Seeder Calibration Field Test

Once the equipment is calibrated and prior to seed installation, perform a field test within a plot approximately 100 feet long in distance to demonstrate that the drill seeder is seeding uniformly at the specified seeding depth and that the furrows are properly covered with soil. Check the uniformity of seeding throughout the day, as many variables can affect calibration of the equipment. Changes in weather conditions such as temperature or humidity can have an effect. Different seed lots of the same mix can also behave differently in the equipment.

Travel speed when seeding is important, particularly in rough terrain or in areas with plant thatch present. Higher rates of speed can cause an increase in disk bounce height when hitting objects in the field, causing areas to be missed, improper furrow depth because the seeder may not dig a deep enough furrow for seed placement or soil displacement further away from the furrow leading to inadequate soil coverage of the seed mix in the planting furrows (Kees 2006). In general, travel speeds are typically set to between 3 and 4 miles per hour.

6.2 HYDROSEEDING

Hydroseeding can be used in areas that are not accessible by an imprinter or drill seeder and may be the only seeding method option on steep slopes. Hydroseeding is a planting process that uses a hydraulically applied slurry of ingredients including cellulose wood

fiber, the specified seed mix, organic binder and tackifier (e.g., "M-Binder"), and any amendments to be added (e.g., slow-release fertilizer, AM fungi). Hydroseeding equipment has access constraints and there must be a source of water for the batch preparation of slurry. The water source may be near the equipment, or water can be transported to the equipment by water truck for example. The slurry can be applied by a spray nozzle mounted to the equipment or by a nozzle attached to a hose to direct application. Long lengths of hose and/or hard pipe can be designed to allow application at up to 700 feet or more, depending on conditions such as pump pressure and the viscosity of the slurry. Prior to hydroseed application, the site should be cleared of plant thatch to provide good seed-to-soil contact.

Hydroseeding can be applied in a one- or two-step process. The one-step application consists of applying the slurry of ingredients in one step. The two-step application consists of applying the specified seed mix, one-quarter of the cellulose wood fiber, and amendments in the first step. The second step consists of adding and applying the remaining cellulose wood fiber and organic M-binder.

For very steep slopes, the best available method for seed application is the hydroseed method, because specially formulated erosion control products can be added, such as Flexterra® High Performance-Flexible Growth Medium™ (HP-FGM™) or EarthGuard® Fiber Matrix™. Refer to the manufacturer's specifications for application rates when applying seed with products such as HP-FGM™ or Fiber Matrix™.

6.2.1 HYDROSEEDING IMPLEMENTATION

The following are sample one-step and two-step hydroseeding application specifications, which should be modified as necessary for the project site application.

Prior to hydroseed application, the site should be cleared of plant thatch to provide good seed-to-soil contact.

Hydroseed mixing should be done in a clean tank. The hydroseeder must be equipped with a continuous agitation recirculation system to produce a uniform slurry. Once the seed and AM fungi inoculum (if needed) are added to the mixing tank, application must be within one hour of preparation. If AM fungi is used, then commercially available *Rhizophagus intraradices* is recommended for the AM fungi amendment, as it is ubiquitous and will not impede the development of other native mycorrhizae species.

A slow-release organic fertilizer may be used, if appropriate. However, the benefit to encouraging germination and growth of the seeded species must be weighed against the risk of encouraging vigorous growth of any weed species remaining in the seed bank. Many of the upland native vegetation community species have physiological traits and/or symbiotic associations with mycorrhizal fungi that colonize the plant's roots, which allow them to grow in lower nutrient content soils, so fertilization may not be necessary or desired.

One-Step Hydroseeding

The one-step application consists of the hydraulic application of a slurry mixture that contains water, cellulose wood fiber, seed, AM fungi (if needed), and organic soil stabilizer as follows:

- 2,000 lbs per acre of virgin cellulose wood fiber or recycled newsprint paper fiber (Enviro Fiber S-100 Hydroseeding Mulch or comparable product)
- 60 lbs per acre of AM fungi amendment (approximately 3,300,000 live propagules per acre of AM fungi based on the guarantee of the supplier) *
- Specified seed mix
- 160 lbs per acre of organic M-binder (Ecology Control or comparable product).

**If needed (most undisturbed native soils do not require the addition of AM fungi).*

Two-Step Hydroseeding

Step 1 – Hydraulic application of a slurry mixture that combines water with the following components:

- 500 lbs per acre of virgin cellulose wood fiber or recycled newsprint paper fiber (Enviro Fiber S-100 Hydroseeding Mulch or comparable product)
- 60 lbs per acre of AM fungi amendment (approximately 3,500,000 live propagules per acre of AM fungi based on the guarantee of the supplier) *
- Specified seed mix

**If needed (most undisturbed native soils do not require the addition of AM fungi).*

Step 2 – Hydraulic application of a slurry mixture that combines water with the following components:

- 1,500 lbs per acre of virgin cellulose wood fiber or recycled newsprint paper fiber (Enviro Fiber S-100 Hydroseeding Mulch or comparable product); and,
- 160 lbs per acre of organic M-binder (Ecology Control or comparable product).

If the air temperature at the site exceeds 90°F, the second hydroseeding step must be applied within three hours of the application of the first step. Regardless of the air temperature, the second hydroseeding step must be applied the same workday as the first hydroseeding step.

6.3 MECHANICAL BROADCAST SEEDING

In restoration areas that are accessible by mechanical equipment, a broadcast seed spreader can be used. Many types of broadcast seeders are available in a range of sizes and can be mounted to an all-terrain vehicle (ATV), tractor, or similar equipment. Broadcast seeders work by centrifugal force and the weight of the seed material (USDA

2009). Mechanical broadcast seeding works best in large restoration areas that are accessible by equipment but where conditions limit the use of a drill seeder.

Disadvantages of broadcast seeding include higher rates of seed loss from wind or predation, higher potential for uneven distribution of seeds, with dense seeds or overcrowding in one location and sparse seeds or lack of seeds in another location, a decrease in seeding depth precision compared to drill seeding, and calibration inaccuracies inherent in the equipment. Calibration of broadcast spreaders is not as accurate for drill seeders because of the different seed delivery methods of the equipment (USDA 2009). Inaccurate calibration will influence the desired seeding rate causing over- or under-seeding.

6.3.1 MECHANICAL BROADCAST SEEDING IMPLEMENTATION

Prior to broadcast seeding, thatch material should be removed from the site because a well-prepared seedbed is critical for seed- to-soil contact (USDA 2009). Good seed-to-soil contact is key for successful germination of the seed mix.

Wheat bran should be added at ¼ the weight of the specified seed mix bulk weight to facilitate seeding. The bran helps to keep the seeds evenly dispersed in the seeder and produces uniform seeding of different sized seeds (St. John et al. 2012).

Materials to be applied during mechanical broadcast seeding include:

- Specified seed mix for each area
- Bran at ¼ the weight of the specified bulk seed

Prior to broadcast seeding, the surface of the soil should be lightly scarified with a hand rake or a 6-foot wide cultipacker attached to an all-terrain vehicle, crawler type dozer, or tractor. Scarification of the ground before applying the seed mix is important to facilitate seed-to-soil contact.

The materials (seed mix and wheat bran) should be divided into two equal parts. Half of the seed should be broadcast across the entire area in a linear orientation appropriate for the site to ensure even coverage. The remaining half of the seed should be broadcast across the site in a linear orientation perpendicular to the first application.

Following seed broadcast, the seed material should be incorporated into the soil at less than ½ inch deep with a cultipacker pulled by a tractor, ATV, or similar equipment. This will increase seed-to-soil contact to improve germination success and reduce loss of seed to wind, erosion, and seed predation.

Mechanical Broadcast Seeder Calibration

Broadcast seeders require calibration prior to seed installation. Refer to the equipment manual for specific guidelines on calibration and how to perform seeder adjustments. The following are general guidelines for broadcast seeder calibration (USDA 2009).

Note: When calibrating the equipment, be sure to calibrate the broadcast seeder accordingly if applying the seed in two separate passes. The seeding rate for calibration should then be divided in half.

Step 1. Determine the bulk seeding rate per acre and convert to anticipated seed per square foot.

Step 2. Several tarps should be placed at different locations within the test area.

Step 3. Run the broadcast seeder within the test area over the tarps and determine the average bulk weight per square foot on the tarps.

Step 4. Increase or decrease the seed flow by adjusting the adjustable gate to achieve the desired seeding rate.

6.4 HAND-BROADCAST SEEDING

Broadcast seeding is an all-purpose seeding method that can be used in relatively small areas limited by access or areas with a high density of natives or sensitive species. Hand-broadcast seeding is the best option in areas where sensitive resource protection is required.

The disadvantage of this method is that hand-broadcast seeding will result in the greatest potential for loss of seed due to wind, runoff, and seed predation, higher potential for uneven seed distribution, greater potential for poor seed-to-soil contact and inefficient coverage in large areas (e.g., greater than one or two acres in size).

6.4.1 HAND-BROADCAST SEEDING IMPLEMENTATION

Prior to hand broadcast seeding, thick plant thatch should be removed to accomplish incorporation of seed into the soil because a well-prepared seedbed is critical for seed-to-soil contact (USDA 2009). Good seed-to-soil contact is key for successful germination of the seed mix.

Hand-seeding will be implemented using a small hand-held seed spreader to evenly broadcast the seed mix.

Wheat bran will be added at ¼ the weight of the specified seed mix bulk pounds to facilitate seeding. The bran helps to keep the seeds evenly dispersed in the seeder and produce uniform seeding of different sized seeds (St. John et al. 2012). It is important to note, since there is a high potential for the loss of seed from hand broadcast seeding, that the specified seed mix may need to be doubled.

Materials to be applied during hand-broadcast seeding include:

- Specified seed mix for each area
- Bran at ¼ the weight of the specified bulk seed

Prior to hand-seeding, the surface of the soil should be lightly scarified with a hand rake or a 6-foot wide cultipacker attached to an all-terrain vehicle, crawler type dozer, or

tractor. Scarification of the ground before applying the seed mix is important to facilitate seed-to-soil contact.

The materials (seed mix and wheat bran) should be divided into two equal parts. Half of the seed should be hand broadcast by walking across the entire area in a linear orientation appropriate for the site making sure of even coverage. The remaining half of the seed should be hand-broadcast by walking across the site in a linear orientation perpendicular to the first application.

Following seeding, the soil will be scarified either with hand-held rakes or a 6-foot wide cultipacker attached to an ATV, crawler type dozer, or tractor. Scarification of the soil following seeding will aid in seed-to-soil contact and provide a thin covering of soil over the applied seed mix. Seeds should be incorporated into the topsoil no more than ¼ inch and less than ½ inch deep.

The method used for scarification of the soil following seeding will depend on access to the site and the size of the restoration area. If the site is accessible with mechanical equipment, then scarification with mechanical equipment is more efficient than hand raking.

Hand Broadcast Seeder Equipment

A hand broadcast seeder is typically comprised of a seed hopper, agitator, flow gauge, "on-off" lever, hand crank for seed dispersal, and shoulder harness.

Hand Broadcast Seeder Calibration

Prior to seeding, the equipment requires calibration to insure uniform distribution of the seed mix. Refer to the equipment manual for specific guidelines on calibration and how to perform seeder adjustments. The following describes general guidelines for seeder calibration and is based on the EarthWay® hand crank broadcast spreader.

Note: when calibrating the equipment, be sure to calibrate the hand-seeders accordingly if applying the seed in two separate passes. The seeding rate for calibration should then be divided in half.

Step 1. Mark the beginning and end of an area 50 feet in length.

Step 2. Calculate the amount of specified seed mix including the wheat bran to be applied to a 1,000 square foot area.

Step 3. Weigh and record the weight of enough seed mix to fill the seeder at least half full.

Step 4. Select an appropriate Setting Rate position on the seeder for the seed material. In general, start with the setting in the middle if unsure of the appropriate setting rate.

Step 5. Start far enough behind the beginning of the 50-foot test area to achieve the desired walking speed. Use a normal pace and crank the handle so that the crank makes one revolution for each step then stop seeding at the end of the 50 feet.

Step 6. Measure the entire spread width of the broadcast seed.

Step 7. Record the weight of the remaining seed material in the seeder and calculate the amount of seed applied.

Step 8. Calculate the amount of seed mix required for test area.

$$Weight\ of\ seed\ mix\ per\ 1{,}000\ square\ feet \times \frac{Spread\ width\ x\ 50\ feet}{1{,}000\ square\ feet} = Seed\ mix\ required\ for\ test\ area$$

Step 9. Compare the results in Step 7 with the calculation in Step 8. If too little or too much seed was applied in the test area, adjust the rate setting accordingly and repeat the test again until the desired application rate is achieved.

All hand-seeders should be calibrated prior to seeding since variations can occur between equipment and the operator. The calibrated rate setting from one seeder can be used as a guide or starting point for calibration of other seeders.

6.5 IMPRINT SEEDING

Imprint seeding is best used in areas with few to no native species already present. Steep topography, areas of shallow soil, and the presence of medium size rocks will limit the use of imprinting. Imprinters consist of a metal roller with teeth that create v-shaped imprints in the soil (Dixon and Carr 2000). The seed is applied at the same time the imprints are made thereby pressing the seed into the soil for better seed-to-soil contact. The imprints should be at a specified depth and stable so that erosion of the imprints or collapse does not occur. Imprint seeding generally requires the soil to be cleared of thatch and ripping or disking prior to imprinting to allow the imprinter to make the specified imprints in the soil. The specified imprints can be made in areas with "soft" soil without the need for disking or ripping. However, if the soil is too soft, such as areas with coarse soils with a high sand content, the imprints can be too unstable. In these instances, imprinting should not be the seeding method utilized. An unstable imprint is subject to erosion of the imprint or collapse burying the seed too deep.

The purpose of the imprint is to provide a "safe" microclimate protecting the seeds from wind, providing shade to prevent desiccation, and serves to collect water to provide moisture for germination. Imprinting is best done in the fall since rain can help to stabilize the imprints and prevent erosion and/or collapse of the imprint. While imprinting works best if soils are moist, imprinting should not be done in wet soils as the soil can stick to the imprinting teeth and resulting in improper imprints. Imprints can generally last for a couple of years and continue to provide moisture for germinated seedlings and provide wind protection from evaporation. It is important to note, that in instances where the soil requires ripping or disking, this will encourage the germination of weed seed that would not otherwise have germinated. Hence, disking is more appropriate in a condition where there is a limited weed seed bank and few native plants. Disking can also result in collateral death to ground dwelling wildlife (e.g.,

snakes, gophers). Drill seeding is generally the more appropriate method in settings where imprint seeding may also be an option.

6.6 SEED BALL BROADCAST SEEDING

An alternative method for hand-broadcast seeding is the use of seed balls. Seed balls are mixtures of clay, compost, seed material and water formed into small balls. The benefit of using the seed ball method is the reduction in loss of seed from wind and herbivory and the clay combined with the compost provides a growing medium and nutrients for germinating seeds. The general recipe for making seed balls is as follows:

- 5 parts dry terra cotta clay
- 3 parts dry organic compost
- 1 part seed mix
- Sufficient water to bind the materials and allow for rolling into marble-sized balls.

The seeds in the seed mix are often very small therefore, the seed mix part of the recipe can be increased in volume with an inert material, such as sand, in order to distribute the seed mix at the desired rate. The amount of seed per seed ball should be adjusted to reach the desired pure live seed (PLS) rate for the restoration area. Too much seed should not be applied to the seed ball so that competition for resources prevents successful establishment of any germinated seeds. Generally, spacing of the seed balls 1-2 feet on-center between will ensure good coverage. Seed balls can be pressed gently into the soil so that approximately half of the seed ball is in the ground.

The seed balls should be allowed to thoroughly dry before storage or placement to prevent premature germination of the seed material.

6.7 SEED MIX ESTABLISHMENT

The health, development, and cover of native vegetative should be estimated visually by site walk overs, performed regularly during the post seed addition maintenance period.

For purposes of evaluating whether remedial seeding may be required to achieve the project success criteria, the project restoration ecologist/biologist shall use the following general guidance for establishment of native cover. Observations will typically be made in spring, but the actual timing of native cover estimates will depend on the phenology of plant growth each year with respect to factors such as weather. The target values for absolute cover of the native vegetation will be as follows:

- **Seed Mix Establishment Monitoring Year 1.** At least 10 to 15% absolute native cover.
- **Seed Mix Establishment Monitoring Year 2.** At least 15 to 25% absolute native cover.
- **Seed Mix Establishment Monitoring Year 3.** At least 25 to 35% absolute native cover.
- **Seed Mix Establishment Monitoring Year 4.** At least 50 to 75% absolute native cover.

Actual cover values will depend in part on growing conditions (e.g., soil nutrients, humidity, temperature, and rainfall) during the establishment and weed maintenance periods and the habitat restoration type. The established vegetation cover and distribution will likely not be uniform, in response to microvariation and fuel management activities in the project zones. Hence, some level of patchy distribution of vegetation cover is expected and natural. Consequently, the target native cover values shall apply to areas of homogenous vegetation cover and will exclude areas that develop conditions that prevent significant vegetative growth, such as extreme soil conditions that are not practical to amend to promote growth. Bare areas or seasonally bare areas although not vegetated, still provide microsite diversity to the habitat.

7 CONTAINER PLANTS AND CUTTINGS

Cuttings and container plants provide three important functions in habitat restoration: (1) to allow plants that are past the vulnerable seedling stage to be introduced and to establish onsite, (2) to provide the means of introducing species that do not establish well from seed, and (3) to provide some diversity of plant age to promote natural regeneration earlier in the restoration process.

7.1 PLANTING LAYOUT

Prior to plant installation, the planting locations for container plants and cuttings should be marked onsite using different colored pin flags and under the supervision of the restoration specialist/project biologist. Groups of container plants should be spaced in a natural-looking mosaic to mimic existing habitat and not planted in rows. The spacing should follow the specified spacing on-center for each species from other container planting and existing native plants. The layout should be determined based on micro topographic features, soil conditions, and site conditions, e.g., aspect or slope.

7.2 CUTTINGS

Direct planting of cuttings can be used for some native species and either don't require being grown in container plants or establish better from cuttings compared to container plants. During container plant production, especially for tree species, the long tap roots can quickly become root bound, which can cause long-term health issues for the planting.

Cuttings are typically done for riparian species such as mulefat (*Baccharis salicifolia*) and willow species (*Salix* spp.). Cuttings should be collected from nearby, intact riparian habitat if feasible and ideally harvested no more than 12 hours prior to installation on the restoration site. Cuttings should be collected in the fall during the dormant season and planted during the rainy season.

For sites that will be irrigated, it is recommended cuttings for both willows and mulefat are made from branches between 3/8- and 5/8-inch in diameter and a minimum of 4

feet in length. Proximity to groundwater depth should be kept in mind when determining cutting length to be able to install the cuttings as close to groundwater depth as possible, particularly for willow species. Cuttings should be kept moist until installation, and it is recommended to dip the cuttings in a rooting hormone and vitamin powder immediately prior to planting. No more than 1/3 of the cutting should be above ground once planted. For cuttings that will be installed with no supplemental irrigation, they should be tall enough (eight feet or greater or depending on groundwater depth) to reach the groundwater when planted. Planting should be time to occur during the rainy season and prior to a forecast rain event so the cuttings can be watered in.

7.3 ACORNS

7.3.1 ACORN COLLECTION

Acorn production varies from year to year depending on many factors, particularly local weather patterns. The abundance of acorns can vary as well as the viability of the acorns. Acorn collection is typically in early fall to early winter. Start assessing acorn production in late summer to determine collection areas and monitor for collection timing. The best time to collect acorns is when they are turning from green to brown and are starting to fall from the tree, usually early fall (September/October). The caps should be easy to remove. Ideally, acorns are collected from the tree since they are generally the healthiest acorns. Collection of acorns from the trees can be accomplished by knocking the tree with a pole or some implement and laying a tarp on the ground under the tree to collect the acorns. Acorns can be collected from the ground; however, these acorns tend to dry out and become damaged. If acorns are collected from the ground, don't collect acorns that are small, cracked, have parasite entrance/exit holes, or feel light.

The general belief is that acorns should be collected from local populations to maintain the integrity of the local oak populations since evolution of certain genetic traits allow the oaks to survive in a particular region (UCANR, Accessed 2023). Ideally, acorns should be collected as close to the planting area as possible trying to match soil, slope, elevation, and exposure to the planting site.

7.3.2 ACORN STORAGE

Acorn caps should be removed, and the acorns soaked in water for a day before storage. Acorns that float should be discarded since these likely have insect damage or have dried out. Place the acorns on absorbent material such as newspaper, paper towels, or the like, to air dry the surface, typically about half an hour. Once dry, place the acorns in plastic bags leaving the bag partially open to reduce mold development and store in the refrigerator. The temperature should be as cold as possible but above freezing. Cold storage in the refrigerator slows down metabolic activity and depletion of stored reserves. Acorns should be inspected occasionally for mold development while in storage and if mold is detected rinse the acorns to remove the mold and then put them back in cold storage. In general, acorns can only be stored for a couple of months and

should be planted the growing season following collection (UCANR Accessed 2023). If the acorns begin to germinate in cold storage, they should be planted as soon as possible as the radicle, or root system, can start to rot in a few weeks.

7.3.3 ACORN PLANTING

Acorns can be planted beginning in November, after the first rains have soaked the soil, through March. Planting acorns as early as possible will allow for maximum root development before dry weather. Acorns planted late in the season, February, or March, will need supplemental irrigation. Planting holes should be dug several inches wide to loosen the soil to allow for root expansion and should be dug as deep as possible. The holes should be backfilled with excavated soil and tamped down firm to approximately one inch below grade. Tamping prevents the soil from settling and the acorn sinking deeper into the hole. Place the acorns on their side in the planting hole and cover with the remaining soil so that the acorn is approximately ½ to 1-inch below the soil surface. If the acorns have germinated, position the acorn so that the root is pointing downward, being careful not to break the tip.

To increase the chances of producing the desired density of oak trees in an area, multiple acorns, as many as four, can be planted per planting hole. Multiple acorns planted in a planting hole should be spaced approximately six inches apart. It is recommended to place at least two acorns per planting hole to increase the success rate for each planting basin. Plant spacing between planting basins depends on the desired density of the oak trees. Spacing should be a minimum of five feet on center for acorn plantings and arranged in a natural mosaic and not in rows.

To improve acorn establishment success, the acorns can be pre-germinated prior to planting. To pre-germinate the acorns, the acorns should be placed in shallow trays with a mixture of moist vermiculite, sand, or peat. The acorns should be laid on their side on the medium and gently pressed in. The medium should be kept moist but not saturated. The trays should be kept at room temperature and observed for the emergence of the radicle (plant embryo that develops into primary root) from the pointed end of the acorn. Once the radicle has emerged, the acorns should be planted as soon as possible.

To increase seedling survival, weeds should be controlled in an approximately two- to three-foot radius around the oak planting and the weeds maintained for at least the first couple seasons of development. This will reduce competition for scarce resources, particularly available soil moisture. After clearing the areas of weeds, mulch can also be used to suppress weed development and conserve soil moisture.

7.3.4 ACORN SUPPLEMENTAL IRRIGATION

Acorn success rate increases with the use of supplemental irrigation for at least the first couple of seasons. If irrigation is not possible, as stated above, the acorns should be installed at the start of the rainy season to maximize development time before dry weather starts. In drought years with significantly lower than average precipitation, acorn survivorship decreases without supplemental irrigation.

If irrigation is possible, the acorns should be irrigated immediately after planting. Dependent on rainfall, the general guideline for irrigation is for weekly irrigation until germination, then weekly for the first month, every other week during the second month and once a month through to the next winter, or as needed and dependent on rainfall. Monitoring of oak irrigation needs is crucial since too much or too little water can be injurious/detrimental to establishing oak plants. A soil probe or shovel should be used to examine soil moisture and rooting depth directly. The amount of applied irrigation should be adjusted as the trees develop to ensure deep penetration of the root system.

Depending on the oak development and the annual rainfall, irrigation may need to continue for a second season following once a month irrigation events or as needed. It is best to avoid or limit the amount of irrigation applied in the summer and should only occur in the first planting season and only in the second season if necessary due to severe drought conditions.

Care should be taken to avoid having the tree trunk and particularly the crown wet or moist for extended periods of time, especially in the summer. This leaves oaks susceptible to various diseases and pathogens. If possible, apply the irrigation away from the base of the tree while still ensuring moisture is delivered to the root system. If mulch is applied around the oak tree, ensure that moist mulch does not contact the crown or trunk of the tree for extended periods, particularly in the summer.

7.4 NURSERY-GROWN PLANTS

Container plant production will be done by the Conservancy at their on-site nursery or if this is not feasible because of the quantities needed for the project, a local nursery that has experience in growing native plants and at least three years of experience growing native plants for the target vegetation communities of the project should be used. The plants should have a well-developed root system and conditioned (prepared to withstand the elements of the natural environment), prior to planting. Mycorrhizal inoculum, if specified, should be incorporated with the greenhouse soil mix according to the label at the time of transplantation to containers.

The container plants should be inspected by the project restoration ecologist/biologist during the growing period. Upon delivery for planting, the restoration specialist should also verify that the plants are the correct species and quantities, are free of weeds, pests, and disease, and show signs of healthy growth. Plants should be grown in the specified container long enough to develop a root system that reaches the bottom of the container and forms a healthy root ball without becoming root bound. Any container plants that are not within these standards should be rejected and replaced. Substitution of plant material at the time of planting depends solely upon the discretion of the project restoration specialist.

It is generally recommended for tree species that deep tree pots are used for large woody shrubs and tree species to allow for healthy development of the deep tap roots

and prevent injury. Injury to tap roots of oaks, for example, has been shown to affect the health of the tree in perpetuity.

7.5 PLANT INSTALLATION

Upon delivery of the contract grown plants from a native plant nursery, or if container plants produced by the Conservancy are stored at the project site prior to installation, the container plants should be properly stored in a designated storage location and kept safe from herbivory, vandalism, theft, as well as maintained (watering) while they are in storage.

All container plants and cuttings should be planted to the following specifications:

- Plants shall be planted with the roots untangled. Roots shall be protected from weather exposure during planting.
- Planting holes will be made with the minimum disturbance to accommodate the root ball or cuttings. For container plants, the planting hole shall be no more than 1.5 times the diameter and 2 times the depth of the container species to be planted made to accommodate the root ball. Oak container planting holes shall be augured with a minimum of disturbance and be no more than 2 times the diameter and depth to accommodate the root ball.
- Planting holes should be backfilled 25 percent with excavated native soil, filled with water, and allowed to drain completely prior to planting. Container plants must never be installed in planting holes with standing water; all water shall be allowed to settle and infiltrate through the soil prior to plant installation.
- A fertilizer packet (Bio Pak™ from Reforestation Technologies International) should be added to each planting hole prior to planting—if needed.
- Plantings shall be set in well-drained planting holes with the crown of the root ball no more than 0.5 inches above grade. Under no circumstances shall the plant crown be buried. Cuttings will be planted so that a minimum of two-thirds of the cutting is buried in the ground. The soil around the planting shall be tamped down sufficiently to eliminate any air pockets in the soil.
- A basin around the planting shall be constructed by creating a berm above the existing grade approximately 24 inches in diameter around the planting.
- Each planting shall be sufficiently watered at least once after installation so that water reaches the lower roots. If possible, the plantings should be watered twice on the day of installation.

7.5.1 SOIL AMENDMENTS

A specially formulated, slow-release fertilizer provided in planting packets can be installed with container plants to aid establishment of the nursery-grown stock. The packets should be buried below the container plant so that their nutrients are available

only to the plants and not weedy seedlings that may develop at the soil surface. Specific formulations are available for different plant types, such as shrubs and trees.

For shrub and herbaceous species, each packet (10 grams weight) should contain a blend of 16% total nitrogen, 6% available phosphoric acid, and 8% soluble potash plus minor nutrients. The nitrogen, phosphorous, and potassium should be coated with a polyurethane coating to provide 15.69% coated slow-release nitrogen, 5.09% coated slow-release available phosphate, and 6.80% slowly available soluble potash. For example, Bio Pak™ meeting these specifications are available from Reforestation Technologies International.

For tree species, each packet (30 grams weight) shall contain nitrogen, available phosphoric acid, and soluble potash plus minor nutrients. The nitrogen, phosphorus, and potassium shall be coated with a polyurethane coating to provide 22 percent coated slow-release nitrogen, 10 percent coated slow-release available phosphate, and 7 percent slowly available soluble potash. For example, Booster Pak™ meeting these specifications are available from Reforestation Technologies International.

7.5.2 PLANT PROTECTION

Local wildlife such as rabbits, pocket gophers and other rodents are expected to browse on the plantings and seed material. If the project restoration ecologist/biologist determines that the plantings are being jeopardized by wildlife, corrective measures such as organic, non-toxic deterrents and fencing/plant cages may be used. No rodenticides should ever be used for a restoration project. Invertebrate pests are rarely a serious problem in this type of habitat restoration project if site conditions are appropriate to the desired habitats.

To protect newly planted acorns or 1-gallon oak trees in areas where gophers and ground squirrels are present, below ground root protection are recommended to be installed to protect against root herbivory/damage. Root guards should be 18-gauge wire with ¾ inch mesh. The planting basin should be approximately 18” in diameter depending on the number of acorns planted per planting hole. The root guard shall be buried approximately 24 inches below ground and extend above the ground two to four inches. The root guard shall have an open bottom so as not to inhibit plant roots. Power augers can be used to dig the holes to the appropriate depth and width. The root guard material shall not be galvanized so that it breaks down in the environment over time after it is no longer needed for root protection.

If browsing is detected on young saplings, above ground protection can be installed. Wire caging, similar to the root guards can be installed using 18-inch gauge wire with ¾ inch mesh, such as chicken wire. The recommended diameter of the cage is approximately four feet with a height of four feet to protect the sapling from browsing while not inhibiting growth. The wire can be “stitched” together with binding ties and anchored to the ground using two pieces of rebar on opposite sides of the cage. Inspection of the planting cages should occur regularly to ensure tree growth is not inhibited by the cage and damage/girdling is not occurring.

Planting cones or tree shelters are an alternative to the cages; however, they are not recommended. Cones and shelters tend to inhibit lateral expansion of the root crown, do not protect the upper portions of the sapling that extend beyond the top of the shelter from browsing, and can increase the ambient temperature near the tree. Tall tree guards that significantly reduce available light can produce spindly top-heavy young trees that may be too heavy for the trunk to support the tree crown which allows for the tree to be easily damaged from high winds. If planting cones or tree shelters are used, inspect the health of the plant regularly to ensure the tree guards are not inhibiting growth and development of the tree.

Once the above ground plant protection is no longer needed, or if it begins to inhibit the development of the tree, the guards should be carefully removed.

7.6 PLANT SURVIVORSHIP

In at least the first two years of establishment after planting, survivorship of container planted trees and shrubs should be visually assessed during the spring and determined by counting the total number of dead container plants. Survival of container plants within the first two growing seasons should typically be at least 80 percent. Plants should be replaced if survivorship falls below 80 percent in the first season, including loss due to vandalism. Replacements should be planted as previously specified and maintained for one growing season, with hand-irrigation if necessary. Replacement tree species such as oaks may need more than one year of maintenance before they are established.

After the second year of establishment, container plant survival should be visually estimated. As sites develop, it is very difficult to implement direct counts of all the container plants especially in woodland and riparian habitats. Natural recruitment of trees and shrubs in these habitats should occur and preclude the necessity for plant replacement. Replacement planting after the first season should only be specified if the visual estimate indicates substantial mortality over 60 percent in the second establishment year and the function of these species has not been replaced by seeded material and natural recruitment.

8 TEMPORARY IRRIGATION SYSTEM

When nursery-grown plants or cuttings are used, a temporary irrigation system is often necessary to supplement natural rainfall. There are several types of irrigation systems, as well as alternative watering systems, including the following: overhead, drip, micro-sprinkler, bubbler, hand watering from water truck or reservoir, and biodegradable watering shelters (e.g., Cocoon by Land Life Company).

The advantage of overhead irrigation is that it mimics natural rainfall, provides an even distribution of water across the site and is durable and low maintenance. However, overhead irrigation uses the most amount of water and there is loss through evaporation.

Drip and micro-sprinkler irrigation systems both make more efficient use of water by directing water application, but they can be readily damaged by weathering or animals. Bubbler irrigation systems also are water efficient, direct the application of water with strategically placed bubbler heads, and have the advantage of being more durable.

When a limited number of watering events are required or a limited number of plants need to be irrigated, hand watering can be an effective approach. Plants can be watered by hand using a hose that is attached to a water truck or a reservoir/basin that is filled externally by a water truck, from a well or from a municipal water source, for example. Another option is to install biodegradable watering shelters in which basins are placed in the planting holes, fitted around the plant stem(s), and filled with water by hand. The intent of using the watering shelters is to provide enough water for the first year of establishment.

Water used for irrigation must be of good quality with total dissolved solids (salts) at no greater concentration than 500 parts per million (ppm). Individual chemical constituents should be evaluated against the site soil tests, if available, to avoid salt build-up in the soils.

The following are typical specifications for an overhead irrigation system with impact sprinklers and a bubbler irrigation system.

8.1 OVERHEAD IRRIGATION SYSTEM

A temporary above-ground irrigation system should include the following features, as appropriate:

- The mainline will have lateral lines and gate-valves to separately manage the different areas or habitats, as necessary, depending on soils and landform.
- Sprinkler heads will be tested to accommodate the infiltration rate of the soil and landscape position. The size of the sprinkler heads and application rate will be determined after infiltration is evaluated in each area.
- The system will be laid out so that the wetted area from each sprinkler head has no more than a two- to three-foot overlap with adjacent sprinklers. The final layout design will depend on the system water pressure and the size of the sprinkler heads (based on the infiltration rate of the soil).
- Separate valves will be installed to manage overhead impact sprinklers. This is important because it may be required to turn off valves where nesting sensitive bird species are present.
- All impact sprinkler stems will be fitted with on/off ball valves to allow for hose connections and hand watering of container plants at installation and during establishment, as necessary. These valves will also allow specific areas to be shut off, as necessary.

The size of the sprinkler heads and application rate should be determined after infiltration is evaluated for the restoration area. Sandy and sandy loam soils typically have high infiltration rates.

For riparian habitat restoration, the system should be flexible and easily disassembled when it runs across waterways for easy removal during periods of high flow. If the irrigation system is in the active floodplain, then it should be portable for removal prior to the onset of heavy rains or other conditions that might result in the loss of the irrigation system.

An overhead irrigation system can also be used to germinate and establish seeded material, as appropriate.

8.2 BUBBLER IRRIGATION SYSTEM

For more direct irrigation of planted trees and large shrubs, such as island scrub oak. A temporary bubbler irrigation system should include the following features, as appropriate:

- A mainline with lateral lines will be installed with gate valves to separately manage areas within the restoration site, as necessary depending on site soils and landforms.
- PVC lateral lines will be laid out from the mainline to individual container plants.
- Full circle bubbler nozzles will be installed at each planting location.
- Individual bubbler nozzles will be pressure regulating.
- The irrigation system shall be fitted with on/off ball valves to allow for hose connections and hand watering of container plants at installation and during establishment, as necessary. These valves will also allow areas to be shut off, as necessary.

8.3 IRRIGATION SYSTEM OPERATION

Supplemental irrigation should be timed to mimic natural rainfall patterns to extend the rainy season in the fall and spring. Upon completion of plant installation, irrigation should occur weekly for about the first month in the absence of adequate rainfall to prevent desiccation of the container plants or cut material.

For the establishment of tree species, the container plants should be irrigated once per week in the weeks without sufficient rainfall for the first two months and then monthly for the remainder of the first year of establishment with approximately 10 to 15 gallons of water provided for each container plant. Irrigation in the second year will be applied to mainly supplement or mimic natural rainfall patterns in the spring and fall in such a way that plants develop deep root systems to maximize survival and vigor after irrigation is removed. Irrigation in the third year will only be used as sparingly as possible if drought conditions are severe.

For riparian and woodland habitats, in general, the temporary irrigation system is used for a minimum of two years to establish container plants. Native trees and shrubs may require irrigation in the summer of the first year, as well as several subsequent seasons of irrigation for successful establishment.

The irrigation system should not be operated with any type of controller or automatic timer. The irrigation system should be run manually and only when at least one maintenance person is on site to check the system for leaks and prevent blowouts.

The timing of irrigation events will depend on the amount of evapotranspiration between events and soil moisture. Regarding irrigation, there are only guidelines to follow and no cookbook formula (i.e., step-by-step prescriptive procedures) for successful water management of native vegetation.

The following is a sample irrigation management scheme:

- Irrigate soil to full field capacity to the desired depth (approximately 18 inches during germination and seedling/cutting/plant establishment; and 18-24 inches during subsequent establishment).
- Initially keep seeded areas moist until seeded material has germinated (if applicable).
- Allow soil to dry down to approximately 50-60 percent of field capacity (in the top 6-10 inches after germination and during seedling and plant establishment; and 8-12 inches during plant establishment) before the next irrigation cycle.

Wetting of the full root zone and drying of the soil between irrigation events is essential to the maintenance of the plants and the promotion of a deep root zone that will support the vegetation in the years after establishment. A soil probe or shovel should be used to examine soil moisture and rooting depth directly.

9 ON-GOING MANAGEMENT

One of the goals of a restoration plan is to create native habitats that will be self-sustaining and long term. Initially, maintenance of a project will be necessary to establish the newly seeded and or planted restoration area. To achieve habitat restoration goals, on-going management of the restoration site may be necessary after site preparation (i.e., weed management) and seed addition. There are several reasons that the habitat restoration project may require on-going management, including the following:

- There are portions of the project that have higher weed loads than others and require post-seeding weed maintenance to facilitate the establishment of the native vegetation
- To contain or eradicate the population of a high priority invasive plant species
- Supplemental irrigation for installed container plants or cuttings

- Remedial seeding in areas where germination of the native seed mix failed after at least one season of adequate rainfall
- Replacement of container plantings or cuttings in localized areas with less than 80 percent survival in years one and possibly year two of plant establishment, based on visual assessments of substantial mortality
- Installation of erosion control best management practices (e.g., straw wattles and a native remedial seed mix) following significant erosion requiring repair
- Conservation activities for sensitive species
- Pest and disease control, if necessary (no rodenticides should be used)
- Removal of trash, debris, and litter (Restoration Contractor is only responsible for trash produced as part of this project; Restoration Contractor is not responsible for illegal dumping, trash left by neighbors or the public on the trail system)

The amount of remedial weeding required each year will depend on weather conditions, development of the native habitats and the density and type of weed species in the restoration area. Post-seed installation maintenance period can be up to five years beginning after installation of plant material. In general, the most intense maintenance is in the first two years of establishment and only seasonal spot-weeding activities in the third through fifth years, as needed. Weed control should be as needed to control weed species while minimizing disturbance to the restoration area and should be scheduled as determined by the project restoration ecologist/biologist.

Remedial weeding effort can be greatly reduced with an increase in the duration and/or intensity of nonnative weed management prior to seeding. It is very important to wait to add native plant material until after it is determined that adequate weed management has been accomplished.

9.1 POST-SEEDING WEED MANAGEMENT

After seed and plant installation the primary method of weed management should be hand weeding; however, under the direction of the project restoration ecologist/biologist, select use of other methods, including targeted spot spray application of herbicide using a low-pressure nozzle for high priority invasive species or perennial weeds, or line trimming of dense stands of weeds, may be allowed. The restoration ecologist/biologist must weigh the relative cost-benefit of the effectiveness of weed control with either herbicide or line trimming compared to unavoidable collateral damage to the native plants in the treatment area. Only post-emergent herbicides should be used and applied according to methods and recommendations described in the restoration plan and be consistent with the Conservancy's herbicide use policies.

Timing is critical to successful weed management, so the restoration ecologist/biologist should conduct phenological monitoring to determine the appropriate timing and method of weed control events.

Post-seeding weed management should be concentrated where nonnative plants inhibit native plant germination and/or growth, as well as to continue the control of high priority invasive species that can readily re-establish in the restoration area. The amount of post-seeding weeding required each year will depend on weather conditions, development of the native habitats, and the density and type of weed species in the restoration area. The objective of post-seeding weed management is to reduce nonnative plants to a threshold level that allows desirable native species to establish and thrive.

Careful weeding shall be done by trained crews to avoid damage to the establishment of the native vegetation. Weeds should be removed on a regular basis, as necessary and if possible, before they set seed and/or reach approximately 12 inches in height. All seed material that has set prior to a weed control event should be carefully collected and removed from the site so as not to be introduced into the weed seed bank. All weeded material should be raked, removed from the site, and properly disposed of.

Adaptive management is key to success and includes regular monitoring to guide the scheduling and selection of control methods. Care should be taken to limit the amount of soil disturbance and trampling of native seedlings from weeding activities. The management of weeds must be balanced with the negative side effects on native plant development (i.e., not all weeds in a site need to be treated). It is important to train the crews to weed by sweeping through a site and target weed control for the weeds that need to be weeded at the stage described above. Other weeds that have not reached the desired control stage should be left to weed later. This will limit the amount of disturbance in each area during a weed control event.

9.1.1 CONTROL OF HIGH PRIORITY INVASIVE SPECIES

Control of the target high priority invasive species should follow the species-specific best management practices (BMPs) of the Conservancy's CHIRP program to treat high priority invasive species that may not be controlled with routine weed management methods. If herbicides are used, great caution should be used with foliar spray application to avoid any drift or overspray to establishing native plants. To limit herbicide drift or overspray, the stump-cut method should be used when possible and appropriate for woody perennial invasives.

9.1.2 REMEDIAL SEEDING

Remedial seeding may be necessary in areas with significant erosion or if native cover is low. Significant erosion areas should be repaired and re-seeded in the first fall seasons after damage. Re-seeding should occur in areas if coverage is less than 20 percent of native species over any contiguous area of 200 square feet. Collecting and storing extra

seed for remedial seeding purposes is advised to ensure that seed is available and ready to use at the time needed for remedial seeding.

Remedial seeding is often best accomplished using hand broadcast seeding methods when the area to be repaired is relatively small (e.g., less than one acre). Seed should be applied using the hand broadcast seeding method using a hand-operated device. The ground shall be lightly scarified with a hand rake prior to seeding. Scarification of the ground is important to facilitate seed-to-soil contact. Wheat bran should be added to the seed mix to achieve even dispersal of the seed material. Seed shall be mixed with the carrier stated above and divided into two equal parts. Half of the seed shall be hand-broadcast by walking across the entire area in a linear orientation appropriate for the site making sure of even coverage. The remaining half of the seed shall be broadcast by walking across the site perpendicular to the first application. Materials to be applied during hand broadcast seeding are the following:

- Specified remedial seed mix
- Wheat bran at ¼ the weight of the specified bulk seed
- 60 lbs/acre of AM fungi (commercial variety *Rhizophagus intraradices*)

Following seeding, the soil will be scarified with hand-held rakes. Scarification of the soil following seeding will aid in seed-to-soil contact and provide a thin covering of soil over the applied seed mix. Seeds should be incorporated into the topsoil no less than ¼ inch and no more than ½ inch deep.

9.1.3 Container Plant Replacement

Container plantings and cuttings should be replaced if survivorship falls below 80 percent after the first year of plant establishment. Replacements should be planted as previously specified and maintained for a minimum of one growing season, as necessary. As sites develop, it is impractical to implement direct counts of all the container plants. Replacement planting after the first season shall only be specified if the visual estimate indicates substantial mortality and the function of these species has not been replaced by seeded material and natural recruitment.

Oak Plant Replacement

Oak container plant replacement can be accomplished by replanting of container plants or through the planting of acorns. Acorn replacement can be accomplished more readily than container plants since between the time of acorn collection, plant production, and planting will be approximately one year. Alternatively, acorns can be collected and planted immediately in the same season. Acorns can either be planted in container planting basins or new planting basins can be created for installation.

Container plantings and acorn plantings should be planted as previously specified Section 7.5 and Section 7.3.3 in the restoration plan and maintained (e.g., irrigated) for up to two years or as needed for plant establishment.

9.1.4 Erosion Control

Erosion control measures, including straw wattles, silt fencing, or erosion mats, may be required for protection of the project as wells as any necessary repairs from washouts and rutting that may occur from rain events or irrigation related issues. Erosion control measures and erosion repairs should be as needed and approved by the project restoration ecologist/biologist and the Conservancy prior to implementation.

9.1.5 Pest and Disease Control

Local wildlife such as rabbits, pocket gophers and other rodents are expected to browse on the plantings and seed material. If the Restoration Specialist determines that the plantings are being jeopardized by wildlife, corrective measures such as organic, non-toxic deterrents and fencing/plant cages may be used. No rodenticides should ever be used on the project. Invertebrate pests are rarely a serious problem in this type of habitat restoration project if site conditions are appropriate to the desired habitats.

If it is observed that the root systems of coast live oak plantings are being predated upon by pocket gophers, then open bottom protective root guards shall be installed in the planting basins prior to acorn plantings or container plant replacement. Root guards shall consist of using 18-guage gopher wire with ½ inch mesh to protect against gopher herbivory. The root guard material shall not be galvanized. The root guard shall have an open bottom so as not to inhibit plant roots. The root guard shall be buried at a minimum of 24 inches below ground and extend above ground two to four inches.

9.1.6 Removal of Trash and Debris

During project implementation, the restoration area should be kept free of trash and debris. If large trash items are dumped illegally in the project area, the Conservancy should be responsible for the cost of removing the items.

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Appendix G

Regulatory Setting

1 FEDERAL RESOURCE REGULATIONS

Federal Endangered Species Act (16 US Code 153 et seq.)

The FESA of 1973 provides for (1) the conservation of plant and animal species that are listed by the federal government as endangered or threatened with extinction throughout all or a significant portion of their range and (2) the conservation of the ecosystems on which they depend. A federally listed species is protected from unauthorized "take" pursuant to Section 9 of FESA. "Take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or to attempt to engage in such conduct. Persons are prohibited from taking a federally listed species unless and until (1) the appropriate Section 10(a) Permit has been issued by the USFWS or (2) an Incidental Take Statement is obtained as a result of formal consultation between a federal agency and the USFWS pursuant to Section 7 of FESA and the implementing regulations that pertain to it (50 Code of Federal Regulations [CFR] 402).

Migratory Bird Treaty Act (16 US Code 703–711)

The federal Migratory Bird Treaty Act (MBTA) of 1918 implemented the 1916 Convention between the U.S. and Great Britain (for Canada) for the protection of migratory birds. Later amendments implemented treaties between the U.S. and Mexico, the U.S. and Japan, and the U.S. and the Soviet Union (now Russia). At the heart of the MBTA is this language:

Establishment of a Federal prohibition, unless permitted by regulations, to "pursue, hunt, take, capture, kill, attempt to take, capture or kill, possess, offer for sale, sell, offer to purchase, purchase, deliver for shipment, ship, cause to be shipped, deliver for transportation, transport, cause to be transported, carry, or cause to be carried by any means whatever, receive for shipment, transportation or carriage, or export, at any time, or in any manner, any migratory bird, included in the terms of this Convention . . . for the protection of migratory birds . . . or any part, nest, or egg of any such bird." (16 U.S.C. 703)

Under current interpretations, disrupting the nesting of nearly any native bird species may be considered a violation of the MBTA.

2 STATE OF CALIFORNIA RESOURCE REGULATIONS

California Endangered Species Act (California Fish and Game Code Section 2050 et seq.)

Pursuant to the California Endangered Species Act (CESA) and Section 2081 of the Fish and Game Code, an incidental take permit from the California Department of Fish and Wildlife (CDFW) is required for projects that could result in the take of a state-listed threatened or endangered species. Under CESA, "take" is defined as an activity that would directly or indirectly kill an individual of a species. An incidental take permit

authorized by CDFW under Section 2081(b) of the California Fish and Game Code would be required where a project could result in the taking of a state-listed threatened or endangered species. The application for an incidental take permit under Section 2081(b) requires the preparation of a conservation plan, generally referred to as a Habitat Conservation Plan.

The State of California considers an endangered species as one whose prospects of survival and reproduction are in immediate jeopardy; a threatened species as one present in such small numbers throughout its range that it is likely to become an endangered species in the near future in the absence of special protection or management; and a rare species as one present in such small numbers throughout its range that it may become endangered if its present environment worsens. The rare designation applies only to California native plants. Under CESA, CDFW is authorized to issue permits authorizing incidental take of threatened and endangered species.

California Fish and Game Code (Sections 1600–1616)

Pursuant to California Fish and Game Code Section 1600, CDFW regulates all diversions, obstructions, or changes to the natural flow or bed, channel, or bank of any river, stream, or lake that supports fish or wildlife or riparian vegetation. Activities conducted by private parties that involve such alterations (i.e., diversions, obstructions, or changes) to natural streambeds or lakes that support fish or wildlife require authorization from CDFW by means of entering into a streambed alteration agreement pursuant to Section 1602.

California Fish and Game Code (Sections 3511, 4700, 5050, 5515)

These sections provide for the protection of bird, mammal, reptile, amphibian, and fish species that are “fully protected.” Fully protected animals may not be harmed, taken, or possessed.

California Fish and Game Code (Sections 3503, 3503.5, 3513)

These sections make it unlawful to take, possess, or needlessly destroy the nest or eggs of any bird, except as otherwise provided by this code or any regulation made pursuant thereto. Section 3503.5 explicitly provides protection for all birds of prey, including their eggs and nests. Section 3513 makes it unlawful to take or possess any migratory non-game bird as designated in the federal MBTA.

California Fish and Game Code (Title 14, California Code of Regulations, Sections 670.2, 670.5)

These sections list animals designated as threatened or endangered in California. CDFW designates species considered to be indicators of regional habitat changes, or potential candidates for future state listing, as California Species of Special Concern.

Appendix H

Nesting Bird Management Plan

Prepared for

CATALINA ISLAND CONSERVANCY™

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1 MANAGING FOR NESTING BIRDS

Effective management of nesting birds involves preventing nest failures while minimizing project delays, as outlined below:

1. Conduct pre-project nesting bird survey no more than one week prior to start of planned project actions.
2. For each active nest detected, establish, and delineate a species-specific buffer in which project activities shall be restricted to avoid take of active nests, eggs, nestlings, or nesting birds.
3. Conduct periodic biological monitoring of active nests within or adjacent to restoration sites, to ensure that buffers are being adhered to and to confirm that buffers are adequate to avoid disruption of any active nest.

1.1 DEFINITION OF "ACTIVE NEST"

The term "active nest" is not defined in either the federal Migratory Bird Treaty Act or the California Fish and Game Code. For purposes of this NBMP, a nest is considered "active" when construction of a new nest or use of an existing nest commences. In most cases, a previously active nest becomes inactive when it no longer contains viable eggs and/or living young and is not being used by a bird as part of the reproductive cycle (eggs, young, fledging young still dependent upon nest). In some cases, a nest can be abandoned by the bird constructing it and become inactive prior to egg laying. In such cases, determination that the nest is inactive is to be made on a case-by-case basis based on consistent observations and the determination of the Biological Monitor. Using this approach, buffers are established around the nest upon nest discovery and/or prior to commencement of construction activities and will remain established until the nest is determined to be inactive by the Biological Monitor or restoration activities are completed in the nest vicinity.

1.2 SURVEY METHODS

During each field visit the surveyor will watch for birds, and for evidence of bird nesting, within the survey area. Evidence of nesting includes observations of copulation, carrying nest material, nest building, agitated behavior, distraction displays, carrying food, removal of fecal sacks, and other characteristic behaviors that indicate the presence of an active nest.

Trees within 300 feet of work areas shall be inspected for the potential presence of nesting raptors.

Once a nest is found, the surveyor will attempt to determine the stage of nesting (nest building, incubation/brooding, small young, large young, or fledglings near the nest). If

no adult or juvenile bird activity is observed after one hour (four hours for raptor nests), the nest can be considered inactive.

Every effort will be made to avoid exposing the nest to potential predation because of survey and/or monitoring activities. All nest visits will be conducted by a single surveyor and will last only as long as necessary to check the nesting stage or until circumstances necessitate departure (e.g., potential nest predator detected or sustained indications of stress by any protected bird).

Surveyors will remain of the possibility of additional, undetected nests nearby. They will avoid creating a scent or visual path that directs animals to the nest (e.g., leaving no trampled spot by the nest and continuing past the nest upon leaving it rather exiting on the entrance path).

1.3 ESTABLISHING NEST BUFFERS

Upon discovering an active nest, the Biological Monitor will establish a buffer within which construction activities will be temporarily restricted. Table A identifies standard buffer distances based on the natural history and known tolerances of bird species known to nest on the island. Beyond the identified buffer distance, project activities are considered very unlikely to cause nest failure. The starting point for these standard buffers is the table of buffer distances approved by the US Fish and Wildlife Service and California Department of Fish and Game for previous projects in southern California (ICF International and Bloom Biological 2011, Hamilton Biological 2021). The standard buffer distances proposed herein also reflect Robert Hamilton's experience conducting nesting bird surveys and monitoring nesting birds in a variety of settings. Prior to finalization of this plan the buffer distances were reviewed and adjusted by personnel from the Catalina Island Conservancy, the biologists most familiar with the sensitivity to disturbance of different bird species on Catalina Island.

The bird species included in Table A reflect Mr. Hamilton's understanding of the nesting birds of Catalina Island, based mainly on the *Checklist of the Avifauna of Santa Catalina Island* (Dvorak 2015). Any additional bird species that might unexpectedly nest within the project's area of potential disturbance would have to be addressed on a case-by-case basis.

Buffers shall not be required for non-native and domesticated species, including domesticated geese and ducks, Wild Turkey, Feral/Rock Pigeon, Eurasian Collared-Dove, Spotted Dove, parrots, parakeets, Swinhoe's White-eye, European Starling, and House Sparrow. Whereas no requirement exists to provide a disturbance-free buffer around the nests of the above-identified exotic and domesticated species, note that the destruction and/or removal of the active nest of *any* bird species is prohibited under Section 3503 of the California Fish and Game Code.

Nest buffers are normally established in the field using colored flagging tape but may be established using other materials or methods so long as the buffer's limits are clearly demarcated for those who must stay clear of the buffer.

When establishing the buffer, the Biological Monitor will evaluate the appropriateness of establishing either a reduced or an expanded buffer (relative to the distance given in Table A) based on relevant factors. A reduced buffer may be appropriate if, for example, the nest is effectively shielded from human activity by existing infrastructure; if the birds appear to be unaffected by ongoing, non-project human activities; if the type of restoration activity is relatively benign; or if the nest already has young that are unlikely to be abandoned due to previous parental investment in the nest. An expanded buffer may be appropriate if, for example, the nest is positioned in an exceptionally vulnerable location; if the birds' behavior indicates unusual sensitivity to human activity; if the construction activity is unusually intense; or if the nest is at an early stage, when parents may be more likely to abandon.

If the Biological Monitor establishes a buffer larger or smaller than the standard buffer identified in Table A, the monitor will document the reasoning behind this decision. Relevant information to mention in the discussion of a variance may include:

- Distance to project activity.
- Type and anticipated duration of project activity.
- Microhabitat at the location of the nest that may provide visual or acoustic barriers.
- Observations of bird behaviors at the nest.
- Reproductive cycle stage.

Upon establishing the buffer, the Biological Monitor will provide a map of the buffer to the restoration foreman and inform them of the restrictions to work activities within the buffer.

1.4 PERIODIC NEST MONITORING

The adequacy of the buffer around a given nest, for the activity being conducted nearby, shall be evaluated, and documented by the Biological Monitor during periodic monitoring of the nest during construction activity. If a nesting pair is seen to become agitated or an incubating bird leaves the nest in apparent response to project activity, the Biological Monitor shall increase the buffer distance and then evaluate the adequacy of the increased buffer. The Biological Monitor shall be authorized to halt work in the vicinity of the nest until verifying that an adequate buffer has been established.

Table A. Standard Nest Buffers.

Avian Group	Species	Standard Buffer (ft)
Waterfowl	Mallard	100
Waterfowl	Ruddy Duck	100
New World Quail	California Quail	75
Doves	Mourning Dove	25
Swifts	White-throated Swift	50
Hummingbirds	Anna's Hummingbird	25
Hummingbirds	Allen's Hummingbird	25
Rails	American Coot	100
Shorebirds	Black Oystercatcher	125
Shorebirds	Killdeer	125
Alcids	Scripps's Murrelet	300
Gulls and Terns	Western Gull	150
Gulls and Terns	Caspian Tern	300
Storm-Petrels	Leach's Storm-Petrel	150
Storm-Petrels	Ashy Storm-Petrel	150
Cormorants	Brandt's Cormorant	300
Cormorants	Double-crested Cormorant	150
Herons and Egrets	Great Blue Heron	150
Herons and Egrets	Black-crowned Night-Heron	150
Birds of Prey	Osprey	150
Birds of Prey	Bald Eagle	300
Birds of Prey	Red-tailed Hawk	150
Barn-Owls	Barn Owl	150
Typical Owls	Northern Saw-whet Owl	150
Woodpeckers	Acorn Woodpecker	25
Woodpeckers	Northern Flicker	25

Avian Group	Species	Standard Buffer (ft)
Falcons	American Kestrel	100
Falcons	Peregrine Falcon	300
Flycatchers	Western Flycatcher	25
Flycatchers	Black Phoebe	25
Flycatchers	Ash-throated Flycatcher	25
Vireos	Hutton's Vireo	25
Crows and Jays	Common Raven	50
Larks	Horned Lark	100
Swallows	Barn Swallow	25
Wrens	Rock Wren	100
Wrens	Bewick's Wren	25
Mockingbirds, Thrashers	Northern Mockingbird	50
Finches	House Finch	10
Finches	Lesser Goldfinch	25
New World Sparrows	Chipping Sparrow	50
New World Sparrows	Dark-eyed Junco	25
New World Sparrows	Spotted Towhee	25
New World Blackbirds	Western Meadowlark	100
New World Blackbirds	Hooded Oriole	25
New World Warblers	Orange-crowned Warbler	50
New World Warblers	Common Yellowthroat	50

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