Conserving California's Coastal Habitats

A Legacy and a Future with Sea Level Rise

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California's iconic coast occupies a special place in the hearts of Californians, draws visitors from around the world, and fuels the state's economy. California's beaches, intertidal areas, estuaries, wetlands, and coastal uplands are critically important. These ecosystems provide habitat for many species, provide opportunities for recreation, buffer our coast from storms, improve water quality, and support coastal fisheries. The Nature Conservancy and the California State Coastal Conservancy have worked to protect these natural resources for the past half century. However, California's legacy of coastal protection and conservation, and resulting benefits to our communities, are at risk from sea level rise and climate-driven storm surges, the effects of which are already being seen along California's coast. Every decision we make at the coast now and into the future needs to be made with these future conditions in mind, and this cannot be done without an understanding of the important role of natural systems in buffering these impacts. As two organizations dedicated to coastal protection and restoration, we are pleased to present *Conserving California's Coastal Habitats: A Legacy and a Future with Sea Level Rise.* This statewide assessment quantifies and maps the vulnerability of California's coastal habitats, imperiled species, and conservation lands to sea level rise, as well as opportunities for conservation strategies to maintain coastal habitat area in the face of sea level rise. We hope this assessment will help decision-makers and California's communities better understand what is at risk from sea level rise, where California's coastal resources are most vulnerable, and what we can do to ensure that California's future coast will be as well conserved, diverse, accessible, and valuable as it is today.

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Executive Summary

The California coast that we know today will not be the coast of the future. Sea level rise and other climate change impacts will have profound effects on our coastline and its natural resources. California harbors high numbers of native, rare, and imperiled species in an array of unique coastal habitats. A majority of California's coastline exists as natural habitat, over one-third of which has been preserved by a legacy of conservation efforts. Yet, this conservation legacy is at risk and we must act now to conserve the unique values of California's coast—for both people and nature—into the future.

To inform current and future adaptation decisions and conservation actions we conducted the first statewide, comprehensive assessment of the vulnerability of California's coastal habitats, imperiled species, and conservation lands to sea level rise. Coastal habitats exist in narrow bands at the land-sea interface and are therefore extremely susceptible to inundation by sea level rise. However, some habitats may be able to adapt vertically and possibly move inland, assuming local topography and the built environment do not constrain this movement. We assessed the vulnerability of 40 habitats to sea level rise by quantifying the sensitivity and spatial extent of projected exposure of each habitat patch to intertidal and subtidal waters, relative to its ability to move inland in response to rising sea levels.

Results of this spatially explicit assessment show that five feet of sea level rise will have dramatic impacts on coastal habitats, biodiversity, and protected lands along California's coast. The study found that as much as 25% of the existing public conservation lands within the analytic zone will be lost to subtidal waters. Eight imperiled species—including coastal dunes milk-vetch, California seablite, and California Ridgway's rail—only occur in areas that are projected to be inundated with a projected five feet of sea level rise. At least half of the documented haul-outs for Pacific harbor seals and Northern elephant seals, and nesting habitats for focal shorebirds like black oystercatchers, are also highly vulnerable.

A majority of the area for several key coastal habitats are highly vulnerable, including:

- 58% of rocky intertidal habitats, most of which is located in the North Coast and Central Coast ecoregions,
- 60% of upper beaches statewide,
- 58% of regularly-flooded estuarine marshes, and
- 59% of irregularly-flooded estuarine marshes in the South Coast ecoregion, and 30% in the San Francisco Bay Delta.

The future of coastal habitats is dependent on the decisions we make today about how we will adapt to rising sea levels and manage coastal resources. By using habitat vulnerability results in combination with other data, we identified five key strategies organized under two larger themes:

Conserve and Manage for Resilience

We need to ensure that our existing conservation lands are maintained and managed for resilience and that we invest in new conservation by investing in the following three strategies:

MAINTAIN EXISTING RESILIENT CONSERVATION LANDS

Approximately half of the habitat area within tracts of conserved lands along the California coast are resilient to sea level rise. Maintaining resilient conservation lands means maintaining the conservation *status* of the landscape as well as taking management steps to ensure that coastal habitats remain resilient to sea level rise. Each ecoregion contains extensive networks of these 'resilient strongholds' which should be managed to preserve natural coastal processes, resilient habitats, and the goods and services they provide to people.

CONSERVE RESILIENT LANDSCAPES

Conserving habitat areas that are not vulnerable to sea level rise as resilient strongholds, is an important strategy for maintaining the overall extent of coastal habitats in the face of sea level rise. Each coastal ecoregion contains areas of resilient habitat that are not yet conserved, representing opportunities to double the overall area of protected, resilient coastal landscapes statewide. Investing in the conservation of resilient strongholds will allow natural coastal processes to be maintained, including the movement and transition of habitats in response to sea level rise. Our results show that investing in the conservation of resilient strongholds will be critical for maintaining area and function of the representative coastal habitats, including the most vulnerable, as well as for maintaining an ecologically-connected network of conservation lands to preserve biodiversity and natural processes.

MANAGE IN PLACE FOR RESILIENCE

Many patches of coastal habitat will not be able to move inland in response to sea level rise, due to topography or the presence of the built environment (e.g., roads, development). Often, the very habitats that lack areas to move inland, also lack a sufficient sediment supply and delivery to enable them to accrete sediments and grow vertically to keep pace with rising seas. Managers can assist these vulnerable habitats by managing in place for resilience through sediment augmentation or sand placement. Our analysis showed that this strategy will be important to the maintenance of estuarine marsh habitats, such as tidal flat and salt panne, and regularly-flooded estuarine marsh. The majority of highly vulnerable conservation lands in need of managing in place for resilience are found in the San Francisco Bay Delta.

Mitigate Potential Losses of Vulnerable Habitats

Some of California's coastal habitats will be lost to sea level rise and we will need to mitigate those potential losses. Our spatially explicit recommendations for the application of two strategies that are essential to mitigating potential losses of vulnerable habitats are:

CONSERVE POTENTIAL FUTURE HABITAT AREAS

In order to maintain the composition and extent of coastal habitats into the future, we need to manage lands now for their future habitat value as sea levels rise. We identified areas with minimal development (e.g., agriculture and developed open space) that are projected to be inundated by sea level rise or are adjacent to vulnerable habitats, as opportunities for conserving 'potential future habitat.' While generally a small proportion of the agricultural lands of each region, these identified areas provide significant opportunities in each ecoregion to increase habitat transition areas. Statewide there are close to 200 km^2 of potential future habitat that could help mitigate the potential loss of vulnerable habitats to sea level rise.

ADAPT THE BUILT ENVIRONMENT

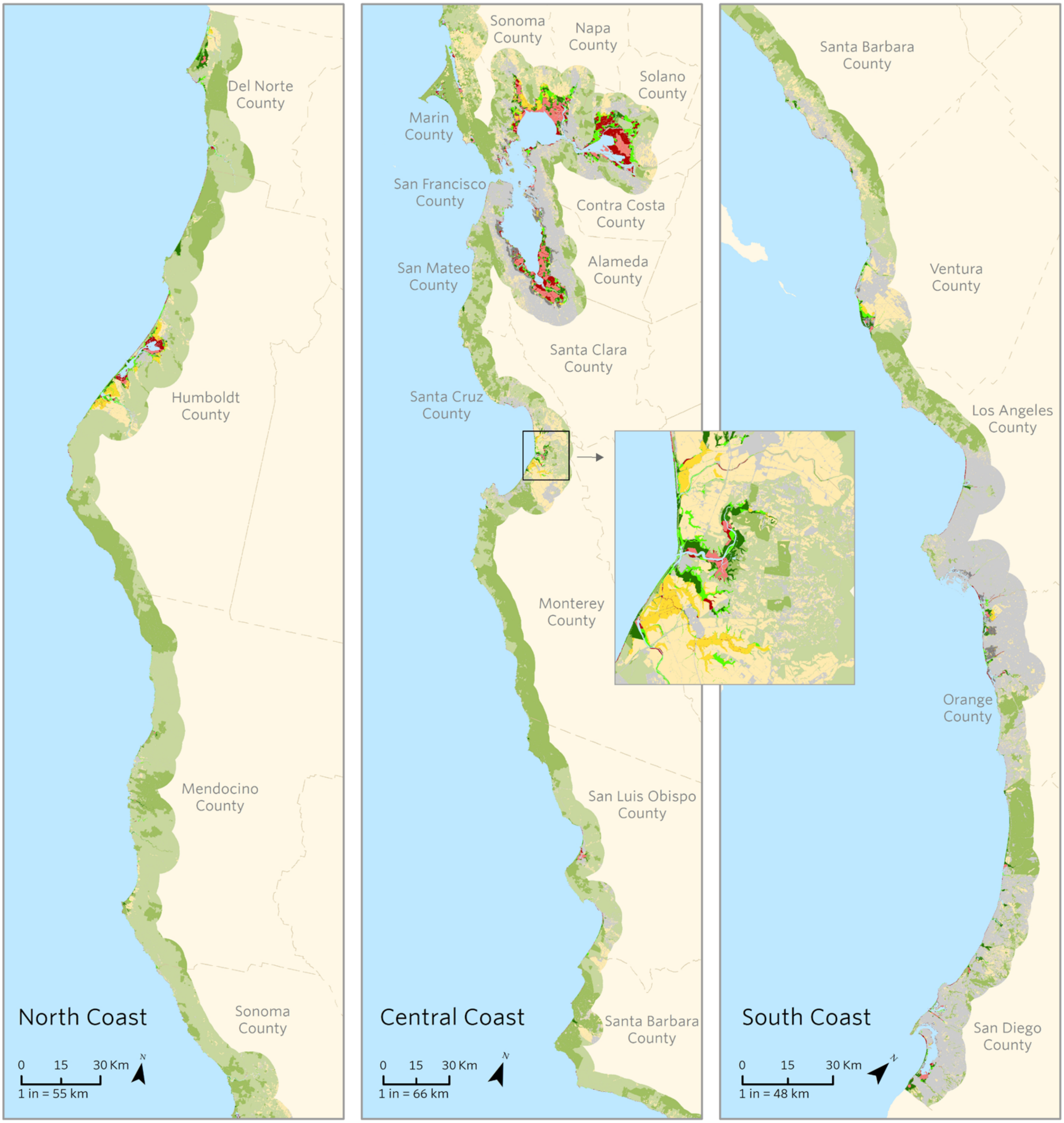
In the more urban regions of the state, such as the San Francisco Bay Delta and the South Coast, the built environment—including roads and other infrastructure—creates barriers that prevent coastal habitats from moving inland. Many of these built structures are themselves also vulnerable to sea level rise. We need to simultaneously protect human community assets and enhance the extent and resilience of coastal habitats by managing this infrastructure with natural coastal processes in mind. In this way, adapting the built environment can yield dividends, both through increased resilience of the built environment, as well as through the protective services provided by coastal habitats. Using coastal habitats as natural infrastructure to protect the built environment provides other valuable co-benefits, such as improving water quality, sequestering carbon, enhancing fisheries, and providing recreation.

Considerable investment in each of the above five adaptation and conservation strategies will be necessary to conserve the extent and composition of coastal habitats and the services they provide to nature and people in the face of sea level rise. As sea levels rise, California's coast will erode and evolve, and habitats will need to shift. The legacy of land conservation along the California coast allows for some habitats to move inland. Our current conservation efforts and land use management decisions must focus on further supporting these natural processes and enabling the transition and movement of coastal habitats as sea levels rise and the climate changes. We need to act today to conserve the extent, diversity, accessibility, and value of California's coastal habitats for future generations.

Opportunities for conserving California's habitat and managed lands in the face of sea level rise. The inset shows the level of detail which may also be observed by zooming in to any area of interest in the high resolution report, or by viewing interactive maps online at CoastalResilience.org/CoastalAssessment.

CALIFORNIA COASTAL CONSERVATION ASSESSMENT

ECOREGION



Resilient Conserved Habitat
Maintain the resilience and conservation status of existing conservation land.

Resilient Non-conserved Habitat
Invest in conserving resilient landscapes.

Vulnerable Conserved Habitat
Manage in place for resilience to help habitat keep pace with sea level rise.

Vulnerable Non-conserved Habitat
Mitigate potential losses by adapting adjacent built environment and/or investing in potential future habitat.

Potential Future Habitat
Invest in conservation and management that allows vulnerable habitat to transgress inland.

Exposed Built Environment
Adapt the built environment to enhance habitat area and function.

Study Area
- Conserved Habitat
- Non-conserved Habitat
- Undeveloped Uplands
- Built Environment

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1.0 Introduction

The California coast that we know today will not be the same coast in the future due to sea level rise and climate change. Investments made to date in coastal conservation to protect important habitats and species, are at risk as ocean waters rise and coastal margins erode. California's current policies and decision-making frameworks are not yet prepared for this threat. Land use, development, and conservation decisions made for California's coastal areas must consider the vulnerability of the coast to sea level rise, and the coastal changes that will unfold over the coming decades. To guide current and future adaptation decisions and conservation actions, we conducted the first statewide, comprehensive assessment of the vulnerability of California's coastal habitats, imperiled species, and conservation lands to sea level rise. How California accommodates and adapts to changes from sea level rise will determine what our future coast will look like, how well conserved and protected coastal ecosystems will be, and what benefits the coast will provide to future generations.

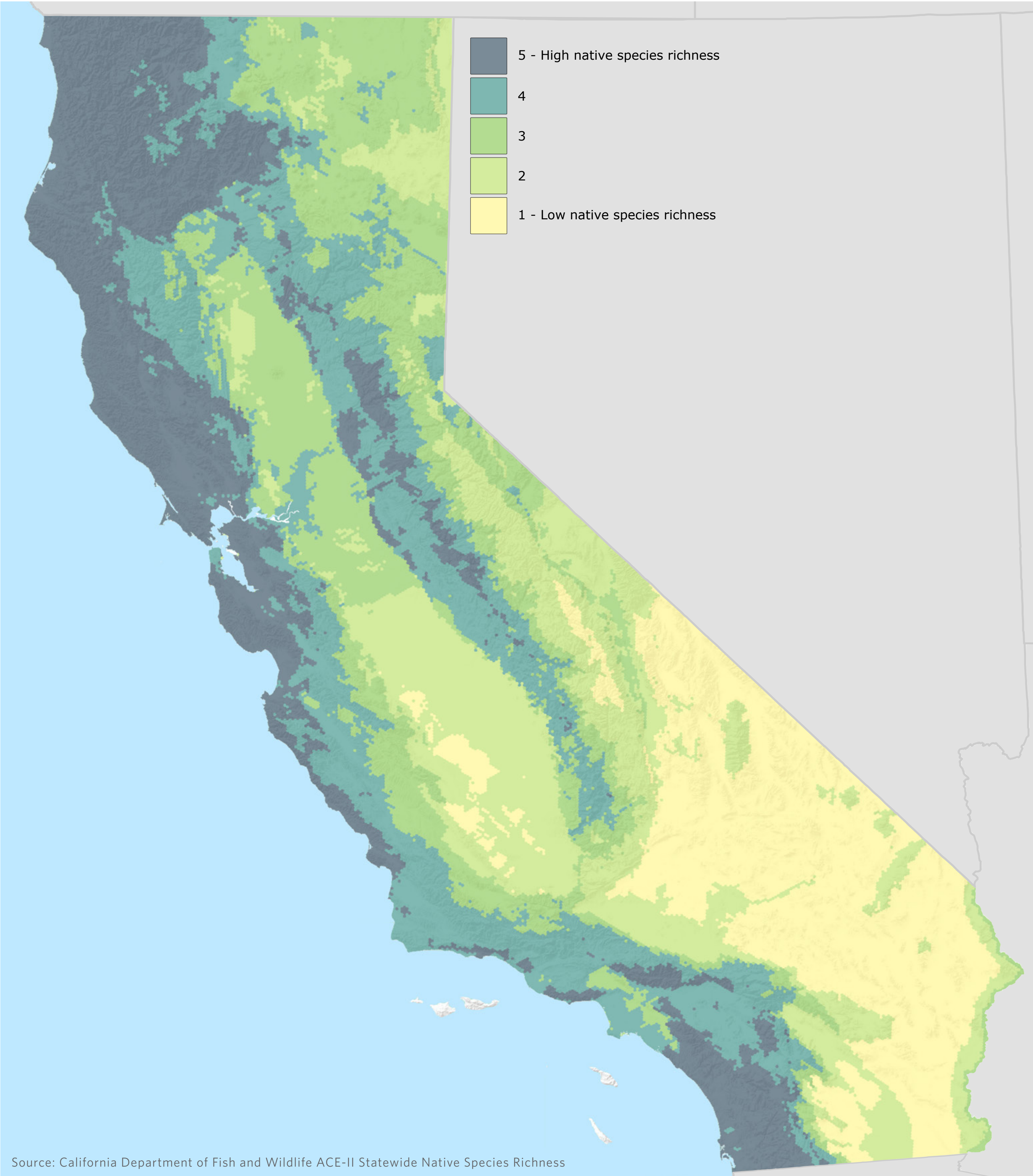

Figure 1.1 Relative distribution of five levels of native species richness across California.

1.1 California's Coast: A Rich Place Worth Conserving

California's open coast spans over 1,100 miles (1,770 kilometers) fronting the Pacific Ocean. With the inclusion of the San Francisco Bay shoreline and detailed mapping of the many smaller estuaries along the coast, the coastline measures over 3,500 miles (5,764 kilometers). This coastal geography encompasses a range of factors such as geology, topography, slope, and climate that together give rise to a diversity of ecosystems, habitats, ecological communities, and species. California has the highest biodiversity of the continental United States (Stein 2002), and the coast of California harbors the highest levels of native species richness (number of species) within the state (CDFW ACE II 2015; Figure 1.1). The many species that make up California's coastal biodiversity are found in a rich array of habitats including rocky shores, beaches, dunes, wetlands, rivers, coastal prairie, chaparral, scrub, and forests. Beaches and rocky shores are dominant habitats of California's outer coast, while marshes and mudflats are dominant habitats overall, nested within the hundreds of estuaries along the coast. California's coast provides resting areas along global migrations for a diversity of species, as well as nesting and pupping habitat, nursery habitat, and important feeding grounds critical to populations of many species, some of which are found nowhere else in the world.

The coast of California is also important to people. Over 89% of all Californians believe that the California coast is personally important to them (Probolsky Research 2017). California is the most populous state in the nation, with 38.9 million people, 68% of whom reside within the 21 coastal counties, out of 58 total counties (State of California 2014; Figure 1.2). California's largest urban centers—Los Angeles, San Diego, and the San Francisco Bay Area—are right on the coast. While California's 21 coastal counties occupy just 23.5% of the state's land area, they are responsible for about 85% of the state's Gross Domestic Product (NOEP 2017). With human populations, transportation infrastructure, industry, and agriculture focused within areas of the coast, there has been an extensive loss of many coastal habitats. Yet, the remaining areas of California's intact coastal habitats and the diversity they support contribute to the state's economy more subtly, through the provisioning of ecosystem services—or the benefits people obtain from ecosystems (Millennium Ecosystem Assessment 2005). Wetlands filter agricultural runoff and other pollutants before they enter the ocean, improving water quality (Valiela *et al.* 1997, Fisher and Acreman 2004, McKellar *et al.* 2007). Healthy coastal estuaries provide nursery habitats for fish and support commercial fisheries (Beck *et al.* 2001, Hughes *et al.* 2014, Hughes *et al.* 2015). Coastal landforms and habitats buffer seaside communities against waves and storm surge, helping residents avoid millions of dollars in damage costs (Arkema *et al.* 2013, Narayan *et al.* 2016). Coastal marshes have some of the highest rates of carbon sequestration of any habitats in the world and therefore are important for mitigating climate change and sea level rise (McLeod *et al.* 2011). Finally, the coast provides recreational opportunities for people—important to local communities, and drawing millions of tourists who fuel California's economy (NOAA 2015).

1.2 A Legacy of Conservation along California's Coast

While the iconic beauty and benefits of nature are inherent qualities of California's rich coast, the fact that most coastal lands today are natural habitats is the result of a legacy of strategic conservation efforts and key policies over the past century. California is recognized for some of the earliest state-led conservation efforts in the nation. For example, Big Basin Redwoods State Park was purchased and conserved in 1902 in the coastal mountains of Santa Cruz County. Much of coastal California was historically managed by private landowners as large ranches that benefited from productive lands for grazing and agriculture yet also contained vast areas of intact coastal habitats. Beginning in the mid-twentieth century, with a mutual interest in preserving these iconic coastal lands, many landowners partnered with conservation organizations and agencies to conserve these lands in perpetuity and prevent development and conversion. Many of the federal, state, and regional parks we now enjoy along California's coast are a result of this conservation legacy.

Figure 1.2 Human population density across California.

BOX 1.1A THE NATURE CONSERVANCY'S LEGACY OF CONSERVATION

The Nature Conservancy (TNC), founded in 1951, began working to conserve California's coast early in the history of the organization. In 1960, TNC conserved the 177 acre Buena Vista Lagoon in the rapidly growing urban area of Carlsbad. The estuarine habitats of Buena Vista Lagoon, now an Ecological Reserve managed by the California Department of Fish and Wildlife, are a bird sanctuary and an important conservation stronghold in an otherwise urban setting.


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Over the years, TNC has worked with private, state, and federal partners to conserve 402 km^2 throughout the study area of this coastal assessment. Many well-known preserves, parks and other protected areas along California's coast are the beneficiaries of TNC's coastal conservation legacy, from Buena Vista Lagoon, to Andrew Molera State Park, the Marin Headlands, Stornetta Ranch, Elkhorn Slough, and the recent 101 km^2 Dangermond Preserve at Point Conception. Within the study area alone, TNC has played a role in protecting 42 km^2 of California's State Parks and Beaches, 15 km^2 of University of California Reserves, and more than 10 km^2 of National Wildlife Refuges.

TNC sometimes conserves land through direct acquisition, as with its property at Ormond Beach, which TNC manages in partnership with the California State Coastal Conservancy (SCC) and the City of Oxnard. Sometimes TNC protects coastal land through conservation easements, as it has with private ranch lands at the Ten Mile River estuary. TNC frequently acts as an agent assisting in acquisitions on behalf of other conservation interests, as it did with the protection of Guadalupe–Nipomo Dunes. TNC has also been influential in the development of state conservation bonds and guiding their use to fund coastal conservation.

Today, although land protection is still an important part of TNC's coastal conservation efforts, TNC now utilizes a growing suite of approaches to conservation and adaptation along the coast. TNC works to bridge the gap between decision-makers and the best available science through CoastalResilience.org (an interactive online resource) and the Coastal Resilience Network that SCC now manages. TNC partners with influential landowners to demonstrate nature-based adaptation and the benefits it provides, and works with disadvantaged communities to implement science-based restoration projects that protect coastal access and coastal habitat for current and future generations. TNC develops and drives the sound science needed to guide conservation decisions, policy, and action throughout California's coast.

California's legacy of coastal protection is also a result of California having some of the strongest coastal policies and agency oversight in the nation—addressing and mitigating threats from development, pollution, resource extraction, and other stressors. At the center of California's coastal policy framework is the California Coastal Act. The California Coastal Act, while now over 40 years old, remains one of the most comprehensive frameworks for planning and regulating land and water uses, including shoreline protection along the coast (Box 1.2). The California Coastal Commission regulates land use planning and development in the Coastal Zone (Box 1.2) so that it is consistent with goals and policies of the Coastal Act. The California State Coastal Conservancy (SCC) is a non-regulatory agency responsible for planning, funding, and implementing projects to protect coastal resources, agriculture, and public access. California's federally authorized Coastal Zone Management Program includes these two agencies, along with the Bay Conservation and Development Commission (BCDC), which is the regulatory agency charged with permitting land use in San Francisco Bay and its shoreline. For decades, these three agencies have worked together to protect California's coastal natural resources and the benefits they provide to nature and people.

BOX 1.1B THE STATE COASTAL CONSERVANCY'S LEGACY OF CONSERVATION

The California State Coastal Conservancy (SCC) was created in 1976 to complement the state's regulatory agencies by working with partners to protect and enhance coastal resources and improve public access to the coast. In protecting many of the most-loved scenic, natural, and recreational resources of the California coast and the San Francisco Bay Area, SCC has played a critical role in shaping the coastal landscape that we enjoy today.

The SCC works on behalf of Californians, developing projects that enhance natural resources for the benefit of all. The SCC operates on a range of geographic scales to plan and implement projects that achieve multiple objectives, such as restoration of habitats, completion of trails and recreational amenities, climate resilience, and economic enhancement of urban waterfronts. The SCC strives to promote environmental equity and justice for the underserved—including disadvantaged communities, persons with disabilities, tribes, and others—through its work to restore habitats and watersheds, provide public access and recreational opportunities, and increase resilience to climate change.

Since its creation, the SCC has completed more than 2,400 projects—building hundreds of miles of trails, constructing scores of public access facilities, and preserving hundreds of thousands of acres of wildlife habitat, coastal farmland, redwood forests and scenic open space. The SCC has helped protect more than 300,000 acres (1,214 km^2) of natural and scenic lands along California's coast and the San Francisco Bay, and led statewide efforts to restore and enhance coastal wetlands throughout California. The Conservancy has supported hundreds of wetlands projects and has been a leader of the State's largest restoration efforts. By working with public and private partners, the SCC has protected and restored over 50,000 acres (202 km^2) of wetlands in coastal areas and around San Francisco Bay.

The SCC works with communities to plan now for climate change and implement projects that reduce potential damage through nature-based strategies. Protecting and enhancing our forests, wetlands, and other natural areas will help nature buffer the effects of sea level rise and extreme weather. These projects reduce greenhouse gases, diminish hazards to harbors and ports, and make coastal communities and natural lands more resilient to a changing environment.

California's Public Trust Lands are also part of the portfolio of coastal habitats managed by the state for values critical to nature and people. Tidelands between mean high tide and mean low tide, and subtidal areas from the shore out three nautical miles into the Pacific Ocean, as well as lakes, streams, and other navigable waterways, are designated as Public Trust Lands that are held in trust by the State for the benefit of the people of California. Since 1938, the California State Lands Commission has been the administrator and guardian of these valuable public interests, with the authority to permit the private use of lands below the mean high tide line, so long as these uses "do not unreasonably interfere with the uses and purposes reserved to the people of the State."

The state of California has been a leader in environmental policy for over a century; however, current policy and decision-making frameworks were developed to reflect static existing conditions and are not well suited for the dynamic needs of adapting to sea level rise because they do not accommodate a changing shoreline. Further, the fruits of California's coastal conservation legacy are themselves at risk of impact from sea level rise.

BOX 1.2 CALIFORNIA'S COASTAL ZONE

The California Coastal Act describes the Coastal Zone as "that land and water area of the State of California from the Oregon border to the border of the Republic of Mexico... extending seaward to the state's outer limit of jurisdiction, including all offshore islands, and extending inland generally 1,000 yards from the mean high tide line of the sea. In significant coastal estuarine, habitat, and recreational areas it extends inland to the first major ridgeline paralleling the sea or five miles from the mean high tide line of the sea, whichever is less, and in developed urban areas the zone generally extends inland less than 1,000 yards. The coastal zone does not include the area of jurisdiction of the San Francisco Bay Conservation and Development Commission."

The California Coastal Act's goals within the Coastal Zone include "to protect and enhance coastal resources, ensure balanced resource use, ensure access and recreational use, prioritize coastal-dependent uses (which excludes residential uses), and encourage coordinated state and local planning."

1.3 Sea Level Rise: The Threat of the Century for Coastal Habitats

The coast is dynamic—continually changing—but accelerated sea level rise and increasing storm intensity and frequency threaten to significantly alter the character, form, and function of California's coast (Heberger *et al.* 2011, Griggs *et al.* 2017, Thorne *et al*. 2015). Sea levels have already crept up California's shores by approximately 0.2 m (8 in) in the past 100 years, and current modeling projections suggest that there is a high likelihood that California will experience an additional 0.3–1.0 m (1.0–3.3 ft) of rise by 2100 (Griggs *et al.* 2017). Projections reflecting an improved understanding of rapid mass loss from continental ice sheets present an even more dire projection of up to 3 m (10 ft) of sea level rise within this century (DeConto and Pollard 2016, Griggs *et al.* 2017). Rising sea levels will increase erosion of coastal bluffs and cause heightened flooding and erosion in low-lying areas, threatening natural resources and human infrastructure. Although taking action now to reduce greenhouse gas emissions is essential to mitigate rates and amounts of sea level rise, greenhouse gas emissions to date have already set the conditions for rising seas for the following century and beyond (Deconto and Pollard 2016, Griggs *et al.* 2017). While sea level rise projections are continually being updated and improved (Griggs *et al.* 2017), we know enough now to take action. Understanding what habitats are at risk from sea level rise, where habitats may be able to move inland in response to sea level rise, and how these challenges and opportunities interact with land use and conservation management lands is key to understanding what biodiversity is at risk, and prioritizing where to act now and in the coming years.

IMPACTS OF SEA LEVEL RISE AND HUMAN ADAPTATION RESPONSES ON COASTAL ECOSYSTEMS

As sea levels rise, coastal habitats may be squeezed into an ever-shrinking area between rising seas and human development and infrastructure. Coastal habitats are at risk of being submerged and their associated species will be lost, without immediate conservation and management actions to ensure those species and habitats have the space and ability to move inland. Higher seas will mean a higher reach for storm surge, which will increase the frequency and extent of coastal flooding, especially during El Niño events. Saltwater intrusion into surface and groundwater aquifers will push further and further inland, potentially altering natural habitat communities and impacting agricultural practices (Nicholls and Cazenave 2010). Currently protected and conserved coastal areas in California and their habitat value, which represent a real and substantial investment for the future, may also be impacted or lost due to sea level rise. This concern has been highlighted along the Atlantic seaboard (Epanchin-Niell *et al.* 2017) but has not been examined along the coast of California.

Development and infrastructure along California's coast also faces significant risk from sea level rise impacts, such as flooding and erosion. It is estimated that sea level rise and associated flooding will threaten nearly $100 billion worth of property along the California coast by 2100 (Heberger *et al.* 2009). Coastal communities may choose to adapt to rising seas and increasing storm damage by using a range of approaches to protect life, property, and/or the environment. Three options of response include: protection, accommodation, and retreat (Box 1.3), and these approaches may be used for different assets within a community, or at different points in time.

BOX 1.3 RESPONSES TO SEA LEVEL RISE

Protection strategies defend the current location of development even as sea levels rise.

Accommodation strategies harness traditional zoning, building code, and flood protection code tools to increase development's resilience to sea level rise.

Retreat strategies channel new development out of vulnerable areas while allowing existing development to be relocated, demolished, or inundated by the rising sea.

(Dronkers *et al.* 1990, Herzog and Hecht 2013)

Protection strategies—such as armoring coastal infrastructure in place with seawalls, revetments, dikes, or levees—can impact natural processes and lead to negative consequences for coastal ecosystems, such as increased erosion, loss of habitat areas, and reduction in key ecosystem services that coastal habitats provide (Dugan *et al.* 2008, Dugan *et al.* 2017, Thorne *et al.* 2015). For example, sea walls disrupt sediment transport and increase erosion along beaches, reducing beach width and coastal access (Griggs 2005, Dugan *et al.* 2008, Dugan *et al.* 2017). Thus, both sea level rise and protection strategies to defend in place pose significant threats to California's remaining coastal shorelines and habitats. Alternatively, modifying the built environment to adapt to a changing coast could increase resilience of both human assets and natural resources on California's coast. Accommodation and retreat strategies promote the ability of natural systems (e.g., beaches, dunes, wetlands) to respond to the many impacts of sea level rise on the nearshore ecosystem, and allow these systems to migrate landward, facilitating their resilience and the benefits they provide (Titus 1990, Nicholls 2011). Using habitats as natural infrastructure can provide protective services to built assets while simultaneously delivering the co-benefits that coastal habitats provide, like recreation, fish nurseries, water filtration, carbon sequestration, and erosion control (Arkema *et al.* 2013). Many of the coastal population centers in California still benefit from the protective services that coastal habitats provide, but those services themselves are at risk of loss due to climate change or human impacts (Arkema *et al.* 2013).

ADAPTING CONSERVATION STRATEGIES FOR SEA LEVEL RISE

Without concerted efforts to protect remaining intact natural habitats and change our traditional conservation approach to account for sea level rise, California faces further loss of its already greatly-diminished coastal habitats to sea level rise. Losses of coastal habitats will not only affect the many unique, rare, endemic, and migratory species that rely on these habitats, but also cascade to impact the abundant services coastal habitats and species provide to humans. Whether the responses that a community chooses for any given area will be strategic and adaptive in nature, and whether they will contribute to healthy nearshore

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ecosystems, will depend on the individual community's priorities, its understanding of its coastal ecological assets, and the costs and benefits of the alternatives.

If we are to conserve the extent and function of coastal habitats in the face of sea level rise and protect our coastal conservation legacy, we must adapt our traditional approach to conservation—one that conserves species and their habitats in place—toward an approach that recognizes the changes underway and sustains overall ecosystem function in the face of these changes. As climates change and sea levels rise, conditions conducive to the survival of a species or habitat in one location may be lost, but may arise in several others. Thus, a regional perspective is necessary to maintain biodiversity, community assemblages, and habitat area. Further, conservation goals should focus on maintaining functional and resilient ecosystems with high diversity and adaptive capacity in a landscape setting that allows species to move (Anderson and Ferree 2010). This will require a thorough understanding of the current ecological and management context, the changes underway due to sea level rise, and the relative vulnerabilities of different habitats so that we can prioritize action and motivate those whose decisions can determine California's future coast.

1.4 Goals of this Assessment

This assessment aims to elucidate the conservation impacts of sea level rise to California's coastal habitats and biodiversity by characterizing the conservation landscape of the coast today, assessing what species and habitats are at risk from projected sea level rise, and identifying where there are opportunities to protect, restore, and conserve coastal habitats and biodiversity into the future. This spatially explicit assessment aims to guide conservation action and to identify where and how it will be possible to reverse the loss of coastal ecosystems in the face of sea level rise. We first characterized the present-day coast by compiling spatial data on the distribution and extent of coastal habitats and focal species, land use, ownership, conservation management status, access and recreation opportunities, and the built environment (Section 3). We then developed and applied an analytic approach to assess the vulnerability of coastal habitats to sea level rise (Section 4). Finally, we used these results to quantify and inform strategies to conserve coastal habitats in the face of sea level rise (Section 5). We identified high-priority areas on a statewide and regional scale to guide conservation action to protect and restore coastal habitats into the future.

2.0 Methods

2.1 Overview

Our approach to the assessment was to first define and divide our study area into regions, over which we overlaid standardized analytic units to help facilitate our analyses. We then characterized the state of the coast in terms of land cover, intertidal conditions, biodiversity, land conservation management status and ownership, and other indicators (methods in Section 2.3 and results in Section 3.0). We projected sea level rise data onto the present-day coast to determine habitat vulnerability (methods in Section 2.4 and results in Section 4.0), and then combined our vulnerability results with ownership and conservation management data to quantify and map strategies for sea level rise conservation (methods in Section 2.5 and results in Section 5.0).

2.2 Study Area and Analytic Units

Our study area includes all lands and waters from mean lower low water on the seaward side to 8 kilometers (5 miles) inland beyond the furthest extent of inundation from projected five feet of sea level rise. The width of the study area varies along the coast since the spatial extent of the projected sea level rise inundation zone also varies. Depending on topography, the study area varies from narrow widths for steep coastlines with cliffs or bluffs (e.g., Big Sur coast), to miles inland in low and flat river valleys (e.g., San Francisco Bay or Salinas River valley). We established our study area as a common 8-km distance beyond the furthest sea level rise projection to provide landscape context for the impacts of sea level rise, including the ability of the landscape to accommodate inland transgression of coastal habitats and species in response to sea level rise. This landscape view also provides important context to conservation in the face of sea level rise, such as minimizing habitat fragmentation, filling conservation gaps, or expanding existing conservation lands to maintain landscape connectivity. It is important to note that our study area boundary extends inland beyond the jurisdictional Coastal Zone boundary in many areas. Our assessment focuses only on the mainland coast of California and not the offshore islands (e.g., Channel Islands or Farallon Islands) or islets; this is due to a lack of sea level rise projection data for offshore features statewide.

We also identified an analytic zone that represents the area of inference for the full suite of coastal habitats to transgress inland in response to sea level rise. Because the area within a 1 km^2 analytic unit may include area that extends far inland beyond sea level rise impacts or well above the elevational boundaries of sea level rise influence (e.g., atop cliffs), we topographically constrained our analyses of sea level rise vulnerability to a realistic zone of influence. To do this, we used NOAA hydro-flattened coastal digital elevation maps (DEMs; NOAA Coastal Services Center) to establish an analytic zone along a contour at an elevation twice that of projected sea level rise. For example, for the 5-ft sea level rise projection, we defined the analytic zone to include the area between current mean lower low water and five feet above the 5-ft sea level rise projection (Figure 2.1).

We divided our study area into ecoregions, with boundaries roughly conforming to national terrestrial ecoregional boundary delineations originally developed by Bailey (2004) and marine ecoregional boundaries (Spalding *et al.* 2007). This allowed us to identify coastal areas of relatively homogeneous ecosystems and species composition, clearly distinct from adjacent systems. The California coast has three distinct ecoregions (Northern California, Central California, and Southern California). While the San Francisco Bay Delta is generally part of the Central Coast region, due to its large size and unique attributes (Figure 2.2), we provide separate results for San Francisco Bay Delta. We overlaid the study area with a grid of 1 km^2 hexagons to serve as standardized analytic units, facilitating summarization and comparison of disparate data and analytical results at multiple scales (Figure 2.2 inset). Within each analytic unit, we characterized and quantified land use, coastal habitats, imperiled species, conservation management status, sea level rise projections, and assessed vulnerability to sea level rise.

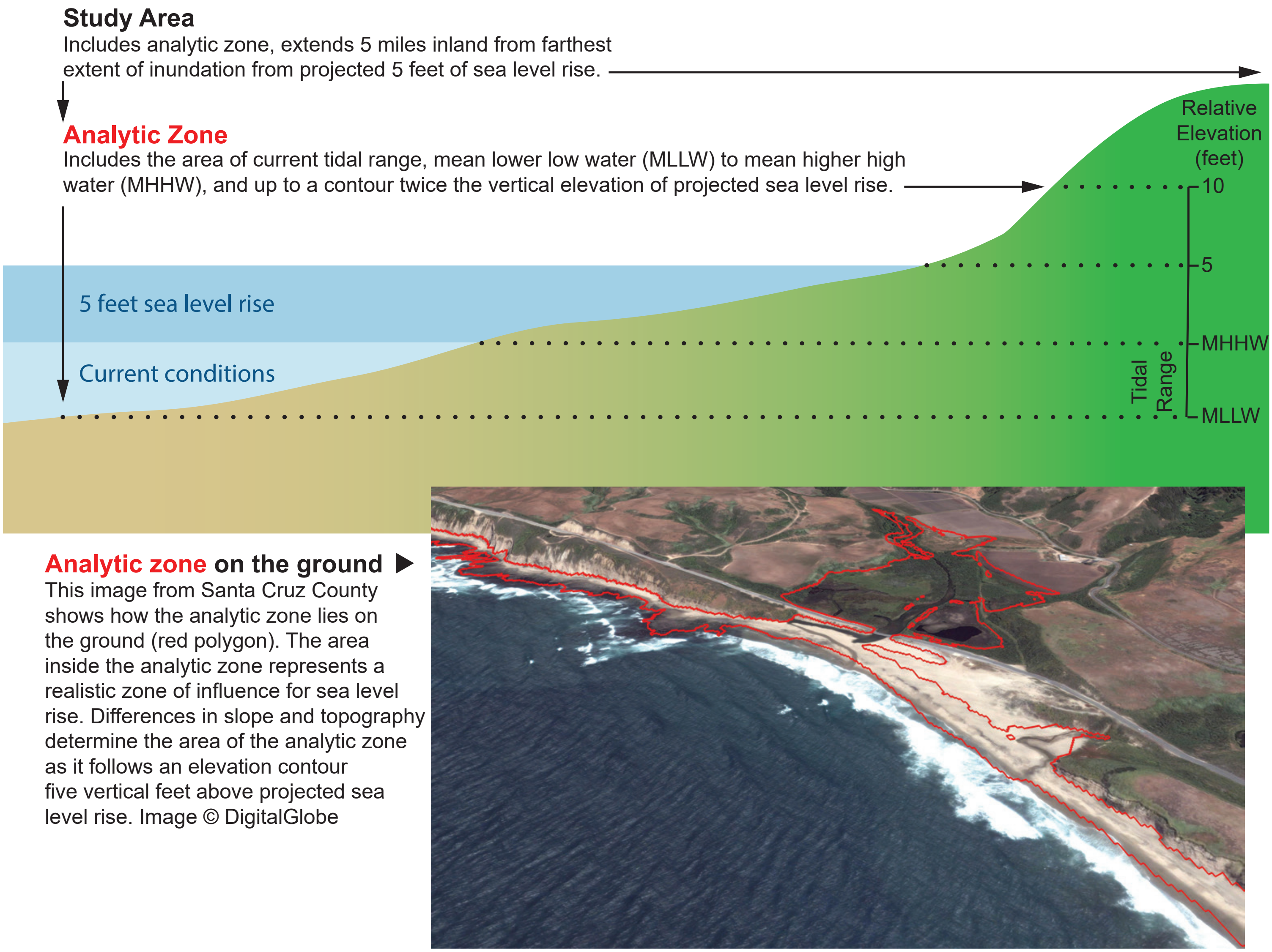
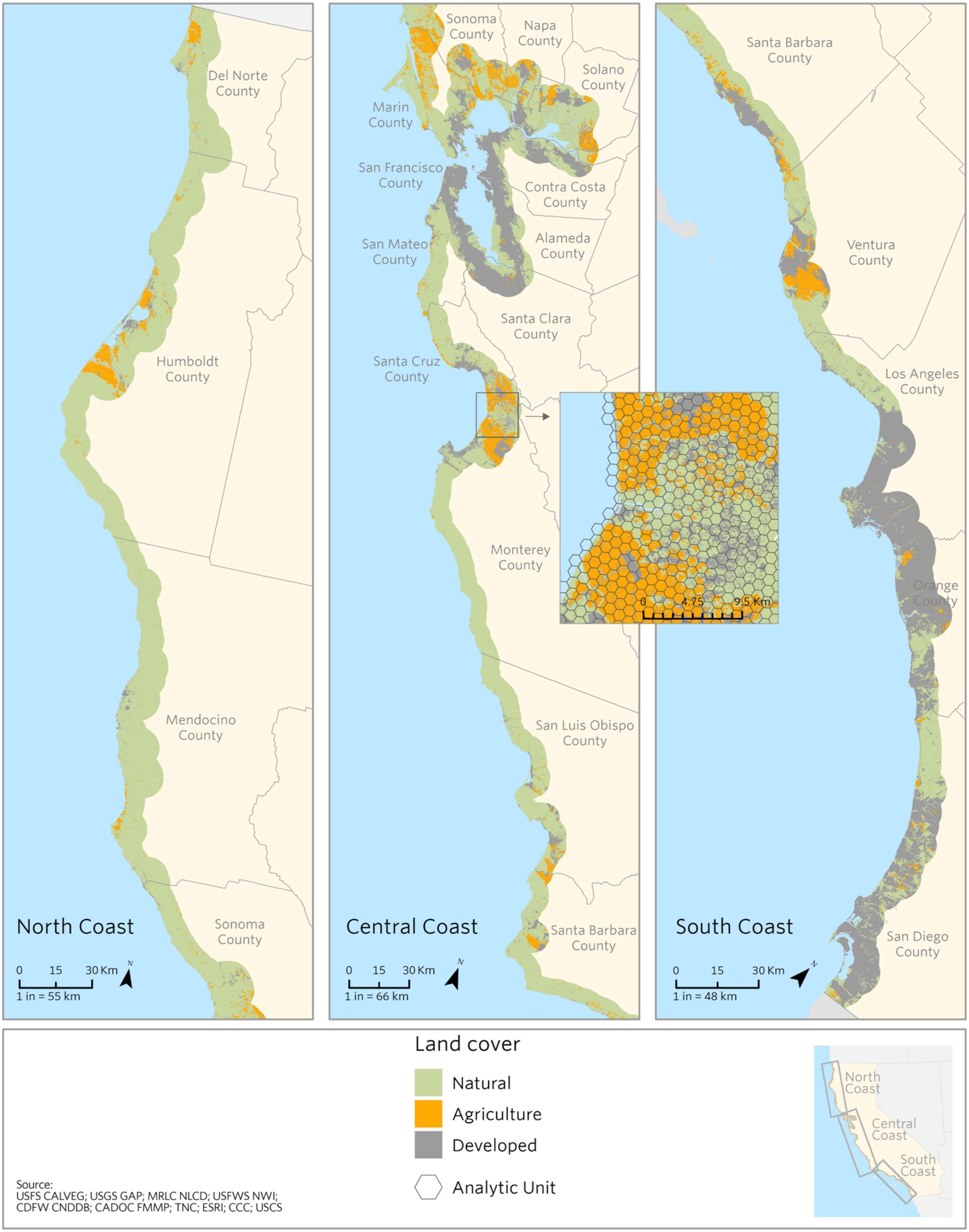


Figure 2.1 Conceptual diagram of how five feet of sea level rise, the analytic zone, and the study area relate spatially.

ECOREGIONS AND LAND COVER IN COASTAL CALIFORNIA STUDY AREA

ECOREGION



Source:
USFS CALVEG; USGS GAP; MRLC NLCD; USFWS NWI;
CDFW CNDDB; CADOC FMMP; TNC; ESRI; CCC; USCS

2.3 Methods for Assessing the Current State of the Coast

2.3.1 CHARACTERIZING LAND-COVER

We compiled spatial data on land cover from the National Land Cover Database (NLCD, Homer *et al.* 2015) and other sources (CALVEG-Existing Vegetation 2014) to develop a comprehensive, wall-to-wall map of land cover for three categories: natural, agriculture, and developed (Figure 2.2 and Appendix A). Natural lands are completely composed of native habitats. Agriculture is further divided into agriculture, prime agriculture, and agricultural wetlands. Prime agriculture, as defined by the U. S. Department of Agriculture, recognizes highly productive agricultural lands that require minimum inputs, and that are generally surrounded by undeveloped, non-agricultural open space. Agricultural wetlands are areas actively being used for agriculture such as row crops or grazing, that are also delineated as wetlands by the National Wetland Inventory (NWI 2016). For the purposes of this assessment, developed areas include fourteen types of built environment ranging from developed open space to high intensity development, including transportation and other infrastructure (Table 2.1).

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Table 2.1 Built environment categories, with landscape development intensity index adapted from Brown and Vivas (2005).

Built Environment Category	Landscape Development Intensity Index
Developed–high intensity	10.00
Wastewater treatment plants	10.00
Once through cooled power plants	10.00
Wind Power	10.00
HWY 4 lane	8.28
Railways	8.28
HWY 2 lane	7.81
Major roads	7.70
Minor roads	7.60
Developed–medium intensity	7.47
Levees	7.00
Prime agriculture	7.00
Developed–low intensity	6.90
Agriculture	4.54
Agricultural wetlands	4.54
Development–other*	3.00
Developed–open space	1.83

** Unclassified development was not included in Brown and Vivas (2005), but was taken directly from Theobald (2013), a direct adaptation of Brown and Vivas (2005).*

Figure 2.2 Land cover for the three ecoregions of coastal California. Inset shows the overlay of one square kilometer analytic units and the level of detail which may also be observed by zooming in to any area of interest in the high resolution report, or by viewing interactive maps online at CoastalResilience.org/CoastalAssessment.

2.3.2 CHARACTERIZING HABITATS AND FOCAL SPECIES

A challenge to any conservation assessment is to identify a subset of habitats and species that adequately represent the biodiversity and ecological functions of the study area (Margules and Pressey 2000); this is particularly true given the dozens of coastal habitats and thousands of species that occur along California's coast. Conserving all representative habitats will likely protect the majority of species that exist within those habitats, especially if complemented by further focus on species or habitats that are rare, endemic, or in severe decline (Noss 1987, Groves 2003).

Habitats

We compiled existing spatial data on coastal habitats to represent the natural diversity and ecological function of California's coast. We crosswalked the hundreds of NWI and CALVEG habitat types to 40 habitat types (Table 2.2) used in previous conservation assessments (Scharffenberger *et al.* 1999, The Nature Conservancy 2006), sea level rise assessments and marsh migration models (e.g., SLAMM (Sea Level Affecting Marshes Model)/warrenpinnacle.com, CoastalResilience.org). In parts of the state, particularly along the shoreline, there were spatial data gaps where CALVEG and NWI did not classify habitats. We used expert classification relative to aerial imagery to appropriately fill these gaps and to ensure proper habitat classification.

While the 40 habitat types provide important conservation context, not all have high proportions within the analytic zone, and therefore not all 40 habitats are equally at risk to sea level rise. To simplify the report and focus results of habitat vulnerability to sea level rise, we aggregated two larger habitat categories and focused on six habitat types that are found throughout the state and have a majority of their area within the analytic zone. Six of the 40 habitats are on the land-sea margin of either the outer coast or estuaries, and therefore are found almost entirely within the analytic zone. These include three marine intertidal habitats: rocky intertidal, swash beach, and upper beach, and three estuarine habitats: tidal flat and salt panne, regularly-flooded estuarine marsh, and irregularly-flooded estuarine marsh. We aggregated all eight distinct freshwater wetland types. Eighteen of the 40 habitats characterized in this assessment are terrestrial and seven of these are rare, representing the high diversity, ecological function, and rarity of terrestrial habitats along California's coast (Table 2.2). We also aggregated the 18 terrestrial habitats into one category. The combination of three marine intertidal, three estuarine, aggregated freshwater wetlands, and aggregated terrestrial habitats form the eight coastal habitat types on which we focus our summaries in this report.

Imperiled Species

There are 159 species with state or federal protected status designations that occur in our coastal study area. To assess the vulnerability of these imperiled species, we compiled existing species occurrence data from the California Natural Diversity Database (CNDDB 2017). We focused on species with high conservation status, ranked as imperiled or critically imperiled at state, federal, and global levels (i.e., G1, G2, S1, S2, T1, T2) that had relatively recent (post-1990) occurrence data, with <5-mile accuracy rating (Appendix B.1). We then tabulated information on number of occurrences by different taxonomic groups within the state relative to the study area, to identify coastal-dependent species (Appendix B.1).

Focal Marine Mammals, Seabirds, and Shorebirds

California's mainland coastal habitats are used by marine mammals, seabirds, and shorebirds as critical haul-outs, pupping, or nesting habitat. We compiled existing spatial data from a variety of sources (Appendix A) on parts of the mainland coast used by six focal species whose life history and use of coastal areas may make them vulnerable to sea level rise: Pacific harbor seal (*Phoca vitulina richardii*), Northern elephant seal (*Mirounga angustirostris*), Steller sea lion (*Eumetopias jubatus*), western snowy plover (*Charadrius nivosus nivosus*), California least tern (*Sternula antillarum browni*), and black oystercatcher (*Haematopus bachmani*). Many of these species are imperiled or recovering, and their mainland habitat use—critical to maintaining populations—is constrained to the coastal margin.

Coastal habitats throughout the study area are also of critical importance to birds migrating along the Pacific Flyway. To inform the potential impact of sea level rise on habitats of significance along the Pacific Flyway, we compiled spatial information on Audubon Important Bird Areas in the study area (Appendix B.2).

Table 2.2 Coastal habitat types assessed.

General type	Specific habitat type	General type	Specific habitat type
Intertidal marine	Aquatic Bed	Water	Lakes / Ponds
	Rocky Intertidal		Riverine
	Swash Beach	Terrestrial	Annual Grassland
	Upper Beach		Barren
Estuarine	Alkaline Marsh		Chaparral
	Artificial Salt Pond		Coastal Conifer Forest and Woodlands
	Estuarine Forested/Shrub Wetland		Coastal Dune
	Invertebrate Reef		Coastal Prairie
	Irregularly-flooded Estuarine Marsh		Coastal Scrub
	Regularly-flooded Estuarine Marsh		Mixed Evergreen Forests and Woodlands
	Tidal Channel		Oak Forests and Woodlands
	Tidal Flat and Salt Panne		Other
Freshwater wetland	Freshwater Marsh		Perennial Grassland
	Inland Shore		Rare Chaparral
	Rare Riparian Forest and Shrub		Rare Coastal Conifer Forest and Woodlands
	Riparian Forest and Shrub		Rare Coastal Scrub
	Seasonal Freshwater Marsh		Rare Mixed Evergreen Forests and Woodlands
	Tidal Freshwater Forested/Shrub		Rare Oak Forests and Woodlands
	Tidal Freshwater Marsh		Rare Serpentine Systems
	Vernal Pool		Rare Vegetated Dune

Biodiversity Index

We compiled spatial data on each of the 40 habitats and 159 imperiled species described above into the 1 km^2 analytic units. A rarity-weighted richness index (RWRI, *sensu* Albuquerque and Beier 2005) was then calculated for each analytic unit to characterize the relative biodiversity and conservation value across the landscape in terms of richness of habitat area and imperiled species presence. The species component of the RWRI was calculated as presence within an analytic unit divided by the number of analytic units the species has been documented in throughout the study area. Each imperiled species was weighted by the proportion of occurrences that were within the study area relative to their statewide occurrences, to appropriately represent rarity and focus on coastally-dependent species. The habitat component of the RWRI was calculated as the area of a given habitat in an analytic unit divided by the total area of that habitat throughout the study area as follows:

$$RWRI = \sum_{i}^{N} (H_i/H_T) + \sum_{i}^{N} (1/C_i)$$

for habitats i through N, where H_i is the area of habitat i within the analytic unit and H_T is the total area of that habitat throughout the study area, and for species i through N where C_i is the number of analytic units that species is found in throughout the study area. Analytic units with high RWRI values were considered to be of high conservation value and used to prioritize areas for conservation actions among strategies.

2.3.3 CHARACTERIZING CONSERVATION MANAGEMENT STATUS

We developed a comprehensive layer for conservation management status across the study area, based mainly on assigned conservation status from the California Protected Areas Database (CPAD 2016). We categorized lands into four classes of conservation management: highly conserved lands, conserved lands, non-conservation public lands, and non-conservation private lands (Table 2.3). However, we also augmented the CPAD data with additional data sources for other types of conservation lands:

- Wilderness areas. We used data from the U. S. Bureau of Land Management (BLM) (www.blm.gov/ca/gis/) and other sources (www.wilderness.net/nwps/geography), and categorized all BLM Areas of Critical Environmental Concern and Wilderness areas as highly conserved.
- Conservation easements. We used data from the California Conservation Easement Database (www.calands.org/cced), and assigned conservation easements to the highly conserved category.
- Military lands. We used data from the BLM Land Status data (v10; www.blm.gov/ca/gis/). Military installations with greater than 50% natural land cover were characterized as conserved; installations with less than 50% natural land cover were characterized as non-conservation public lands.

2.3.4. CHARACTERIZING PUBLIC COASTAL ACCESS

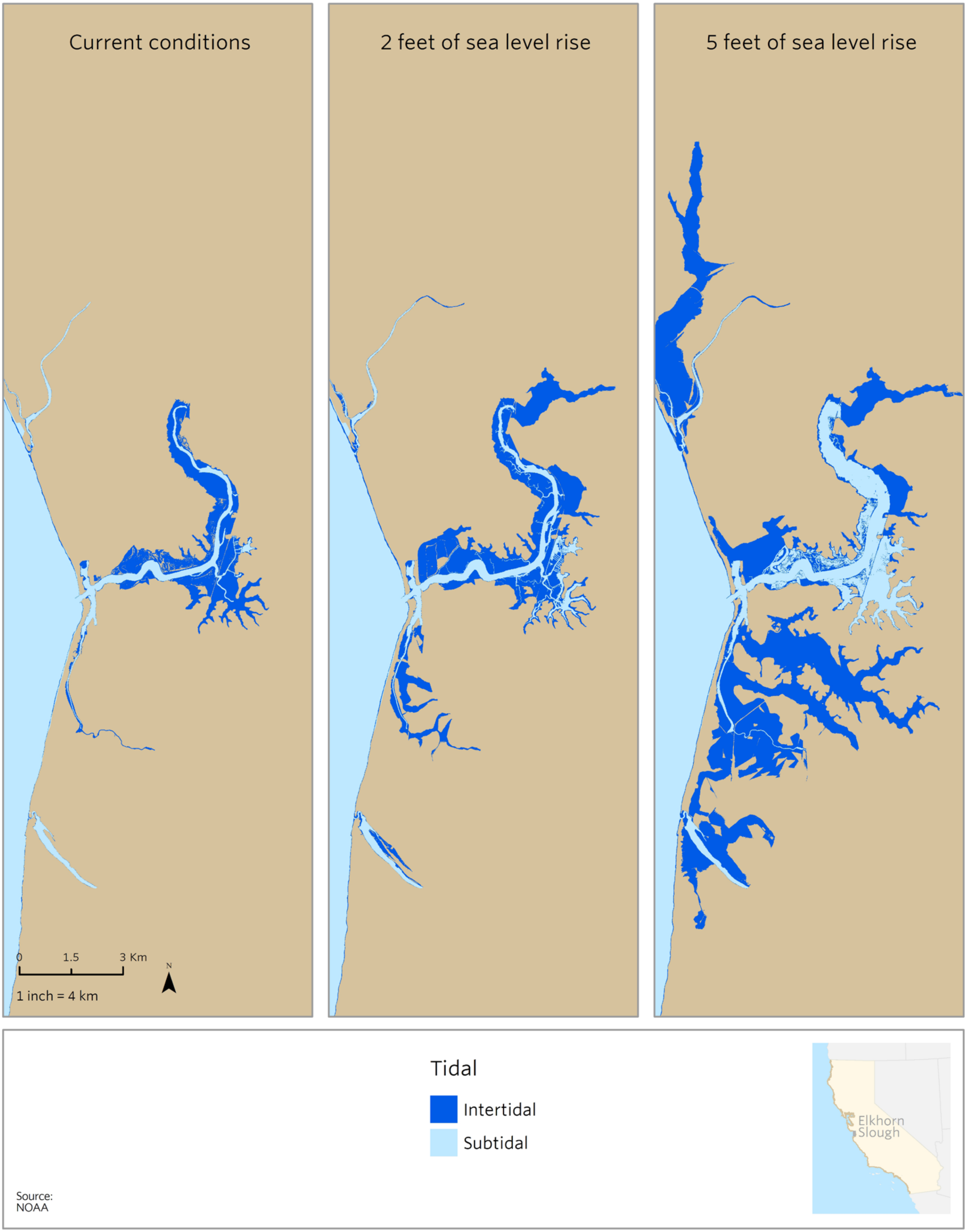
We used the California Coastal Commission's geospatial inventory of public coastal access and recreation opportunities within the Coastal Zone (CCC 2017). We focused specifically on sandy beaches with facilities such as parking and restrooms.

Table 2.3 Description and examples of conservation management status categories.

Category	Description	Examples
Highly Conserved	Highly conserved public and private lands with a focus on biodiversity and ecosystem protection	• National parks (e.g., Redwoods National Park) • Wilderness areas (e.g., Kings Range) • Nature p/reserves (e.g., Point Lobos State Reserve) • Wildlife areas (e.g., Lake Earl) • UC Natural Reserve System sites (e.g., Younger Lagoon) • BLM Areas of Critical Environmental Concern • Private conservation lands and easements
Conserved	Public or private lands with conservation value, though multiple uses or limited extraction may occur	• National monuments (e.g., Fort Ord) • National seashores (i.e., Point Reyes) • National forests (e.g., Los Padres) • State parks and beaches (e.g., Big Basin State Park, Santa Monica State Beach) • Regional and local parks, or shorelines with significant natural area (e.g., Redwood Regional Park) • Designated open space (e.g., City of San Diego Open Space) • Greenbelts, hiking trails, and corridors connecting natural areas • Military installations with significant natural area
Non-conserved–Public	Public lands with neither conservation focus nor significant natural area	• Regional or local parks with heavy recreational focus (e.g., Quarry Lakes) • County/municipal beaches • Recreational/community areas (e.g., sports fields, dog parks, cemeteries, golf courses) • Urban greenbelt areas with little natural area • Military installations with high development or little natural area
Non-conserved–Private	Non-conserved, privately owned lands	• Conservation easements to preserve farming values • Suburban parks managed by homeowners' associations • All other private lands

CHARACTERIZING INTERTIDAL AND SUBTIDAL ZONES UNDER CURRENT CONDITIONS, 2 FEET OF SEA LEVEL RISE, AND 5 FEET OF SEA LEVEL RISE

ELKHORN SLOUGH



Source:
NOAA

2.4 Methods for Assessing Vulnerability to Sea Level Rise

2.4.1 CHARACTERIZING SEA LEVEL RISE

We used statewide NOAA sea level rise projections (NOAA Coastal Services Center) to assess the vulnerability of California's coastal habitats and species to sea level rise. We chose the NOAA tidal sea level rise projections because they are statewide in coverage, while acknowledging that there are more sophisticated projections available at focal geographies (e.g., USGS CoSMoS, CoastalResilience.org). Because of the uncertainty associated with time horizon-based projections, we chose to use specific sea level rise elevations. We assessed habitat vulnerability at two feet and five feet of projected sea level rise, which is within the range of projections adopted by the California Coastal Commission in its Sea Level Rise Policy Guidance (CCC 2015). Results for five feet of sea level rise are presented in this report, results for both two feet and five feet of sea level rise are available in the Appendices.

2.4.2 ASSESSING HABITAT VULNERABILITY TO SEA LEVEL RISE

For this assessment, *Vulnerability* was defined as the degree to which coastal habitats are susceptible to, and unable to cope with, negative impacts of sea level rise (IPCC 2007). Vulnerability assessments have generally focused on assessing three main components of *Vulnerability*: *Exposure, Sensitivity, and Adaptive Capacity* (Glick *et al.* 2011 (eds.), Stein *et al.* (eds.) 2014). Assessing each of these components independently and understanding the relationship among them provides insight into what underlies *Vulnerability* for a given habitat within an area, to better direct management actions (Glick *et al.* (eds.) 2011, Stein *et al.* (eds.) 2014).

The combination of *Exposure* and *Sensitivity* to inundation is considered the *Potential Impact* (Stein *et al.* (eds.) 2014) and is habitat-specific (Glick *et al.* (eds.) 2011). Similarly, *Adaptive Capacity* is a habitat-specific measure of that habitat's ability to cope with a given level of *Exposure* (Stein *et al.* (eds.) 2014). *Vulnerability* to sea level rise inundation was assessed for each habitat within each analytic unit, as well as for all habitats within a unit combined to generate a *Vulnerability Index*.

Figure 2.3 Projected sea level rise characterized as subtidal and intertidal exposure.

Exposure, Sensitivity, and Potential Impact

We assessed *Exposure* to subtidal and intertidal waters separately (Figure 2.3), for each of our 40 coastal habitats because *Sensitivity* to intertidal *Exposure* varies by habitat. For each habitat, we summed the area of that habitat within each 1 km^2 analytic unit that was projected to be exposed to subtidal and intertidal waters separately. By using tidal range data to reclassify NOAA coastal 5-meter DEMs (*sensu* Heberger *et al.* 2009) we characterized the boundary between future intertidal and subtidal waters for both 2-ft and 5-ft sea level rise scenarios (Figure 2.3). This facilitated independent quantification of *Potential Impact* to coastal habitats from both subtidal and intertidal inundation for each sea level rise scenario.

We calculated *Potential Impact* by combining *Exposure* and *Sensitivity* separately for subtidal and intertidal inundation for each habitat.

Sensitivity was defined as the degree to which a habitat is likely to be affected by subtidal or intertidal *Exposure*. We quantified each habitat's *Sensitivity* to intertidal *Exposure* based on the statewide proportion of that habitat within current tidal area, mean lower low water to mean higher high water (Table 2.4), assuming there is an inverse relationship between current tidal exposure and *Sensitivity* to future tidal *Exposure*:

$$Sensitivity = (100 - \%\ Currently\ Tidal)/10$$

we then divided this proportion by 10 so that *Sensitivity* is a continuous parameter ranging from 0 (inferring no sensitivity to exposure) to 10 (inferring absolute likelihood to be affected by exposure) and varies by habitat (Table 2.4). All habitats were given a *Sensitivity* of 10 to subtidal *Exposure*. Importantly, *Sensitivity* is independent of a habitat's ability to move or transgress inland, which is represented by *Adaptive Capacity* (see below).

Potential Impact was quantified in a spatially explicit fashion as the area of *Exposure* of each habitat to subtidal and intertidal waters separately, weighted by that habitat's *Sensitivity* to that *Exposure*. Because *Sensitivity* ranges from 0 to 10, and the area of a habitat within an analytic unit ranges from 0 to 1, *Potential Impact* = *Exposure* * *Sensitivity* therefore ranges from 0 to 10.

Table 2.4 Sensitivity of habitat types to intertidal and subtidal exposure.

Habitat type	Intertidal sensitivity	Subtidal sensitivity	Habitat type	Intertidal sensitivity	Subtidal sensitivity
Swash Beach	0.0025	10.00	Annual Grassland	10.00	10.00
Invertebrate Reef	0.04	10.00	Barren	10.00	10.00
Aquatic Bed	2.12	10.00	Chaparral	10.00	10.00
Tidal Flat and Salt Panne	2.89	10.00	Coastal Conifer Forest and Woodlands	10.00	10.00
Tidal Channel	3.13	10.00	Coastal Dune	10.00	10.00
Other	3.47	10.00	Coastal Prairie	10.00	10.00
Rocky Intertidal	4.64	10.00	Coastal Scrub	10.00	10.00
Seasonal Freshwater Marsh	5.3	10.00	Mixed Evergreen Forests and Woodlands	10.00	10.00
Regularly-flooded Estuarine Marsh	6.83	10.00	Oak Forests and Woodlands	10.00	10.00
Lakes / Ponds	7.39	10.00	Perennial Grassland	10.00	10.00
Inland Shore	7.61	10.00	Rare Chaparral	10.00	10.00
Irregularly-flooded Estuarine Marsh	7.81	10.00	Rare Coastal Conifer Forest and Woodlands	10.00	10.00
Alkaline Marsh	8.45	10.00	Rare Coastal Scrub	10.00	10.00
Artificial Salt Pond	8.83	10.00	Rare Mixed Evergreen Forests and Woodlands	10.00	10.00
Freshwater Marsh	9.01	10.00	Rare Oak Forests and Woodlands	10.00	10.00
Tidal Freshwater Marsh	9.15	10.00	Rare Riparian Forest and Shrub	10.00	10.00
Estuarine Forested/Shrub Wetland	9.41	10.00	Rare Serpentine Systems	10.00	10.00
Riverine	9.52	10.00	Rare Vegetated Dune	10.00	10.00
Tidal Freshwater Forested/Shrub	9.76	10.00	Upper Beach	10.00	10.00
Riparian Forest and Shrub	9.99	10.00	Vernal Pool	10.00	10.00

Adaptive Capacity

Adaptive Capacity refers to the ability of a habitat to cope with a climate change stressor (Stein *et al.* (eds.) 2014). For this assessment, we focused on the ability of a habitat to migrate or transgress inland in response to sea level rise as dependent on the surrounding topography and land use as the indicator of *Adaptive Capacity*. *Adaptive Capacity* was calculated for each habitat within each analytic unit independently following a suite of simple rules. All habitats were not allowed to transgress into the built environment, future subtidal waters, habitats of lower elevation, or their own habitat category. Furthermore, future intertidal waters were also excluded for all habitats except intertidal marine and estuarine habitats. The remaining area of available space at a higher elevation within the analytic zone characterized the area of *Adaptive Capacity* for each habitat. The area available to transgress into in response to sea level rise was multiplied by 10, so that *Adaptive Capacity* is a continuous parameter ranging from 0 to 10 to balance *Potential Impact*.

Vulnerability of Habitats to Sea Level Rise

We quantified *Vulnerability* as the relationship between *Potential Impact* and *Adaptive Capacity* (sensu Stein *et al.* (eds.) 2014). Specifically, we modified a Bray-Curtis Index (Clarke *et al.* 2006) as follows:

$$Vulnerability_{(Habitat1)} = \left(\frac{PI_{Habitat1} - AC_{Habitat1}}{PI_{Habitat1} + AC_{Habitat1}}\right) + 1$$

where PI equals the habitat-specific *Potential Impact* and AC equals the habitat-specific *Adaptive Capacity*. By adding 1 to the Bray-Curtis Index, *Vulnerability* scores range from 0 to 2. There are some qualities unique to the Bray-Curtis Index (Clarke *et al.* 2006) which help inform habitat vulnerability and guide conservation. Specifically, *Vulnerability* scores of 0 and 2 are categorical; the only way to attain *Vulnerability* = 0 is if there is no *Potential Impact*, and the only way to attain *Vulnerability* = 2 is if there is no *Adaptive Capacity* (Clarke *et al.* 2006). Like a ratio, *Vulnerability* = 1 means that *Potential Impact* is equal to *Adaptive Capacity*. However, it is important to note that any *Vulnerability* greater than 0 implies some degree of vulnerability (Box 2.1).

BOX 2.1 POTENTIAL IMPACT, ADAPTIVE CAPACITY, AND VULNERABILITY SCORES

Potential Impact is calculated as the area of sea level rise *Exposure* weighted by that habitat's *Sensitivity*, or degree of impact from, that *Exposure* type.

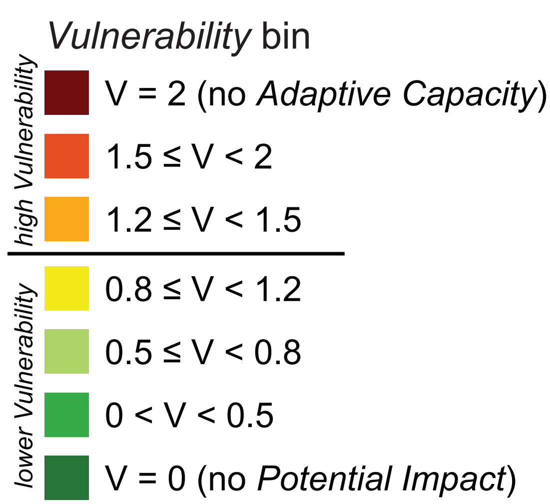
Adaptive Capacity is calculated as the area within the analytic zone of natural habitat available to any given habitat to transgress inland in response to sea level rise, excluding that habitat category, the built environment, and habitats lower in elevation.

Vulnerability represents the ratio of *Potential Impact* relative to *Adaptive Capacity* and ranges from 0 to 2. With no *Potential Impact*, *Vulnerability* = 0. As *Potential Impact* increases relative to *Adaptive Capacity* so does *Vulnerability*, up to V = 2, where there is no *Adaptive Capacity*.

***Vulnerability* = 1.2 a threshold ratio for *Adaptive Capacity* relative to *Potential Impact*.**
Vulnerability = 0.8 to 1.2 represents the range for which *Adaptive Capacity* roughly equals *Potential Impact*.

For *Vulnerability* ≥ 1.2 there is more calculated *Potential Impact* than *Adaptive Capacity*, for ease in description, we refer to this range as "*high Vulnerability*."

For *Vulnerability* < 1.2 *Potential Impact* is less than or equal to *Adaptive Capacity*, for ease in description, we refer to this range as "*lower Vulnerability*."



We calculated sea level rise *Vulnerability* within each analytic unit. We calculated habitat-specific *Vulnerability* for all 40 habitat types. For the aggregated habitat groups of freshwater wetland habitats and terrestrial habitats we calculated an area-weighted mean *Vulnerability* using all representative freshwater wetland or terrestrial habitats respectively within each analytic unit. We also calculated a *Vulnerability Index* as an area-weighted vulnerability of all habitats within an analytic unit. To do this we summed the *Vulnerability* of all habitats within a given analytic unit, each weighted by the area of habitat within the analytic unit. As ratios, habitat-specific *Vulnerability* and the *Vulnerability Index* are independent of area and describe each habitat's or the landscape's ability to maintain the current habitat area in the face of sea level rise within each analytic unit.

2.4.3 CONSIDERING SEA LEVEL RISE IMPACTS TO IMPERILED SPECIES

To investigate the potential for sea level rise to impact populations of imperiled species we tabulated information on number of occurrences for each taxonomic group within the state, study area, and projected sea levels to identify coastal-dependent species and the proportion of each imperiled species' occurrences within projected sea level rise (Appendix C.4).

To investigate the potential for sea level rise to impact populations of focal marine shorebirds and marine mammals we looked at *Vulnerability Index* scores for analytic units with occurrence data for these species. Given the error associated with marine mammal and shorebird occurrence data and our calculated *Vulnerability Index*, further effort is merited to more accurately investigate the vulnerability of these important marine predators, and the results presented here should be considered with caution. However, results provide a rough estimate of the potential for sea level rise to impact habitats that are critical to populations of these sensitive marine species.

To investigate the potential for sea level rise to impact important migratory bird habitat we calculated an area-weighted *Vulnerability Index* within each Audubon Important Bird Area in the analytic zone.

2.4.4 CONSIDERING SEA LEVEL RISE IMPACTS TO CONSERVATION LANDS AND RECREATIONAL ACCESS

To investigate the potential effects of sea level rise to conservation managed lands we overlaid projected extents of intertidal and subtidal waters onto layers of conservation management status and ownership.

For sandy beaches with facilities we overlaid the California Coastal Commission's access data with the results from our vulnerability assessment of upper beach habitat. We classified as *lower Vulnerability* those data points for sandy beaches with facilities falling within analytic units whose *Vulnerability* score for upper beach is lower than 1.2. Beaches with facilities access points within analytic units whose upper beach *Vulnerability* score is greater than or equal to 1.2 were classified as *high Vulnerability*.

2.4.5 CHARACTERIZING THE BUILT ENVIRONMENT TO IDENTIFY CONSERVATION CHALLENGES AND OPPORTUNITIES

The built environment is both at risk from sea level rise, and reduces habitat *Adaptive Capacity* by blocking inland transgression of habitats. We used multiple sources of data (e.g., NLCD, CALVEG), as well as digitization of certain features, to spatially characterize the built environment into 17 classes. We classified four built environment types (developed open space, prime agriculture, agriculture, and agricultural wetlands) as undeveloped uplands because they have minimal development of hard surfaces, and therefore would require less effort, relative to other built environment classes, to restore to habitat. We further characterized potential future habitats as that subset of undeveloped uplands that are projected to be exposed to sea level rise and/or are adjacent to vulnerable habitats. These conditions are considered indicators of suitability for habitat restoration and therefore could be prioritized.

By summarizing the relative amounts of each built environment category within the analytic zone, we identify what may be impeding habitat transgression to direct conservation strategies. We applied a landscape development intensity index (Brown and Vivas 2005) to inform the relative cost of conservation actions (including restoration) for different built environment categories which can be used to prioritize among potential conservation actions (Table 2.1). We developed a *Built Environment Intensity Index* as an area-weighted calculation

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of the area of each built environment type multiplied by its associated landscape development intensity index (Brown and Vivas 2005) within each analytic unit.

2.5 Methods for Analyses to Guide Conservation and Adaptation

We used the spatial data and analytical results described above to assess how different types of coastal conservation strategies may be applied to maintain extent of coastal habitats and biodiversity in the face of sea level rise. Specifically, we used the spatial data on *Vulnerability* of individual habitats, the *Vulnerability Index*, RWRI, the built environment categories, ownership, and conservation management status in overlays of spatial data to identify where different strategies may be more important to deploy across the state. We quantified and mapped the following five strategies organized under two larger themes:

CONSERVE AND MANAGE FOR RESILIENCE

To ensure that our existing conservation lands are maintained and managed for resilience and that we invest in new conservation of a resilient coast, we mapped and quantified the following three strategies:

Maintain existing conservation lands (Section 5.1)—we combined *Vulnerability* with conservation management status to identify resilient patches of conservation lands for which we should work to maintain both their conservation management status as well as the resilience of the habitats within these areas,

Conserve resilient landscapes (Section 5.2)—we combined *Vulnerability* with conservation management status to identify resilient habitats that are not conserved, representing opportunities to invest in conserving resilient landscapes, and

Manage in place for resilience (Section 5.3)—we combined *Vulnerability* with conservation management status to identify where coastal habitats on conservation lands are vulnerable to sea level rise and need to be managed in place for resilience.

MITIGATE POTENTIAL LOSSES OF VULNERABLE HABITATS

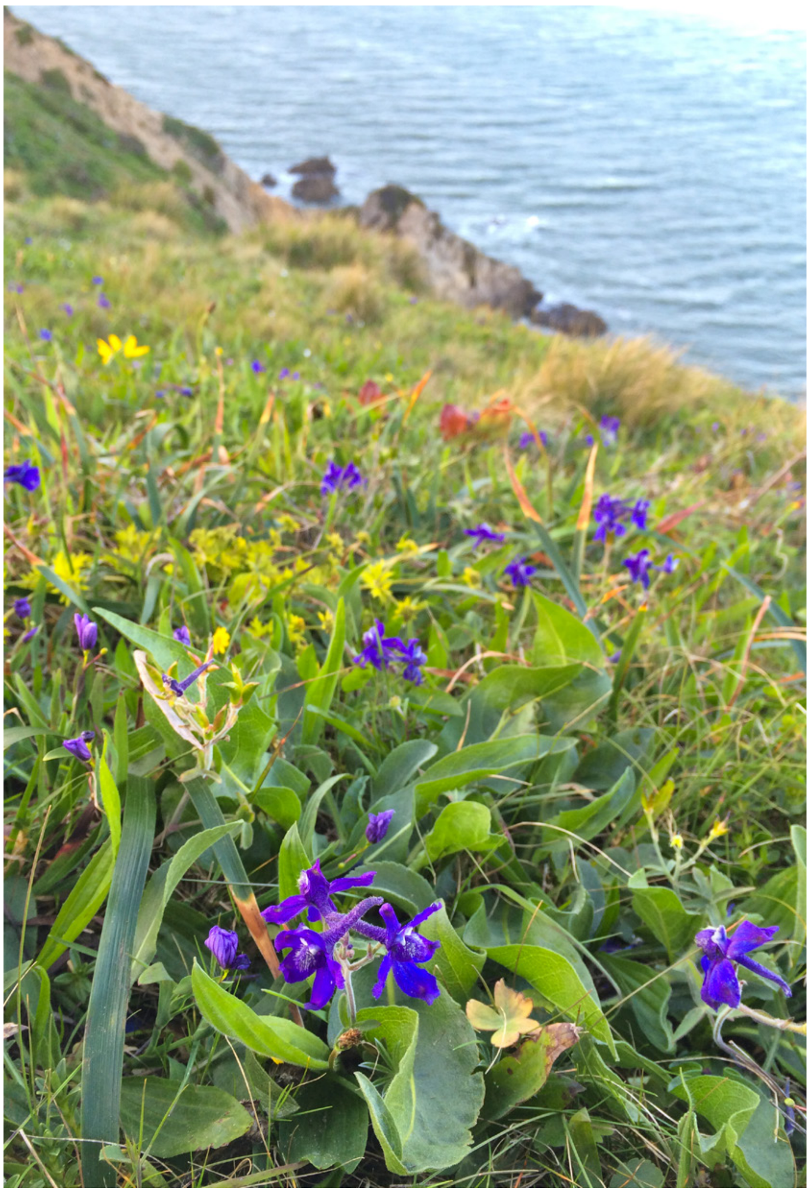
To mitigate the potential loss of coastal habitats to sea level rise, we mapped and quantified the following two strategies:

Conserve potential future habitat areas (Section 5.4)—we used habitat *Vulnerability* and mapped undeveloped uplands to identify where there are vulnerable habitats for which undeveloped uplands could provide area for coastal habitats to be restored or transgress inland, and

Increase Adaptive Capacity (Section 5.5)—we used built environment categories to investigate where there are opportunities to adapt or retreat the built environment to either enhance coastal habitat area or function.

We used the *Vulnerability Index* combined with conservation management status to map and quantify conservation strategies throughout the state (Section 5). We characterized the *Vulnerability Index* into *high Vulnerability* and *lower Vulnerability* using a threshold value of V_i=1.2 (Box 2.1) without rounding this continuous variable (i.e., V_i=1.999, will be considered *lower Vulnerability*). Because the *Vulnerability Index* is an area weighted average of the *Vulnerability* of all habitats within an analytic unit there likely will be habitat specific *Vulnerability* above and below the *Vulnerability Index* score. Thus, both the *Vulnerability Index* and resulting conservation strategies should be used as indicators, to show patterns, prioritize, and guide at regional scales. We recommend exploring the habitat specific *Vulnerability* scores and other associated data from this assessment to further understand local details and what is driving the *Vulnerability Index* score and resulting conservation strategies.

Within each conservation strategy of Section 5, we relate habitat specific *Vulnerability* to the conservation strategies derived from the *Vulnerability Index* to better understand how conservation strategies apply to individual habitats within each ecoregion. We also relate results to other data such as built environment classes and the *Built Environment Index* to further inform conservation strategies to maintain habitat area in the face of sea level rise. We used RWRI to spatially prioritize areas of highest conservation significance within each conservation strategy.



Clockwise from left: © Sue Pollock/The Nature Conservancy; Walter Heady/The Nature Conservancy; © Sylvia Busby

3.0 | What is the Current State of the Coast?

California's iconic coast holds the highest numbers of native species in the state (Figure 1.1) and is relatively well conserved, with many public lands and points of public access to the shoreline. This is particularly impressive as much of California's development, transportation, shipping, and agriculture is also focused along the coast, including the state's largest urban centers. Human activity along the coast has resulted in significant losses of coastal habitats including a loss of 90% of California's coastal wetlands (Dahl 1990, Zedler 1996), and considerable lengths of coast altered by man-made structures such as jetties, levees, and sea walls that accelerate beach loss (Dugan *et al*. 2008, Dugan *et al.* 2017, Vitousek *et al.* 2017). Yet, due to a legacy of conservation actions, 68% of our coastal study area remains in natural habitat (Figure 3.1). Understanding the conservation landscape of the present-day coast is important for guiding conservation strategies to ensure long-term conservation of unique coastal habitats in the face of sea level rise.

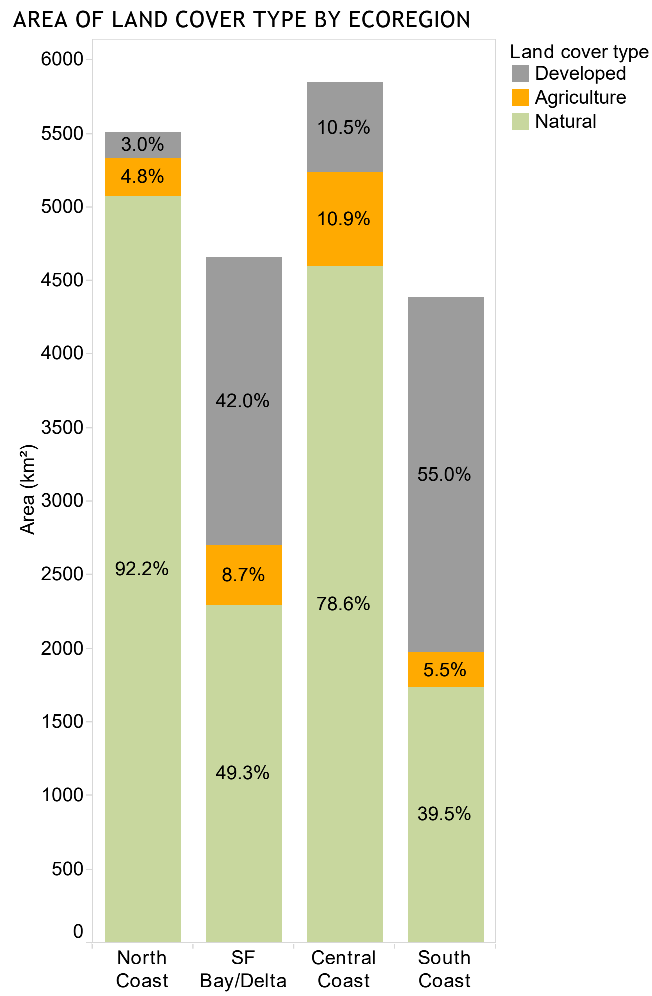


Figure 3.1 Area (km²) by ecoregion of three land cover types: developed, agriculture, and natural. Percentages calculated by ecoregion.

3.1 Land Cover

California's ecoregions have vastly different patterns of natural, agricultural, and developed land cover (Figure 2.2 and Figure 3.1). The North Coast ecoregion from Del Norte County to Sonoma County is dominated by 5,069 km^2 of natural land cover and is sparsely populated, heavily-forested, and mountainous. The Lost Coast of Mendocino and Humboldt counties remains the largest undeveloped oceanfront extent of land in the United States outside Alaska (Wilderness.net 2017).

The San Francisco Bay Delta, despite its more than 1,956 km^2 of intense development, supports the largest tracts of estuarine marshes in the state, among its 2,294 km^2 natural habitats (Figure 3.1). The San Francisco Bay Delta also contains over 405 km^2 of agriculture, more than a quarter of which is classified as prime agriculture.

The Central Coast ecoregion from Marin County to Santa Barbara County has 4,594 km^2 of natural land cover and 564 km^2 of developed land (Figure 2.2). Long stretches of the coast from Marin County to Santa Barbara remain relatively undeveloped. The Central Coast however, has the greatest extent (635 km^2) of coastal agriculture (Figure 3.1) in some of the most productive agricultural lands in the world, 47% of which is classified as prime agriculture.

The South Coast ecoregion from Santa Barbara County to San Diego County (Figure 2.2) has the greatest extent of developed lands in the study area: 2,414 km^2 (Figure 3.1). The development has come at the expense of natural area—with only 1,734 km^2 remaining—the least extensive among the ecoregions (Figure 3.1). However, there are important coastal wetlands, rare coastal scrub habitat, coastal dunes, and a large extent of the state's sandy beaches. While the South Coast holds the lowest extent of agriculture (241 km^2), 59% of it is high-value, prime agriculture.

3.2 Coastal Habitats

The California coast is part of the California Floristic Province, with a Mediterranean climate giving rise to distinct habitat types and high levels of biodiversity. The coast is characterized by temperate conditions and coastal fog. The marine and intertidal communities are part of the California Current Large Marine Ecosystem, one of only five temperate upwelling systems in the world, which supports high marine diversity and productivity. California's shoreline includes stretches of beach and rocky intertidal habitats, punctuated by estuaries and the habitats they harbor, ranging from the large San Francisco Bay to the more than 500 smaller estuaries or streams that flow directly into the ocean (Heady *et al.* 2014). We used coastal habitat characterizations and rare and imperiled species occurrences to represent the biodiversity values throughout the study area (Noss 1987, Groves 2003).

Of the 40 distinct habitat types we used to characterize the present-day coast (Table 2.2), six of these are found only along the coastal margin, three marine intertidal habitats: rocky intertidal, swash beach, and upper beach, and three estuarine habitats: tidal flat and salt panne, regularly-flooded estuarine marsh, and irregularly-flooded estuarine marsh. Because of the distinct characteristics of each of these six coastal habitat types, they are irreplaceable, simultaneously supporting unique suites of marine and terrestrial species and high biodiversity. For our vulnerability assessment, we focused on these six habitats as well as two aggregations of general habitat types: freshwater wetlands and terrestrial habitats. In the following subsections, we describe the habitat type and summarize the current extent of each of these six habitat types and two habitat aggregations throughout the larger study area (Table 3.1).

Table 3.1 Area (km^2) of eight coastal habitat types, among ecoregions and statewide within the study area.

Habitat Types	North Coast	SF Bay/Delta	Central Coast	South Coast	Total (State)
Swash Beach	8.86	0.14	11.39	9.60	**29.99**
Upper Beach	25.10	0.12	16.49	20.41	**62.12**
Rocky Intertidal	6.43	0.01	6.74	0.65	**13.83**
Tidal Flat and Salt Panne	57.58	138.96	22.33	19.58	**238.44**
Regularly-flooded Estuarine Marsh	7.54	176.31	11.58	8.18	**203.62**
Irregularly-flooded Estuarine Marsh	3.93	15.09	5.78	13.71	**38.51**
Freshwater Wetlands[1]	277.58	228.240	148.91	98.10	**752.83**
Terrestrial[2]	4,607.48	1,451.27	4,298.15	1,510.19	**11867.09**
Grand Total	**4,994.51**	**2,010.14**	**4,521.378**	**1,680.42**	**13,206.44**

1. Freshwater wetlands include the following: freshwater marsh, inland shore, rare riparian forest and shrub, riparian forest and shrub, seasonal freshwater marsh, tidal freshwater forested/shrub, tidal freshwater marsh, and vernal pool.

2. Terrestrial habitats include the following: annual grassland, barren, chaparral, coastal conifer forest and woodlands, coastal dune, coastal prairie, coastal scrub, mixed evergreen conifer forest and woodlands, oak forests and woodlands, other terrestrial sub-habitats, perennial grassland, rare chaparral, rare coastal conifer forest and woodlands, rare coastal scrub, rare mixed evergreen forests and woodlands, rare oak forests and woodlands, rare serpentine systems, and rare vegetated dune.

BOX 3.1 THE IMPORTANCE OF MARINE INTERTIDAL HABITATS TO PEOPLE AND NATURE

Marine intertidal habitats along California's 1,770 kilometers of rugged wave washed outer coast include rocky intertidal, swash beach, and upper beach. Being at the ocean's edge, these habitats are important to both marine and terrestrial species, provide benefits to people, and are a dynamic link between the marine and terrestrial realms.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Dynamic in Time and Place

Marine intertidal habitats cycle twice daily between terrestrial habitat exposed to air and marine habitat washed by waves, and also change dramatically seasonally or year-to-year. For example, a habitat may cycle seasonally or interannually between rocky intertidal and beach, when wave energy deposits sand atop a rocky intertidal habitat or scours a beach down to bedrock. The invertebrates and algae of rocky intertidal and the invertebrates of beaches have adapted to such dramatic cycles by being either resilient or quick to colonize and productive in growth. Many marine and terrestrial animals capitalize on the extreme dynamism and productivity found within these habitats.

Abundant Food Sources

During low tides, many shorebirds, seabirds, and even terrestrial birds feed within marine intertidal habitats. These productive feeding and resting grounds may be critical to populations of birds as they migrate along the Pacific Flyway. During high tide, marine intertidal habitats are important foraging and refuge areas for marine invertebrates and fishes and also provide productive foraging habitat for sea otters.

Safe Havens

Marine intertidal habitats provide crucial resting and pupping haul-outs for Pacific harbor seals, Northern elephant seals, California sea lions, and Steller sea lions (Section 3.3). Similarly, upper beach provides necessary resting area for shorebirds and seabirds (Neuman *et al*. 2008). The endangered California least tern and threatened western snowy plover both nest only in upper beaches relatively free from human disturbances (further described in Section 3.3). Black oystercatchers nest on rocky substrate at the base of cliffs free from predators and human disturbance.

Ecosystem Services that Benefit People

Invertebrates and algae of marine intertidal habitats as well as the fishes they support provide food sources for people. The invertebrates of marine intertidal habitats may also filter and clean waters. Large expanses of marine intertidal habitats may provide protective services from sea level rise and storm surge. Marine intertidal habitats are some of the most popular tourist and recreational areas of the United States benefiting people and economies.

Resilience Dependent on Dynamism

Marine intertidal habitats provide a dynamic interface between the marine and terrestrial realms. As long continuous strands of habitat, they may provide corridor habitat connecting patches of intact terrestrial habitats. Whether marine intertidal habitats persist through time depends on many interacting natural factors beyond our present ability to forecast. One thing, however, is certain. Human efforts to armor the coast to make the coastline "permanent" jeopardize not only the adjacent marine intertidal habitat, but marine intertidal habitats up and down the coast.

MARINE INTERTIDAL HABITATS

Rocky Intertidal

Rocky intertidal is inhabited by sessile invertebrates and algae affixed to rocky substrate found predominantly between mean lower low water and mean higher high water along the outer coast. The rocky intertidal community is composed of marine species that have adapted to this environment, ever moving landward to avoid the high levels of predation and competition in the ocean. As such, the upper limit of rocky intertidal species is determined by their ability to resist the drying forces and heat associated with being exposed during low tides, while the lower limit of their distribution is generally established by competition or predation (Connell 1961). Within rocky intertidal habitat, physical conditions and resulting biological communities can vary dramatically within very short distances giving rise to some of the highest biodiversity and density of species found in the world (Ricketts *et al.* 1985). In addition to its intrinsic biodiversity values, rocky intertidal habitat provides important foraging and resting habitat for a diversity of marine, coastal, and terrestrial organisms (Box 3.1). For, example, black oystercatchers feed exclusively in rocky intertidal habitats and nest on rocky substrate at the base of cliffs free from predators and human disturbance (Section 3.3). At low tides, rocky intertidal provides important haul-outs for Pacific harbor seals and other pinnipeds (Section 3.3), as well as important foraging habitat for many shorebirds, seabirds, and even terrestrial animals.

Rocky intertidal is the habitat with the smallest extent (13.8 km^2) within this assessment, dispersed widely as small patches throughout the outer coast of California. The Central Coast ecoregion holds the most rocky intertidal habitat, followed by the North Coast ecoregion, with little rocky intertidal in the South Coast ecoregion (Table 3.1). Some of this already rare habitat has been degraded or lost due to coastal engineering. Trampling, overharvesting, and pollution have also degraded the biodiversity and ecological function of some rocky intertidal habitats (Littler and Murray 1975, Addessi 1994).

Swash Beach

Swash beach is defined as sandy beach habitat found between mean lower low water and mean higher high water. Swash beach is a dynamic habitat within a high wave energy environment, composed of unconsolidated sand, devoid of vegetation, and cycling between periods of being exposed to air and being fully submerged by tidal waters or wave runup throughout each day. It is with this dynamism that swash beach provides important habitat to many marine and terrestrial species (Box 3.1). Pacific harbor seals may use swash beaches, particularly pocket beaches isolated at the base of cliffs, as haul-outs during low tides. At low tides, swash beaches contain high abundances and diversity of macroinvertebrates and thereby provide important feeding habitats for shorebirds (Neuman *et al.* 2008). While the quality of foraging habitat varies among swash beaches, and is even variable within beaches in time and space (Dugan *et al*. 2013; Schlacher *et al.* 2014), the importance of swash beaches as foraging habitat for some shorebirds may be of equal or greater importance than wetland complexes (Neuman *et al.* 2008).

There are 30 km^2 of swash beach habitat along California's outer coast. This is a small area relative to the extent of other habitats within our study area (Table 3.1). However, swash beach habitat is quite evenly distributed statewide (Table 3.1) in a continuous thread along the outer coast—interrupted by coastal confluences, patches of rocky intertidal, and human infrastructure.

Upper Beach

Upper beach habitat is sandy beach stretching from mean higher high water inland into dunes, bluffs, or other habitats. Upper beach habitat typically has drier sand than swash beach. Upper beach is however periodically washed by high tides or strong waves that shape and maintain its area and form and generally keep upper beach habitat relatively devoid of vegetation. Waves may also deposit logs, seaweed, shells, kelp, or other wrack washed up from sea or away from land. Invertebrates in upper beach habitats, often associated with wrack, are important food sources for terrestrial and marine organisms—particularly shorebirds like western snowy plover (Neuman *et al.* 2008; Box 3.1). Dead marine organisms along beaches also provide important food sources for beach invertebrates as well as terrestrial scavengers including large mammals, turkey vultures, and California condors. Several organisms benefit from the potentially large and dynamic areas of upper beach shaped by wind and other disturbances. For example, the endangered California least tern and threatened western snowy plover both nest only in upper beaches relatively free from human disturbances (further described in Section 3.3). Several pinniped species such as the Pacific harbor seal, Northern elephant seal, California sea lion, and Steller sea lion also use upper beaches

BOX 3.2 THE IMPORTANCE OF ESTUARINE HABITATS TO PEOPLE AND NATURE

California has over 500 estuaries, ranging in size from the expansive San Francisco Bay Delta to the hundreds of small streams entering the sea along the outer coast. Estuarine habitats—tidal flat and salt panne, regularly-flooded estuarine marsh, and irregularly flooded estuarine marsh—provide benefits to a diversity of marine and terrestrial species as well as to people (Barbier *et al.* 2011).

Productivity Supporting Diversity

Estuarine habitats are some of the most productive habitats in the world, supporting large marine and terrestrial foodwebs (Barbier *et al.* 2011). The importance of these productive centers to fish and invertebrates extends far beyond the estuary throughout the ocean. The rich soils, abundant invertebrates, and plant food sources of estuarine habitats are also important to a diversity of resident and migratory terrestrial species including many rare, endemic, and imperiled species. These productive feeding and resting grounds are of global significance to birds migrating along the Pacific Flyway.

Rare and Imperiled Species

Many plants and animals within estuarine habitats are rare or imperiled, and some are found nowhere else in the world. For example, rare and endangered plant species such as California sea-blite (*Suaeda californica*), different species of bird's-beak (*Chloropyron spp.*), and Suisun thistle (*Cirsium hydrophilum var. hydrophilum*) are found only within certain estuarine marsh habitats (USFWS 2013). The endangered salt marsh harvest mouse (*Reithrodontomys raviventris*) and several birds such as the state-endangered Belding's savannah sparrow (*Passerculus sandwichensis beldingi*), federally-endangered California Ridgway's rail (*Rallus obsoletus obsoletus*), federally-endangered light-footed clapper rail (*Rallus longirostris levipes*), and California black rail (*Laterallus jamaicensis coturniculus*) are only found within estuarine marsh habitats (USFWS 2013).

Nursery Value

Many fish and invertebrate species use estuarine habitats to rest, feed, and reproduce (Monaco *et al.* 1990, Emmett *et al.* 1991). Because of the increased growth and survival provided by estuarine habitats, these areas may provide nursery value disproportionate to their size for the maintenance of marine populations (Beck *et al.* 2001, Hughes *et al.* 2014). The nursery value of estuarine habitats has been demonstrated for many imperiled and commercially important species such as flat fishes, crabs, and salmon (Thorpe 1994, Bond *et al.* 2008, Barbier *et al.* 2011, Hughes *et al.* 2015).

Ecosystem Services that Benefit People

Estuarine habitats provide many benefits to humans including effective wave reduction and buffering of storm damage (Möller *et al.* 2014, Spalding *et al.* 2014, Narayan *et al.* 2016), some of the highest rates of carbon sequestration (McLeod *et al.* 2011), as well as provisioning of raw materials and food, fisheries production, erosion control, water filtration, recreation, tourism, education, and research (Barbier *et al.* 2011).

Resilience in Nature

The resilience of these dynamic habitats and the services they provide to nature and people are dependent on the natural dynamics that maintain them such as tidal flushing, sediment supply, and natural disturbance, as well as ensuring they have areas to move inland in response to sea level rise.

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as critical haul-outs, breeding, and pupping grounds (further described in Section 3.3). Similarly, upper beach habitats provide necessary resting area for shorebirds and seabirds (Neuman *et al.* 2008).

There are 62 km^2 of upper beach habitat along California's outer coast with 40% in the North Coast, 27% in the Central Coast, and 33% in the South Coast ecoregion (Table 3.1). Upper beach varies dramatically in area and form, ranging from small pocket beaches isolated along cliff faces to long expanses of beaches extending for kilometers. Each of these types appears in each outer-coast ecoregion. Whether a beach is stable, increasing in area, or eroding over time is driven by many interacting natural forces (Hapke *et al.* 2006; Vitousek *et al.* 2017). However, the area of upper beach habitat and its trend of accretion or erosion can also be affected by human actions along the coastline, which may encroach upon the beach itself or interrupt the natural movement of sand along the coast (Hapke *et al.* 2006, Dugan *et al.* 2008, Dugan *et al.* 2017). Sea level rise affects the natural processes governing beaches, exacerbates existing impacts from human alteration of the coastline, and thus may be the single largest threat to beaches (Vitousek *et al.* 2017). For example, sea level rise is predicted to completely erode up to 67% of beaches along the 500 km of beaches in the South Coast ecoregion by 2100 (Vitousek *et al.* 2017). Yet, upper beach habitats are some of the most popular tourist and recreational areas of the United States (Hapke *et al.* 2006). Thus, conservation actions now are necessary to preserve the many benefits that upper beach habitats provide to humans and nature as sea levels rise.

ESTUARINE HABITATS

Tidal Flat and Salt Panne

Tidal flat and salt panne habitat is composed of unconsolidated fine sediments with few stones and boulders and minimal to no vegetation (Cowardin *et al.* 1979). Because tidal flat and salt panne habitat is the lowest elevation estuarine habitat above mean lower low water, it is typically at least partially covered by tidal waters and exposed to air less often than daily (Cowardin *et al.* 1979). Salt pannes are hypersaline unvegetated patches that develop within estuarine marsh habitats. These low-lying areas retain water as tides or wave overwash recedes, and with time the water and soil increase in salinity creating unvegetated flats. Given data limitations, we were unable to differentiate between tidal flats and salt pannes so we combined the two in this assessment. Tidal flat and salt panne habitat are critical to many marine and terrestrial species, and provide benefits to humans (Box 3.2). Healthy tidal flat and salt panne habitat can have high biomass and diversity of shellfish and worms within the substrate (infauna), as well as of other invertebrates above the surface in the water, air, and in wrack. This wealth of invertebrates supports a potentially large food web. The relatively calm waters or dry flats of tidal flat and salt panne habitat are used as critical safe havens by juvenile invertebrates and fish, as well as Pacific harbor seals, southern sea otters (*Enhydra lutris nereis*), and shorebirds. Tidal flat and salt panne habitat is important for maintaining the huge numbers of migratory shorebirds along the Pacific Flyway. The potentially high abundance of shellfish in healthy tidal flats can effectively filter the water of estuaries as well as provide a valuable food source for people.

Tidal flat and salt panne habitat is the most extensive habitat type within the study area (238.4 km^2), with 58% in the San Francisco Bay Delta, 24% in the North Coast, 9% in the Central Coast, and 8% in the South Coast ecoregions (Table 3.1). However, tidal flat and salt panne habitat is dramatically reduced from its historical extent among all ecoregions due to dredging and alteration as well as upstream human disturbances such as dams, which cut off sediment supply. Habitat quality may be further degraded by water pollution, which may dramatically reduce the diversity and biomass of the infauna community (Chapman *et al.* 1987). Salt panne is a unique estuarine habitat that used to be common throughout the South Coast ecoregion but has been dramatically reduced in area from historic levels (Stein *et al.* 2014) and is a focus of wetland recovery goals for the region. Tidal flat and salt panne habitat is at risk of drowning from sea level rise due to its low elevation, particularly in altered settings that lack room for inland transgression. Reduced area and degraded condition of tidal flat and salt panne disrupts the connectivity of marine and terrestrial realms among California's estuaries, and erodes the benefits this vital habitat provides to nature and humans (Box 3.2).

Regularly-flooded Estuarine Marsh

Regularly-flooded estuarine marsh is characterized by erect, rooted, salt-adapted vegetation that is alternately flooded and exposed by estuarine tides at least once daily (Cowardin *et al.* 1979). Regularly-flooded estuarine marsh is typically dominated by some combination of pickleweed *(Sarcocornia pacifica)*, California cordgrass *(Spartina foliosa)*, salt grass *(Distichlis spicata)*, and alkali heath *(Frankenia salina)*, with the relative abundance of each varying regionally, and higher diversity of vascular plant species in southern California (Zedler *et al.* 1992). This plant community is extremely productive (Barbier *et al.* 2011), supports a diversity of marine and terrestrial plants, algae, and animals, provides critical nursery habitat to many marine species, and provides critical foraging and resting habitat along the Pacific Flyway (Box 3.2). Several rare and endangered species are found only within regularly-flooded estuarine marsh (USFWS 2013), highlighting the importance of this habitat for conservation (Box 3.2). Regularly-flooded estuarine marshes also provide many benefits to humans such as some of the highest per hectare rates of carbon sequestration of any habitat in the world (McLeod *et al.* 2011), and protective services for natural and human environments during storm events (Möller *et al.* 2014, Spalding *et al.* 2014, Narayan *et al.* 2016; Box 3.2).

Regularly-flooded estuarine marsh is the single habitat with the second-largest current extent statewide (203.6 km^2); however, this is a fraction of its historical extent due to conversion to agriculture and other built environment categories. Currently, 87% of the state's regularly-flooded estuarine marsh is found within the San Francisco Bay Delta, with the remainder distributed among the North Coast, Central Coast, and South Coast ecoregions (Table 3.1). In addition to loss, urbanization of surrounding lands is linked to poor condition of regularly-flooded estuarine marsh (Solek *et al.* 2012). Dikes, levees, and other water control features negatively impact the health, and function of regularly-flooded estuarine marshes (Anisfeld and Benoit 1997), and have been shown to have some of the highest impacts to the current health and resilience of California's regularly-flooded estuarine marshes (Solek *et al.* 2012). Non-native species also threaten regularly-flooded estuarine marsh by either outcompeting natives or preying on imperiled species (USFWS 2013).

Irregularly-flooded Estuarine Marsh

Irregularly-flooded estuarine marshes are characterized by rooted vegetation that generally remains standing at least until the next growing season and is exposed to tidal or other flooding less often than daily (Cowardin *et al.* 1979). In tidal estuaries, irregularly-flooded estuarine marsh is found fringing the inland edge of regularly-flooded estuarine marsh. Irregularly-flooded estuarine marsh may also be the predominant marsh habitat of non-tidal or bar-built estuaries which may only experience tidal or riverine flooding seasonally or interannually. Irregularly-flooded estuarine marsh may be composed of similar plants as regularly-flooded estuarine marsh such as pickleweed, California cordgrass, salt grass, and alkali heath, and associated rare and endangered plant species. These salt-adapted species may be intermixed with freshwater adapted and more terrestrial plant species. As productive transitional habitats between estuarine and terrestrial ecosystems, irregularly-flooded estuarine marshes provide rich habitat to a heightened diversity of species, many of which are rare or imperiled (Box 3.2).

California has suffered extensive losses of irregularly-flooded estuarine marsh habitat because of conversion to agriculture and the built environment. As a result, irregularly-flooded estuarine marsh is the estuarine habitat with the most limited extent statewide at present (38.5 km^2; Table 3.1). Thirty-nine percent of present-day irregularly-flooded estuarine marsh is found within the San Francisco Bay Delta as a transition between regularly-flooded estuarine marsh and upland habitats. Thirty-six percent is found in the South Coast ecoregion as the predominant estuarine marsh habitat for that region. The remaining 25% is divided between the North and Central Coast ecoregions, as both fringing tidal estuaries and as the predominant marsh for California's many seasonally closed estuaries. The reduction in area and artificial narrowing of irregularly-flooded estuarine marsh habitat has cascading effects on the many rare and imperiled species that rely on irregularly-flooded and regularly-flooded estuarine habitat (USFWS 2013). The conversion of habitats adjacent to irregularly-flooded estuarine marsh further degrades irregularly-flooded marsh habitat quality by reducing buffer width and quality, and by affecting hydrologic, physical, and biological conditions (Solek *et al.* 2012, USFWS 2013, Heady *et al.* 2015).

FRESHWATER WETLAND HABITATS

There are many different freshwater wetland habitat types, all of which experience regular saturation of freshwater as a dominant factor in determining soil and vegetation types (Cowardin *et al.* 1979). We lump eight distinct freshwater wetland categories under the term 'freshwater wetlands' with the following percent composition in our study area, statewide: freshwater marsh (4%), seasonal freshwater marsh (34%), tidal freshwater marsh (1%), tidal freshwater forested/shrub (<1%), inland shore (3%), riparian forest and shrub (58%), rare riparian forest and shrub (<1%), and vernal pool (<1%). Freshwater wetlands are often very productive and provide an important source of food and water to a diversity of species. Because of their unique conditions,

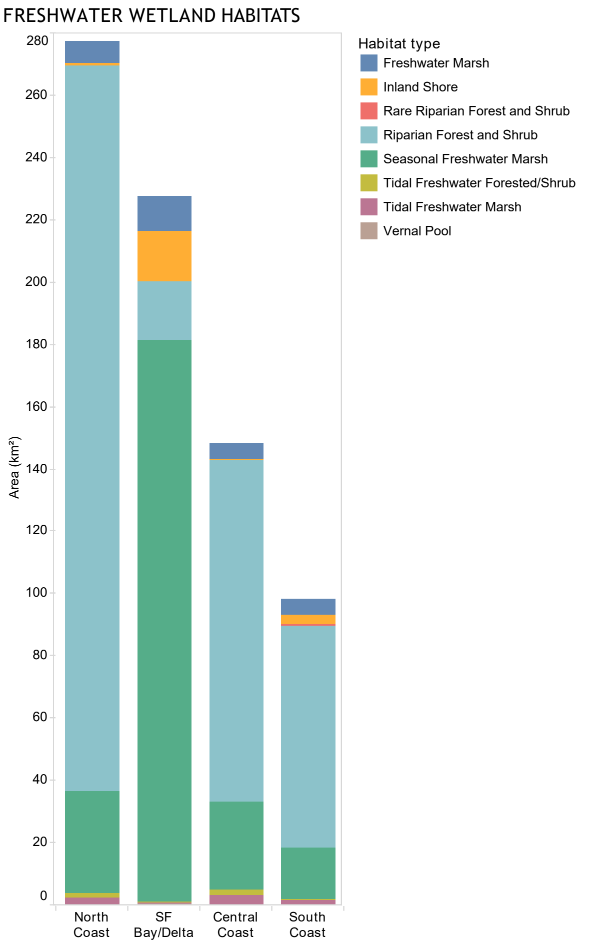


Figure 3.2 Area (km²) of freshwater habitat types by ecoregion.

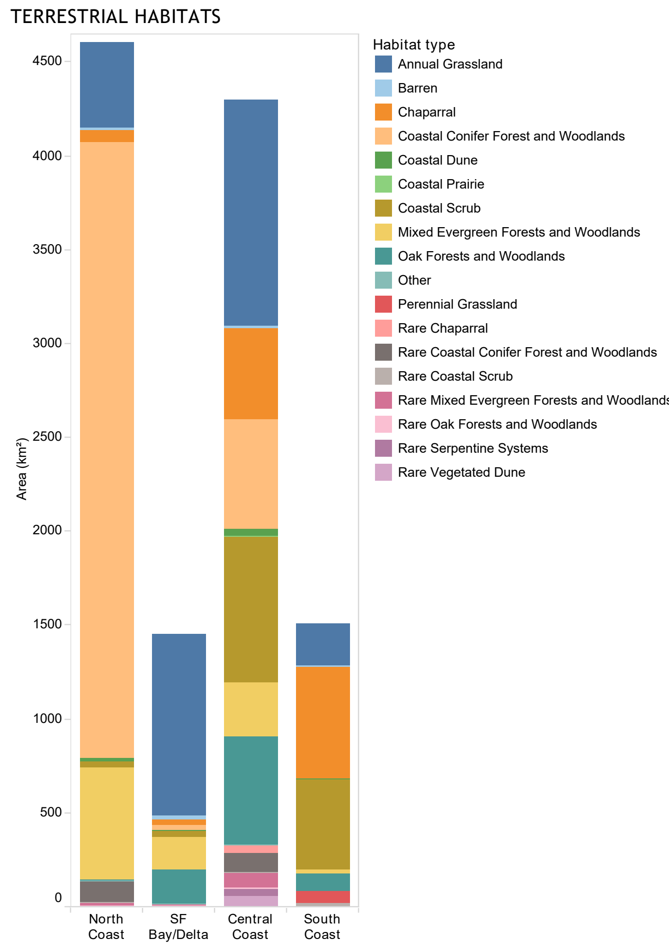


Figure 3.3 Area (km²) of terrestrial habitat types by ecoregion.

freshwater wetlands often support unique or rare plants and animals. The unique conditions and species found within freshwater wetlands all are very sensitive to changes in salinity, and therefore quite vulnerable to sea level rise.

There are 752.8 km² of freshwater wetlands in the study area, with 30% found in the San Francisco Bay Delta, 37% in the North Coast, 20% in the Central Coast, and 13% in the South Coast ecoregions (Table 3.1 and Figure 3.2). Riparian forest and shrub is the most extensive freshwater wetland type with over 434 km² throughout the study area. Further wetland-specific details can be found in Appendix C.2.

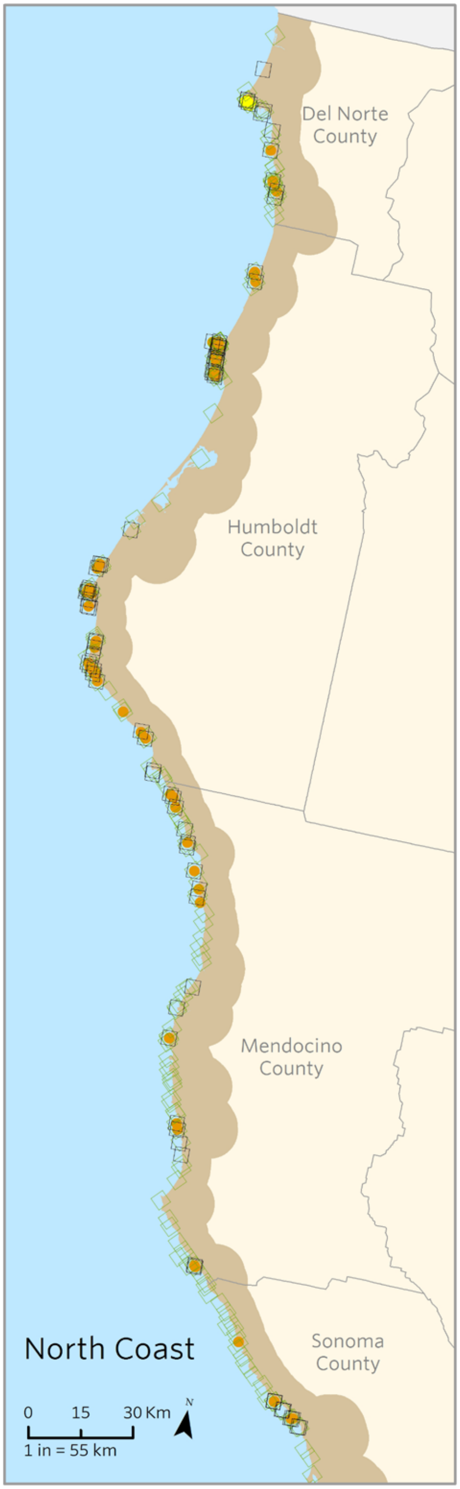
TERRESTRIAL HABITATS

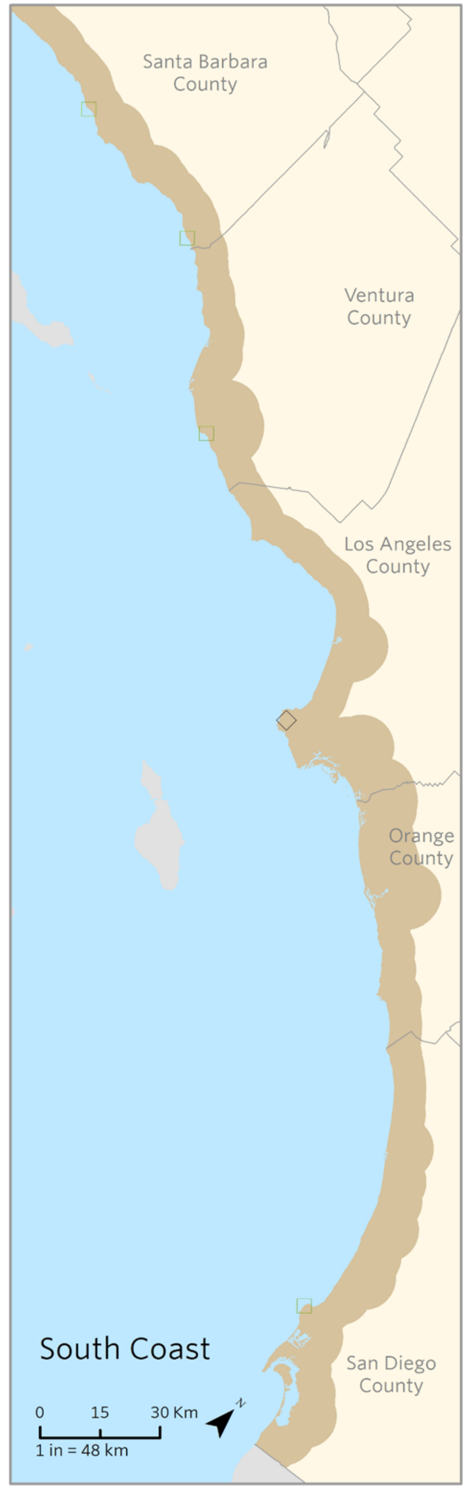
Terrestrial habitats are non-wetland habitats found upslope from California's intertidal habitats. We lumped eighteen of our 40 total habitat types under the term 'terrestrial habitats' which collectively cover 11,867.1 km²—58% of our study area (Table 3.1 and Figure 3.3). These eighteen habitat types represent the high species diversity and ecological function found among California's terrestrial ecosystems.

Most terrestrial habitats are found well inland of tidal influence, providing a landscape context to our sea level rise vulnerability assessment. However, coastal prairie, perennial grassland, coastal dune, and rare coastal scrub are found directly along the coast. Further terrestrial habitat details can be found in Appendix C.2. The composition of terrestrial habitats that fringe tidal coastal habitats will be important as sea level rises. These terrestrial habitats provide areas for tidal habitats to transgress into in response to sea level rise, buffers around tidal habitats, and potentially important habitat and species relationships along the coast. As tidal habitats transgress inland, terrestrial habitats may suffer losses as they convert to tidal habitats, if they do not also have room to move inland in response.

MARINE MAMMAL HAUL-OUTS AND ROOKERIES

ECOREGION





Haul-out or Rookery

- California sea lion
- Pacific harbor seal
- Northern elephant seal
- Steller sea lion

Source:
CDFW BIOS; NOAA

3.3 Important Areas for Marine Mammals, Seabirds, and Shorebirds

California's mainland coast—especially its beaches, rocky intertidal habitats, and estuaries—provide resting and rookery grounds for many species of marine mammals, seabirds, and shorebirds. This study identified seven focal shorebird and marine mammal species for their obligate use of coastal habitats and potential vulnerability of these habitats to sea level rise: black oystercatcher, California least tern, western snowy plover, California sea lion, Steller sea lion, Pacific harbor seal, and Northern elephant seal. These species have documented presence, designated critical habitat, or breeding and haul-out sites throughout the study area that may be vulnerable to sea level rise (Figure 3.4, Figure 3.5, and Table 3.2).

Historically, larger pinnipeds like Northern elephant seals and sea lions formed breeding colonies on the many islands, islets, and rocks along California's shores to avoid predation from grizzly bears and other large predators. Each of these pinniped species were hunted nearly to extinction by people in the 19th century. As populations rebounded after protection, due to a lack of large predators on the mainland, Northern elephant seals, California sea lions, and Steller sea lions established breeding colonies and haul-outs on California's mainland. Haul-outs and rookeries for California sea lions and Steller sea lions are found predominantly along the outer coasts of Northern and Central California (Figure 3.4 and Table 3.2). There are only four mainland Northern elephant seal haul-out/rookeries, each found within the Central Coast ecoregion (Figure 3.4 and Table 3.2). These mainland haul-outs and breeding colonies, now critical to maintaining populations, may be particularly vulnerable to sea level rise (Figure 3.4).

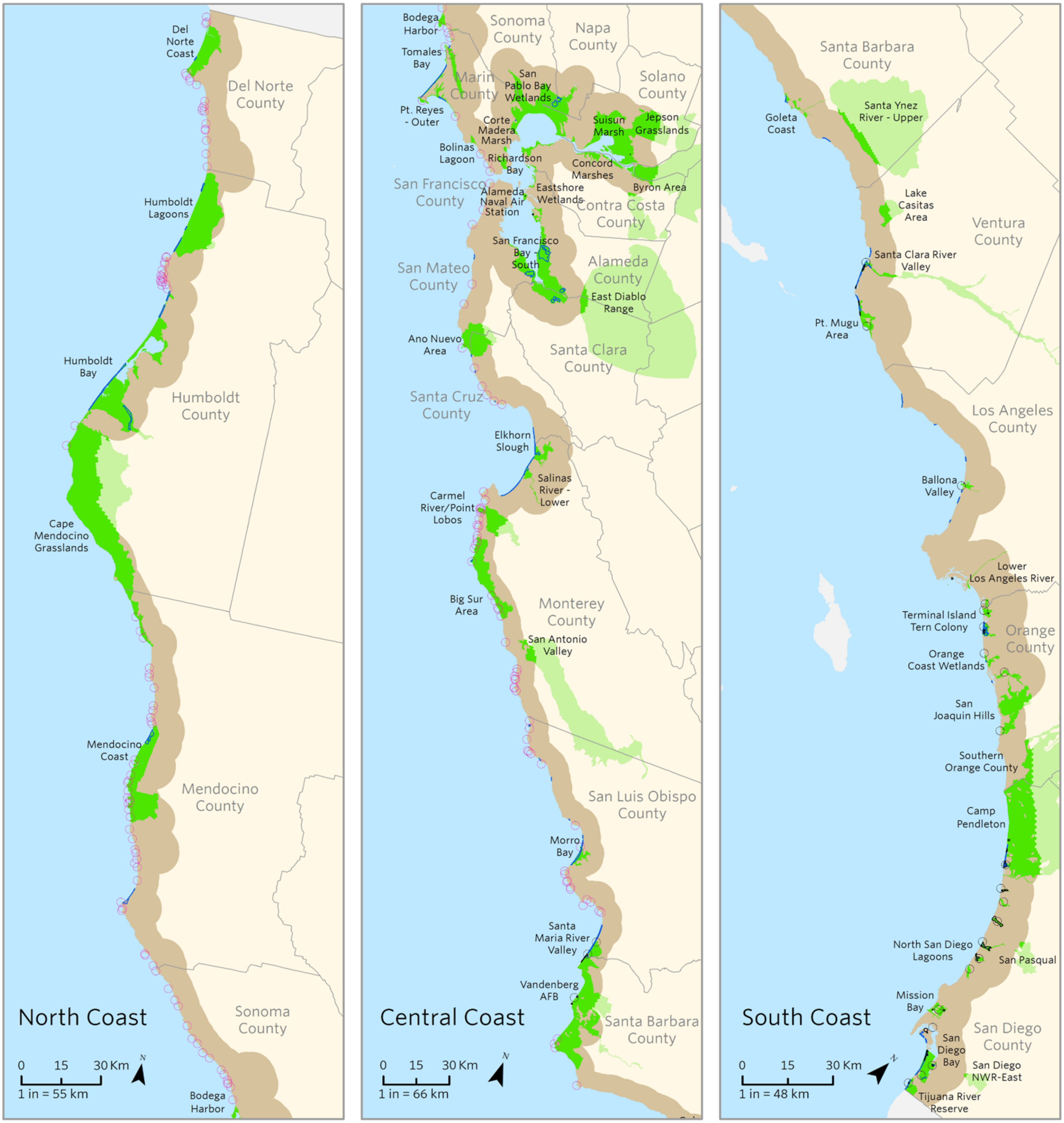
Table 3.2 Documented presence of focal shorebird and marine mammal species in the study area by ecoregion (Data sources: CNDDB, BIOS, USFWS, Audubon and NOAA).

Focal Species	Metric	North Coast	SF Bay/Delta	Central Coast	South Coast	Statewide
Black oystercatcher	Occurrences	37	0	17	0	**54**
California least tern	Occurrences	0	0	2	16	**18**
California least tern	Area of critical habitat	0.00	0.35	1.38	12.27	**14**
Western snowy plover	Area of critical habitat	20.29	36.96	18.98	15.59	**91.81**
California sea lion	Number of analytic units with documented haul-out or rookery	43	2	27	1	**73**
Pacific harbor seal	Number of analytic units with documented haul-out or rookery	112	2	43	4	**161**
Northern elephant seal	Number of analytic units with documented haul-out or rookery	0	0	4	0	**4**
Northern sea lion	Number of analytic units with documented haul-out or rookery	34	0	11	0	**45**

Figure 3.4 Marine mammal haul-outs and rookeries for four species of marine mammals throughout the three ecoregions of coastal California.

COASTAL AREAS OF IMPORTANCE TO BIRDS

ECOREGION



Bird Habitat, Occurrence, or Important Bird Area

- California least tern
- Black oystercatcher
- Western snowy plover
- Important Bird Area

Source:
CDFW BIOS; USFWS Critical Habitat; CNDDB; Audubon

Western snowy plovers are found throughout the state, including within San Francisco Bay (Figure 3.5 and Table 3.2). There are a few California least tern breeding colonies in San Francisco Bay and the Central Coast, with the majority occurring in the South Coast ecoregion. Western snowy plovers and California least terns nest only in relatively undisturbed tidal flat and salt panne, and upper beach habitats, and there is concern for loss of upper beach habitat (Vitousek *et al.* 2017; Dugan *et al.* 2008), particularly those beaches critical for the maintenance of western snowy plover and California least tern populations.

Black oystercatchers feed in the rocky intertidal and nest at the base of rocky cliffs, while Pacific harbor seals pup and rest on beach and rocky intertidal habitats, both preferring sites free from predators and disturbance from humans. As such, most of the documented occurrences for both species are along undeveloped stretches of the rocky bluffs of the North and Central Coast ecoregions (Figure 3.4, Figure 3.5, and Table 3.2). There is concern that the smaller pocket beaches and rocky intertidal areas at the base of cliffs that black oystercatchers and Pacific harbor seals rely on are particularly vulnerable to sea level rise (Hutto *et al.* 2015).

A total of 53 Audubon Important Bird Areas are located within the coastal study area, out of a total of 149 Audubon Important Bird Areas in California (Appendix B.2 for full list). These areas are considered important for breeding, wintering, and migrating birds, especially many shorebirds and waterfowl using the Pacific Flyway. Audubon Important Bird Areas have been identified using criteria based on their global or state importance to populations of sensitive species, the number of sensitive species supported, or the likelihood of seeing thousands of birds in one day. Audubon Important Bird Areas cover 3,931 km^2 within the study region, with 58% of that area in conserved lands (Table 3.3 and Figure 3.5). In addition, 36 of the 50 Audubon Important Bird Areas identified for their potential role as climate refugia in the face of warming, are within the coastal study area (California Important Bird Areas 2014).

Table 3.3 Important Bird Areas (IBAs) in study area (Data source: Audubon).

Region	Number of IBAs	Area of IBAs (km^2)	% of IBA conserved
North	6	1,454	49
SF Bay Delta	15	1,054	46
Central	15	911	73
South	18	513	81
Statewide	**53***	**3,919**	**58**

**Note: Portions of the Bodega Harbor IBA lie in both the North and Central ecoregions, so the statewide total is 53, not 54.*

Figure 3.5 Occurrence and/or critical habitat for three bird species and Audubon Important Bird Areas for the three ecoregions of coastal California.

RARITY-WEIGHTED RICHNESS INDEX

ECOREGION

3.4 Imperiled Species

Imperiled species in the study region span major taxonomic groups including plants, invertebrates, reptiles, amphibians, birds, and mammals, many of which are rare or have limited distributions (Appendix B.1). Of the 159 imperiled species with documented presence in the study area, 136 have more than 20% of their documented statewide occurrences within our coast-wide study area (Table 3.4). Eighty-seven species, with representatives from all major taxonomic groups, have 100% of their documented occurrences within our study area (Appendix B.1). These species are found only in unique coastal habitats such as regularly-flooded estuarine marsh, irregularly-flooded estuarine marsh (Box 3.2), coastal dunes, coastal prairie, or coastal scrub. The number of imperiled plants is especially high in the Central Coast and South Coast ecoregions with many plant species characteristic of, or endemic to, coastal Mediterranean ecosystems. The number of imperiled invertebrates is also relatively high, as many of these invertebrates are dependent on plants that are only found in coastal habitats (Appendix B.1).

Table 3.4 Number of imperiled species in study area by ecoregion and number with >20% of their documented occurrences in the coastal study area, indicating that they are coastal-dependent species.

Taxonomic Group	Number of Imperiled Species with Documented Presence in Study Area	Number of 'Coastal Dependent' Imperiled Species
Plants	109	99
Invertebrates	21	19
Reptiles and Amphibians	8	5
Birds	11	8
Mammals	10	5
Total	**159**	**136**

3.5 Biodiversity Index

Areas of higher biodiversity (based on RWRI), are found in all three ecoregions, particularly around estuaries, on major headlands, along the shoreline, and in areas with large tracts free of built environment features (e.g., conservation and military lands) (Figure 3.6). Important areas of high biodiversity are also found around urban centers such as San Francisco Bay and Orange and San Diego counties (Figure 3.6).

Figure 3.6 Rarity-weighted richness index for each analytic unit using habitats and coastal-dependent species for the three ecoregions of coastal California.

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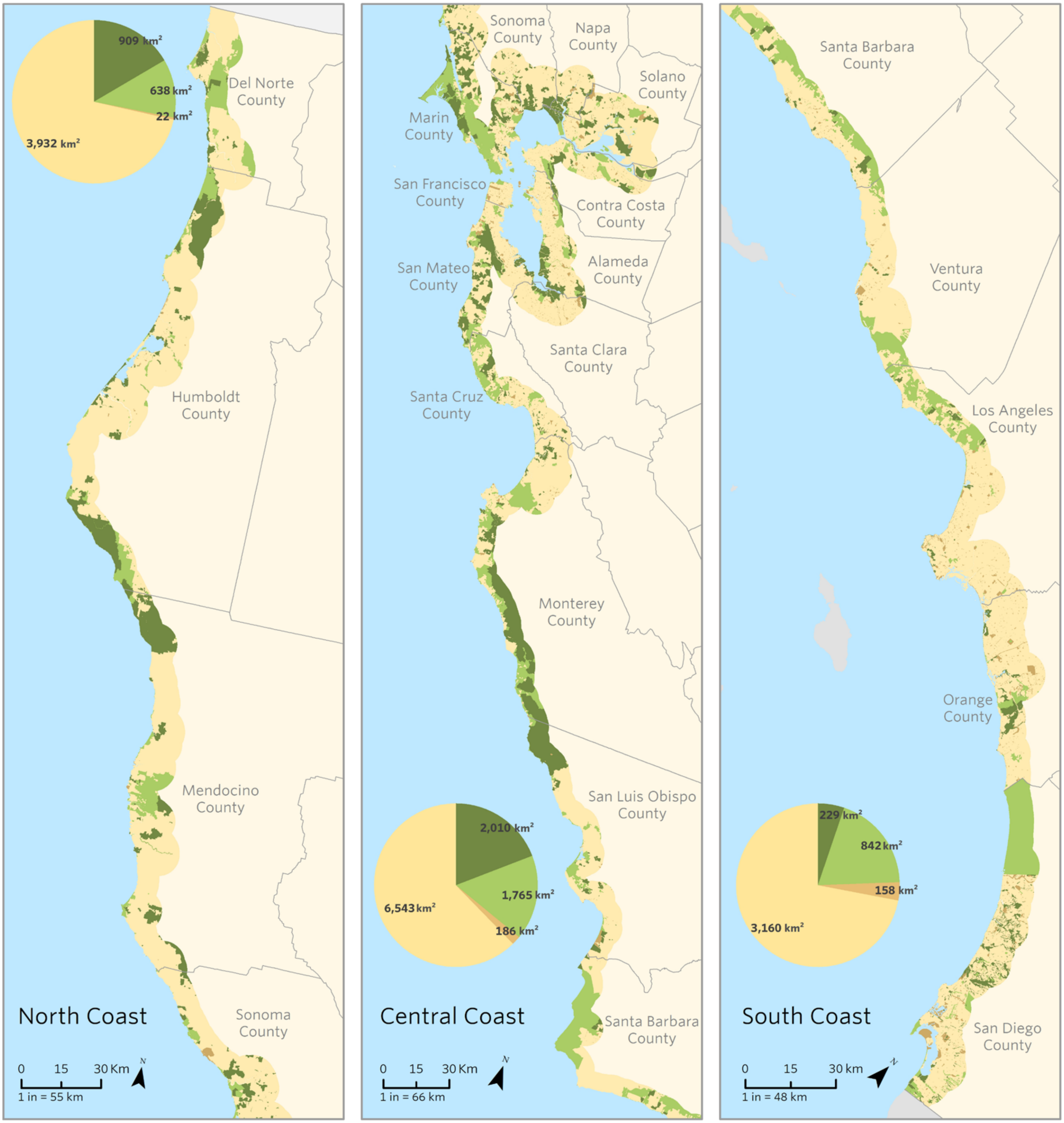
CONSERVATION MANAGEMENT STATUS



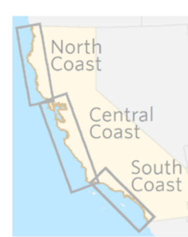
Conservation Management Status

Highly conserved
Highly conserved public and private lands with a focus on biodiversity and ecosystem protection.

Conserved
Public or private lands with conservation value, though multiple uses or limited extraction may occur.

Public non-conserved
Public lands with neither conservation focus nor significant natural area.

Private non-conserved
Non-conserved, privately owned lands.



Source:
CPAD; PADUS; TNC

3.6 Conservation Management Status and Ownership

Well over one-third of California's linear shoreline including San Francisco Bay Delta and 31% of the coastal study area is managed to conserve natural values to some extent (Figure 3.7 and Figure 3.8). Fifteen percent of the study area (3,148 km^2) is managed as highly conserved lands including state reserves, national parks, wilderness areas, ecological reserves, private conservation areas, and conservation easements which are managed to preserve our state's biodiversity and natural beauty. The greatest area of highly conserved lands is along the Central Coast, followed by the North Coast, then the San Francisco Bay Delta and finally, the South Coast (Figure 3.7 and Figure 3.8). Conserved lands include state parks, national monuments, national forests, certain protected military installations, and large greenbelt areas that are managed for multiple objectives including conservation of ecological function, recreation, and potentially limited extraction of resources. Sixteen percent of the study area (3,246 km^2) is managed as conserved lands, with the greatest extent of conserved lands found along the Central Coast, followed by the South Coast, then the North Coast, and finally the San Francisco Bay Delta (Figure 3.7 and Figure 3.8). Less than 2% of the study area (365 km^2) is managed as non-conservation public lands, and the remaining 67% of the study area (13,635 km^2) is non-conservation private lands.

Public land management in California is a patchwork of many entities from federal agencies to municipal governments. Federal agencies manage 51%, state agencies manage 24%, and other agencies such as local park agencies, city governments, water districts, utility providers, cemetery districts, local transportation agencies, county public works departments, and others manage the remaining 25% of all public land in the study area. Federal and state agencies also manage a majority of conservation lands throughout the study area. California Department of Parks and Recreation (California State Parks) is the single agency that manages the most public lands throughout the study area, followed by the U. S. Department of Defense.

Figure 3.7 Conservation Management Status for lands across the three ecoregions of coastal California. Pie charts summarize ecoregional compositions.

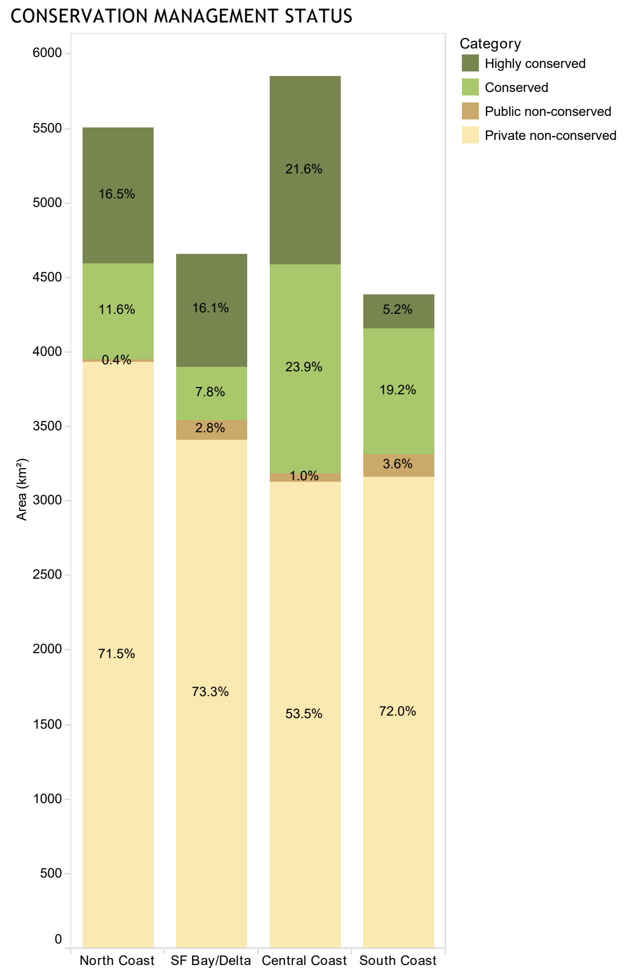


Figure 3.8 Area (km^2) of four conservation management status categories by ecoregion. Percentages calculated by ecoregion.

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Of all the federal agencies, the Department of Defense manages the most lands, with over 900 km² under their care (Figure 3.9). The U. S. National Park Service manages more than 633 km² within the study area, including Redwood National Park in the North Coast, Point Reyes National Seashore along the Central Coast, and the Santa Monica Mountains National Recreation Area in the South Coast. Portions of two National Forests, managed by the U. S. Forest Service (USFS), fall within the study area, the largest being Los Padres National Forest of the Central and South Coasts. The U. S. Fish and Wildlife Service is an important land manager within the San Francisco Bay Delta, managing National Wildlife Refuges among the marshlands. The United States Bureau of Land Management manages the National Monuments within the study area, including Point Arena-Stornetta Public Lands in the North Coast, and Fort Ord and Cotoni-Coast Dairies National Monument in the Central Coast.

State agencies manage a significant portion of coastal lands throughout our study area, particularly of lands allowing public access. California State Parks manages the greatest extent of public land within the study area, about 940 km². California State Parks manage everything from subtidal marine parks to coastal mountain slopes, and the many beaches, rocky shores, wetlands, and scrublands in between. California State Parks' largest management areas are along the North Coast (378 km²) and Central Coast (366 km²), with less overall holdings along the South Coast and the San Francisco Bay Delta. The California Department of Fish and Wildlife manages numerous Ecological Reserves throughout the study area. The California State Lands Commission manages relatively smaller amounts of land, mostly in the San Francisco Bay Delta, as well as the tidal and submerged Public Trust Lands below mean high tide. State agencies manage around 46% of conserved lands along the North Coast, 29% in the San Francisco Bay Delta, and 22% of conserved lands for both the Central and South Coasts (Figure 3.9).

MANAGEMENT OF PUBLIC CONSERVED LAND

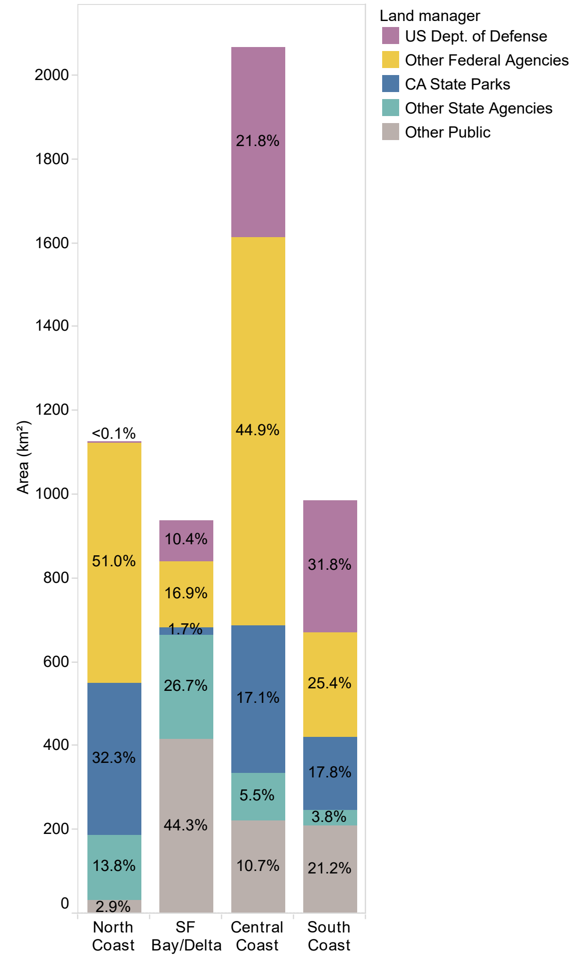

Figure 3.9 Area (km²) of public conserved land within the study area by ecoregion, color coded by management agency. Percentages calculated by ecoregion.

3.7 Public Access

Many of the coastal habitats analyzed in this study provide important public recreation opportunities. There are more than 1,300 recreation and coastal access points within the study area throughout the three outer-coast ecoregions, providing access to coastal bluffs, estuaries, beaches, and rocky intertidal areas (CCC 2017; Table 3.5). These access points allow people to experience California's remarkable coast and its habitats, often within state parks and other public protected lands. California's sandy beaches with facilities such as restrooms and parking allow more people to visit the coast for longer periods of time and thereby have high recreation value for locals and visitors from all over the world.

Not surprisingly, both the number of overall access points and the number of sandy beaches with facilities are more strongly correlated with human density than with the extent and condition of coastal habitats. For example, the North Coast has 40% of the state's upper beach, but only 18% of its sandy beaches with facilities (Table 3.1 and Table 3.5). Previous research suggests that the relative visitation rates at the coast are generally highest along the South Coast, high for the Central Coast, and low for the North Coast (Christensen and King 2017; Table 3.5).

Table 3.5 Total number of public access points within the study area by ecoregion (Data source: California Coastal Commission), the subset of access points that are sandy beaches with facilities, and relative coastal access visitation rates.

Ecoregion	Count of coastal access/ recreation opportunities	Count of sandy beaches with facilities	Relative coastal access visitation rates
North Coast	290	73	Low
Central Coast	440	150	High
South Coast	602	173	Highest

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4.0 | How Vulnerable are Coastal Habitats, Imperiled Species, and Conservation Lands to Sea Level Rise?

© Sue Pollock/The Nature Conservancy

California's unique coastal habitats, high biodiversity, and legacy of conservation are each vulnerable to sea level rise. Sea level rise is projected to inundate more area of natural lands than of agricultural or developed lands, thereby posing a serious threat to each of California's coastal habitats and the rare and imperiled species, marine mammals, and shorebirds that depend on them. Each of the unique coastal habitats and the great biodiversity they serve along our coast have significant area of *high Vulnerability* to sea level rise (Figure 4.1). Unfortunately, many of them are already greatly reduced from historical extent. While the details vary by ecoregion, it is often the most imperiled habitats, species, or regional representations of these habitats or species that are the most vulnerable. This is often because the human alteration of the landscape that imperiled them in the first place will also exacerbate sea level rise impacts. Approximately half of the critical haul-outs for marine mammals and nesting habitats for focal shorebirds have *high Vulnerability* scores. Many imperiled species are found only in distinct coastal habitats and have a high proportion of their documented occurrences within the projected footprint of 5-ft sea level rise (for details see Section 4.4). Thus, the persistence of populations of these species already at risk of extinction depend on the resilience of the coastal habitats. Without concerted and strategic conservation action, we stand to lose much of the area and function of our coastal habitats and the services they provide to nature and people. Sea level rise represents a threat to the future of California's significant investment in coastal conservation lands. While only about 8% of the conserved lands within our greater study area are within projected 5-ft sea level rise exposure, this translates to approximately 30% of conserved lands within the analytic zone being exposed to 5-ft of sea level rise. This implies that coastal managers will need to find ways to enhance the resilience of the coastal habitats they manage, and that of the infrastructure critical to the meeting their conservation mandates, including visitation and interpretation. This also highlights the need to continue building upon our conservation legacy, to both expand existing conservation lands, and to conserve new areas to increase our network of conserved and resilient coastal habitats.

AREA OF FOCAL HABITAT VULNERABILITY BY ECOREGION

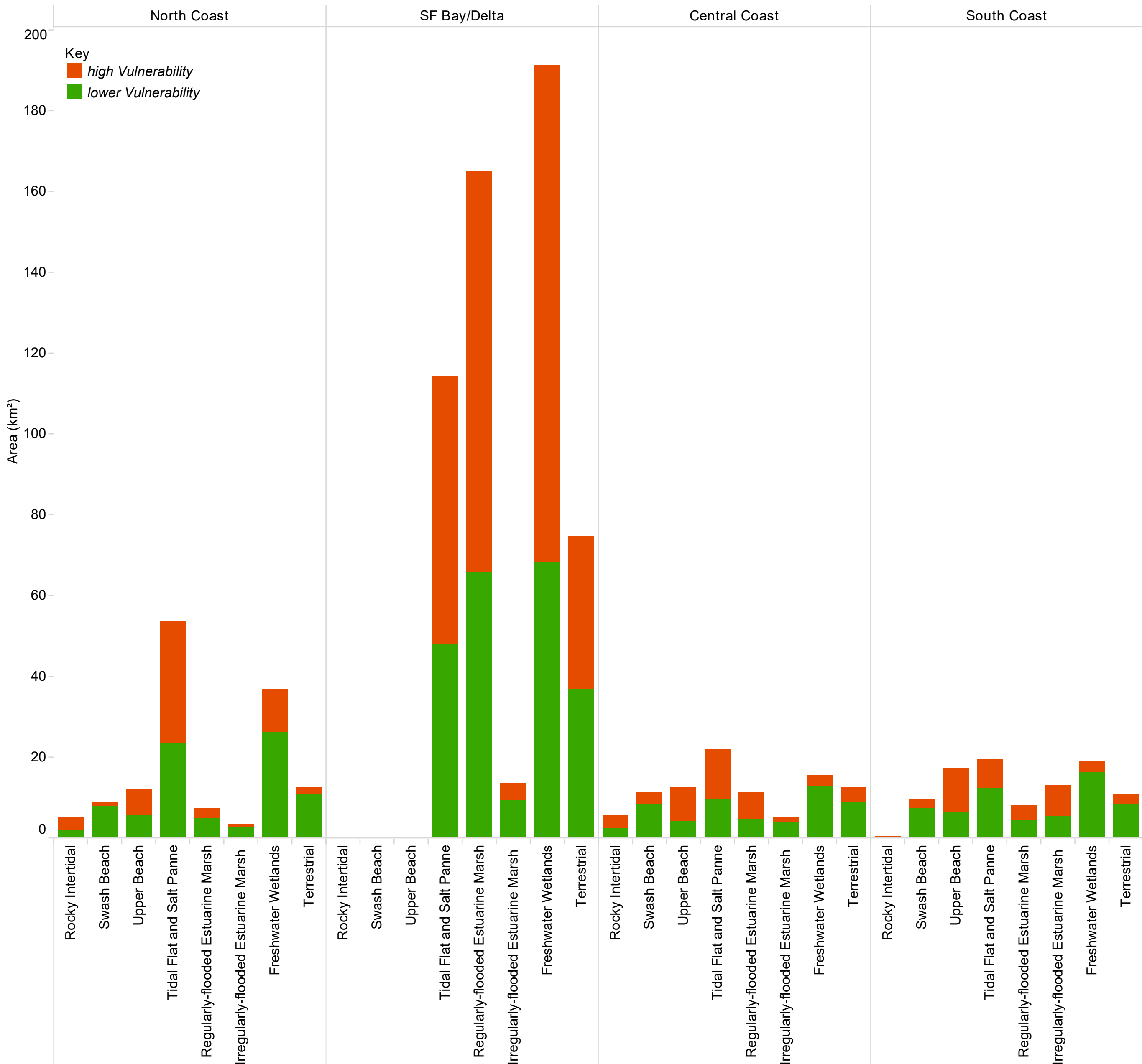
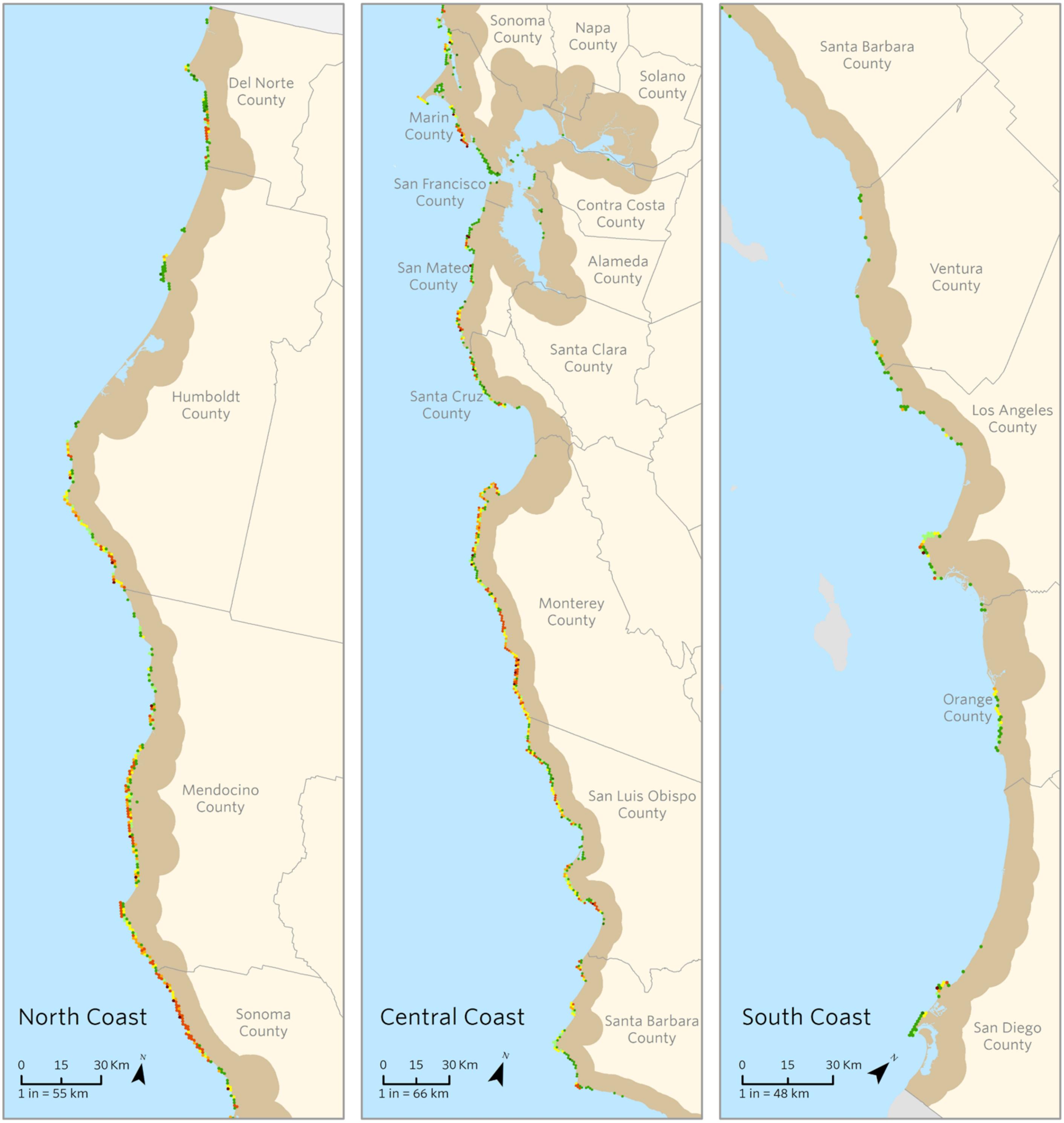


Figure 4.1 Area (km^2) for each of eight coastal habitats with high vulnerability (red), and lower vulnerability (green) by ecoregion.

ROCKY INTERTIDAL

VULNERABILITY, 5FT SEA LEVEL RISE

ECOREGION



Vulnerability

2	No Adaptive Capacity, Highest Vulnerability
1.5 - 1.9	Potential Impact is greater than Adaptive Capacity
1.2 - 1.5	
0.8 - 1.2	Potential Impact is approximately equal to Adaptive Capacity
0.5 - 0.8	Potential Impact is less than Adaptive Capacity
0.0 - 0.5	
0	No Potential Impact

4.1 Vulnerability of Coastal Habitats

MARINE INTERTIDAL HABITATS

Rocky Intertidal

Rocky intertidal habitat is vulnerable to being converted to subtidal habitat with sea level rise. Statewide, 58% of the area of rocky intertidal habitat is projected to transition to sub-tidal habitat with five feet of sea level rise (Appendix C.1). Rocky intertidal is the habitat with the most limited extent (11 km^2) within the analytic zone and nearly all of it is found in small patches along the outer coast in the North Coast (45%) and Central Coast (51%) ecoregions (Appendix C.1 and Figure 4.2). Approximately 60% of the rocky intertidal habitat on the North and Central Coasts has *high Vulnerability* (V≥1.2, Figure 4.3). Of the 0.5 km^2 of rocky intertidal within the analytic zone of the South Coast ecoregion, only 23% has *high Vulnerability* (V≥1.2, Figure 4.3).

Determining the vulnerability of rocky intertidal to sea level rise is challenging, particularly because there are several distinct zones or habitat types within rocky intertidal zone which differ in their exposure time to intertidal waters, and thus potentially differ in their sensitivity and resulting vulnerability. However, due to data constraints, we used the average sensitivity for the entire area of rocky intertidal. In addition, the only appropriate areas for rocky intertidal habitats to transgress into are rocky substrates. Determining the true extent of rocky substrate available for rocky intertidal to transgress into is beyond our ability to calculate, given the data available and scale of our assessment. As such, the estimations of rocky intertidal vulnerability reported here should be thoughtfully considered.

Figure 4.2 *Vulnerability* of rocky intertidal to five feet of sea level rise within each analytic unit for the three ecoregions of coastal California.

ROCKY INTERTIDAL

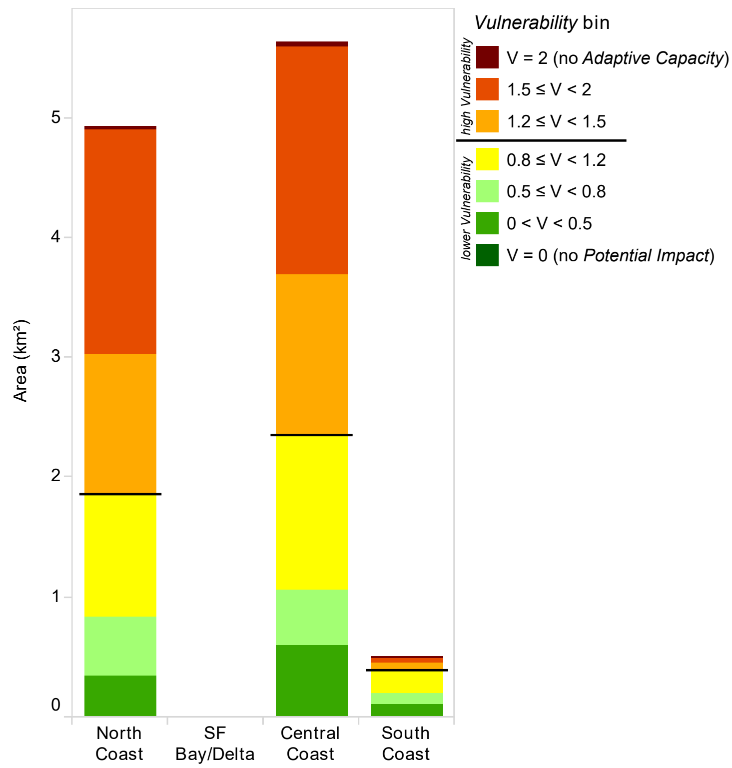
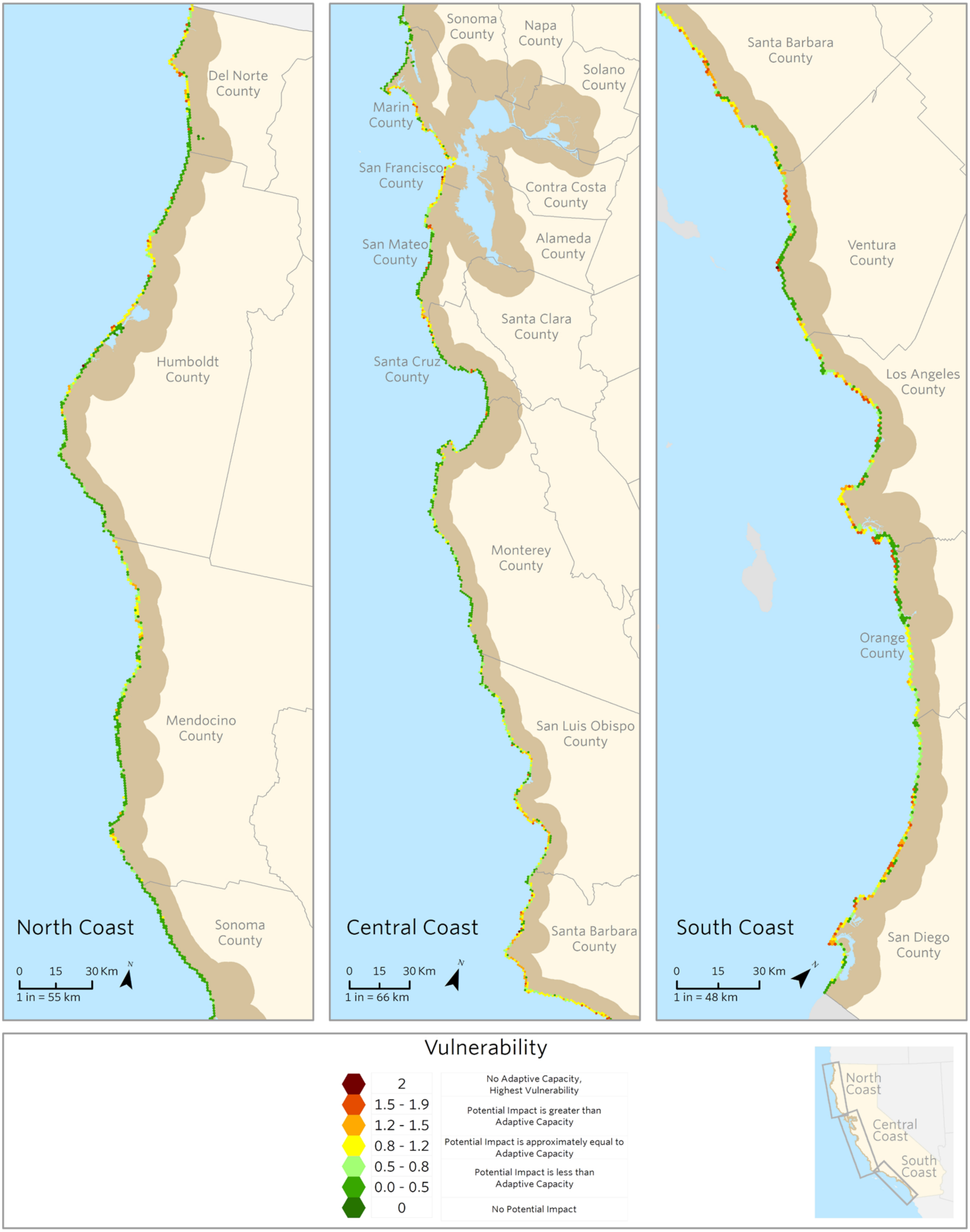


Figure 4.3 *Vulnerability* of rocky intertidal to five feet of sea level rise by ecoregion.

SWASH BEACH

VULNERABILITY, 5FT SEA LEVEL RISE

ECOREGION



Swash Beach

Swash beach is an intertidal habitat also vulnerable to conversion to subtidal waters with sea level rise. Eighty-six percent of the area of swash beach throughout California is projected to be under subtidal waters with five feet of sea level rise (Appendix C.1). However, swash beach typically can transgress into upper beach, potentially mitigating the *Potential Impact* of sea level rise leading to lower *Vulnerability* scores.

Our analysis shows that over 75% of the area of swash beach along California's coast has *lower Vulnerability* (V<1.2; Figure 4.4 and Figure 4.5). There are similar amounts of swash beach among the North, Central, and South Coast ecoregions, each sharing this pattern in *Vulnerability* scores (Figure 4.4 and Figure 4.5). However, some of the habitat values that swash beach provides are only served within a unique setting, such as small pocket beach haul-outs for Pacific harbor seals isolated at the base of cliffs. Because cliff erosion rates and sand supply may not keep pace with sea level rise in these settings, these unique habitat functions of swash beach may be more vulnerable to sea level rise than swash beach in other areas.

Figure 4.4 *Vulnerability* of swash beach to five feet of sea level rise within each analytic unit for the three ecoregions of coastal California.

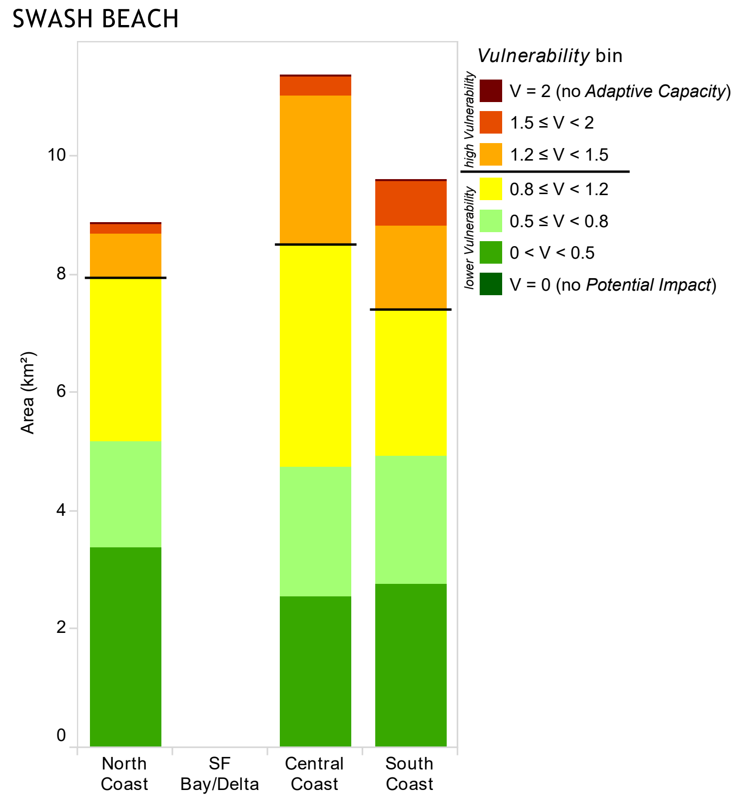
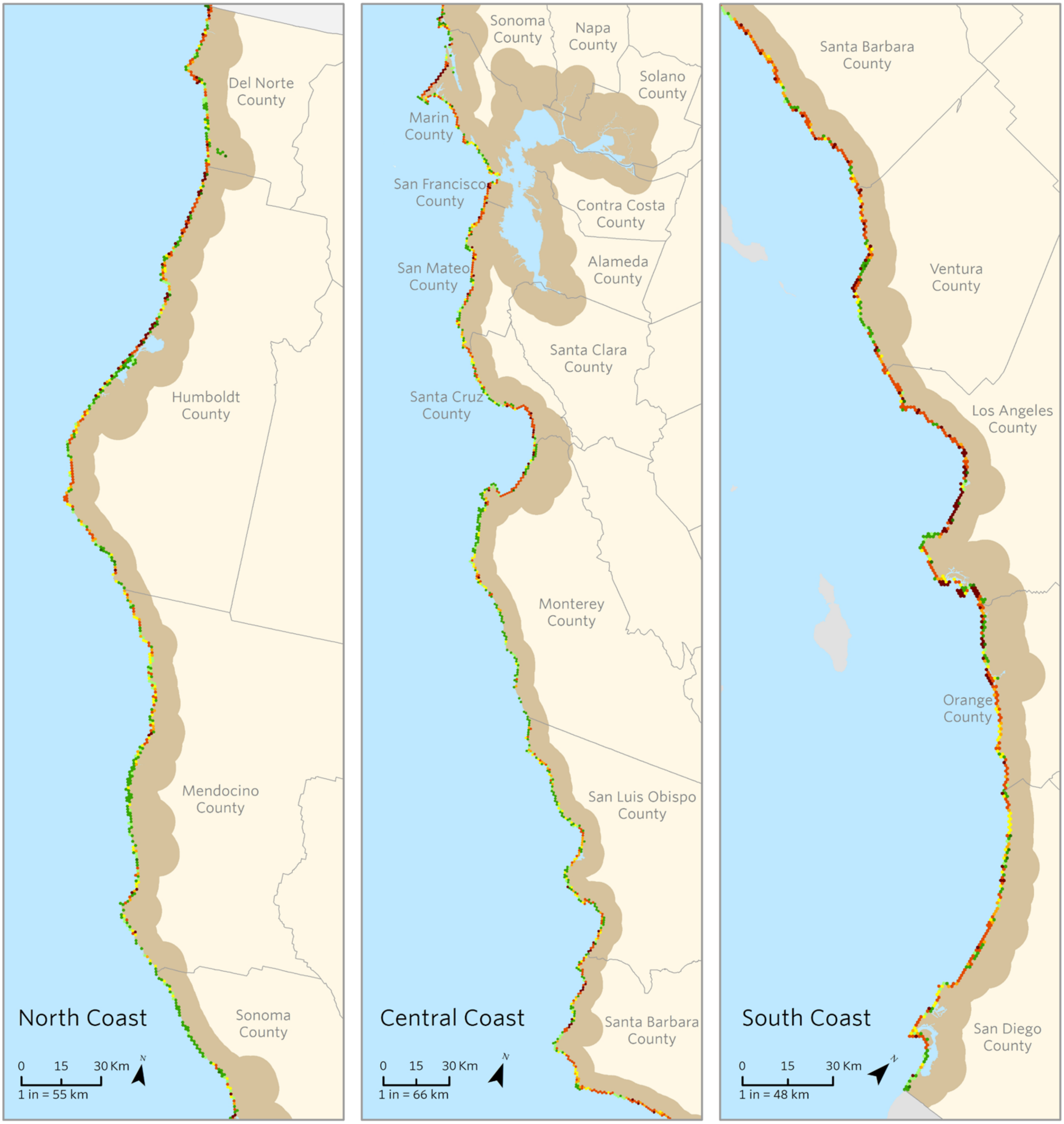
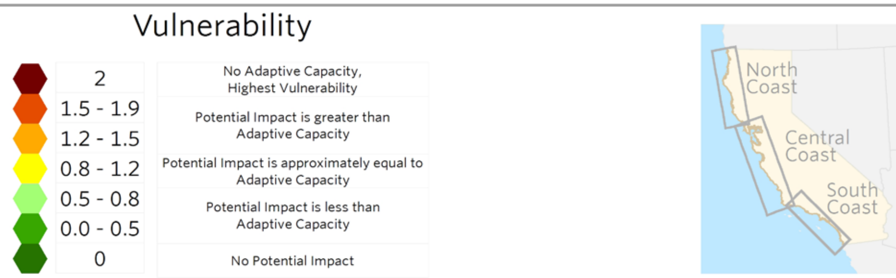


Figure 4.5 *Vulnerability* of swash beach to five feet of sea level rise by ecoregion.

UPPER BEACH
VULNERABILITY, 5FT SEA LEVEL RISE

ECOREGION





Upper Beach

Upper beach has high *Sensitivity* to tidal *Exposure* and is vulnerable to being lost to either intertidal or subtidal habitat with sea level rise. Approximately half of the area of upper beach within the analytic zone is projected to become intertidal or subtidal habitat with five feet sea level rise (Appendix C.1). Upper beach may also have low *Adaptive Capacity* when it is backed by cliffs, bluffs, or the built environment. Thus, it is not surprising that 60% of California's 42 km^2 of upper beach within the analytic zone has *high Vulnerability* (V≥1.2; Figure 4.6 and Figure 4.7). Fourteen percent of California's upper beaches have no *Adaptive Capacity* (V=2; Figure 4.7).

The South Coast ecoregion contains 17.3 km^2 (41%) of California's upper beach, with the remainder evenly divided between the North and Central Coast ecoregions (Appendix C.1). In the South Coast ecoregion, 62% of upper beaches have *high Vulnerability* (V≥1.2) and 18% have no *Adaptive Capacity* (V=2; Figure 4.7). Of the 12.6 km^2 of upper beach in the Central Coast ecoregion, 66% has *high Vulnerability* (V≥1.2), and 9% has no *Adaptive Capacity* (V=2; Figure 4.7). Fifty-one percent of the 12.3 km^2 of upper beach within the North Coast ecoregion has *high Vulnerability* (V≥1.2) and, 13% has no *Adaptive Capacity* (V=2; Figure 4.7).

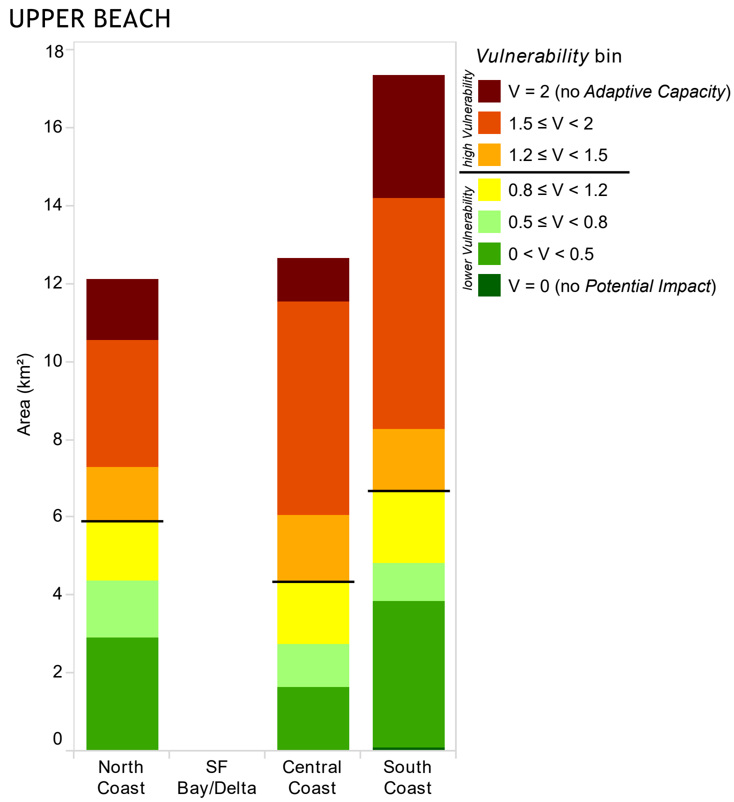


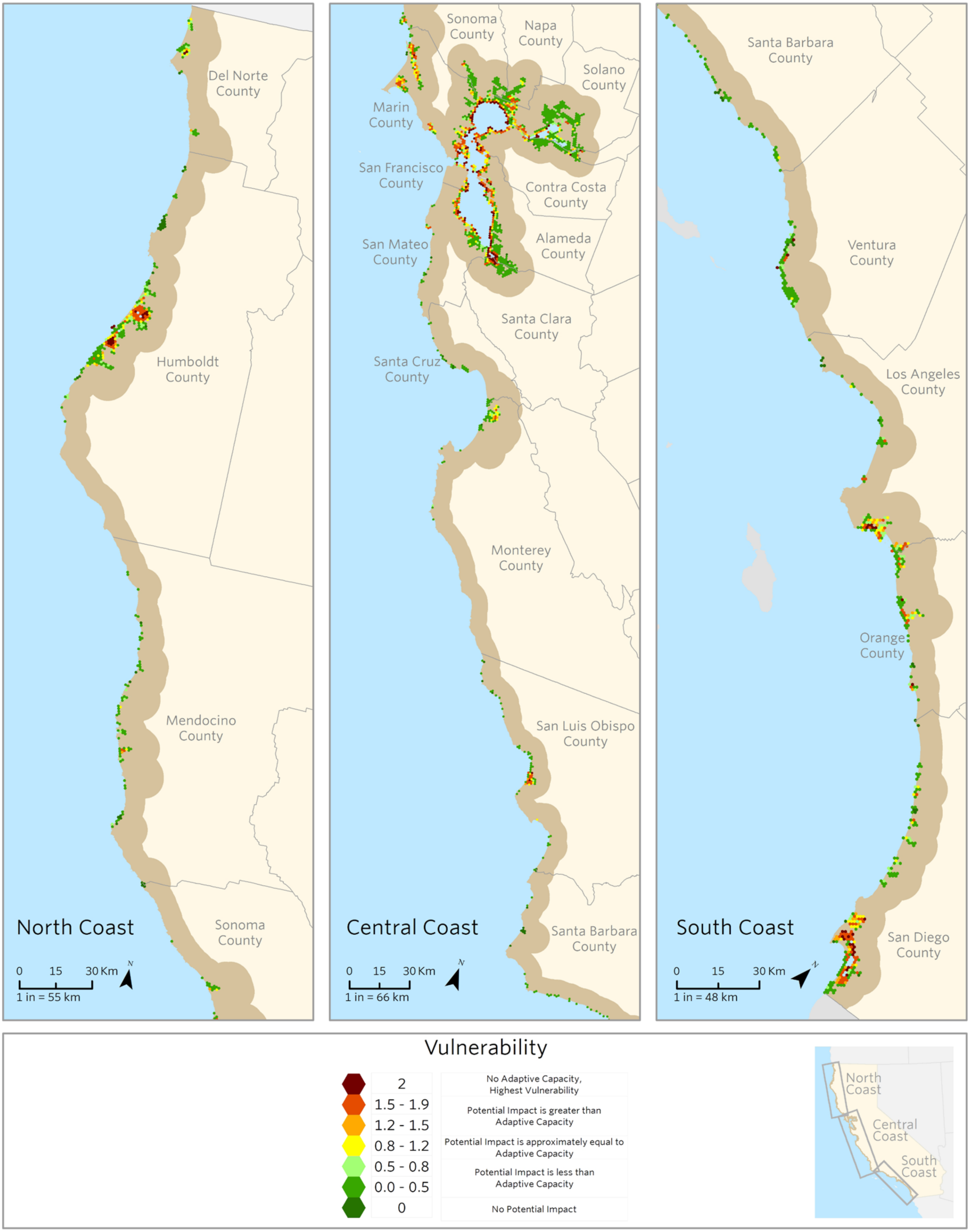
Figure 4.7 *Vulnerability* of upper beach to five feet of sea level rise by ecoregion.

Figure 4.6 *Vulnerability* of upper beach to five feet of sea level rise within each analytic unit for the three ecoregions of coastal California.

TIDAL FLAT AND SALT PANNE

VULNERABILITY, 5FT SEA LEVEL RISE

ECOREGION



Tidal Flat and Salt Panne

As the lowest estuarine intertidal habitat, tidal flat and salt panne is at risk of subtidal exposure, yet also potentially has the most area available to transgress into. Tidal flat and salt panne is the most expansive single habitat type, with over 209 km² found within the analytic zone statewide (Figure 4.1 and Appendix C.1). Like other estuarine wetland types a majority of this habitat is found within San Francisco Bay Delta, however, there are also large expanses of tidal flat and salt panne in the North Coast ecoregion (Figure 4.8 and Figure 4.9).

Statewide, a majority of the area of tidal flat and salt panne has *high Vulnerability*, creating concern that most of this habitat type could be lost to sea level rise in the absence of intervention. This pattern holds true for the San Francisco Bay Delta and all outer-coast ecoregions except the South Coast ecoregion (Figure 4.9). Further, there are 26 km² (12.5%) of tidal flat and salt panne with V= 2, indicating no *Adaptive Capacity* (Figure 4.9). Sixty-two percent of these most vulnerable tidal flats and salt panne areas are in the San Francisco Bay Delta, while 34% are in the North Coast ecoregion.

Figure 4.8 *Vulnerability* of tidal flat and salt panne to five feet of sea level rise within each analytic unit for the three ecoregions of coastal California.

TIDAL FLAT AND SALT PANNE

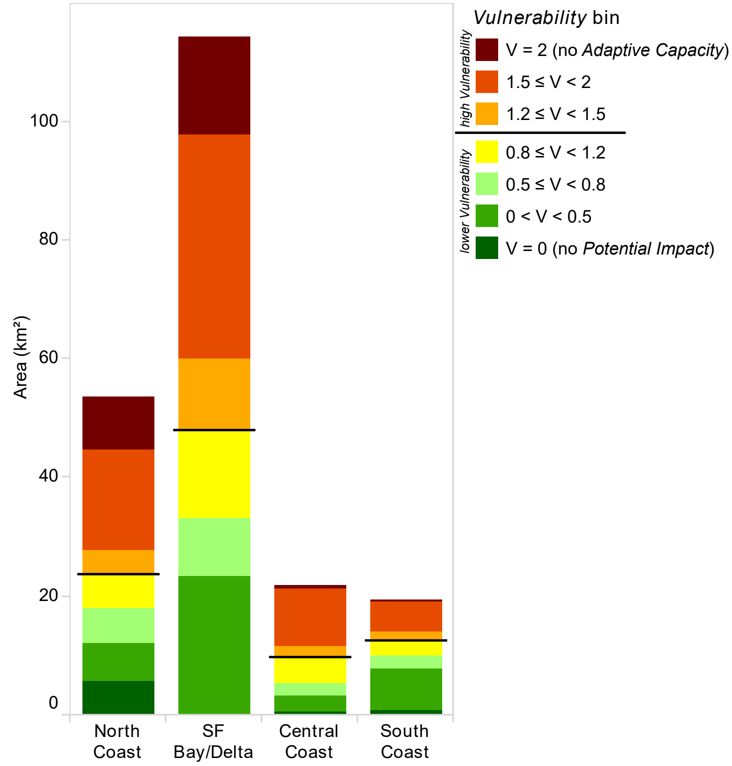


Figure 4.9 *Vulnerability* of tidal flat and salt panne to five feet of sea level rise by ecoregion.

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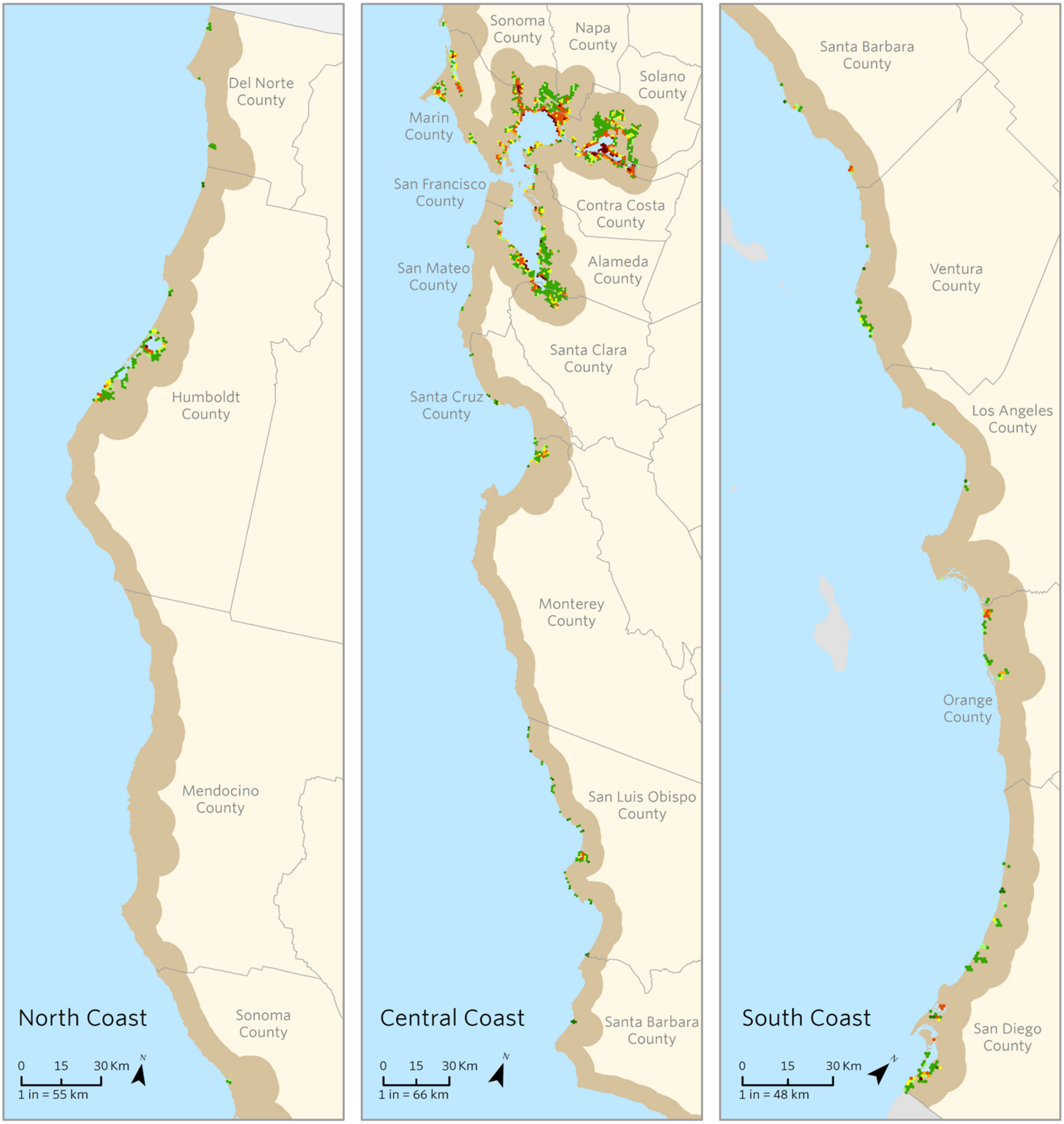
REGULARLY-FLOODED ESTUARINE MARSH

VULNERABILITY, 5FT SEA LEVEL RISE

ECOREGION



Vulnerability

2	No Adaptive Capacity, Highest Vulnerability
1.5 - 1.9	Potential Impact is greater than Adaptive Capacity
1.2 - 1.5	
0.8 - 1.2	Potential Impact is approximately equal to Adaptive Capacity
0.5 - 0.8	
0.0 - 0.5	Potential Impact is less than Adaptive Capacity
0	No Potential Impact

Regularly-flooded Estuarine Marsh

Regularly-flooded estuarine marsh is the dominant vegetated estuarine marsh habitat in tidal estuaries. There are 192 km^2 of regularly-flooded estuarine marsh statewide within our analytic zone (Figure 4.10 and Figure 4.11), making this the third most abundant habitat type in our assessment, second to freshwater wetlands and tidal flat and salt panne. As an intertidal habitat, regularly-flooded estuarine marsh is vulnerable to sea level rise, particularly when constrained by the built environment.

Eighty-six percent of the state's regularly-flooded estuarine marsh is found within the San Francisco Bay Delta, making this an important area for management of regularly-flooded estuarine marsh. Of the 165.1 km^2 of regularly-flooded estuarine marsh found within the analytic zone in the San Francisco Bay Delta, 99.2 km^2 (60%) has *high Vulnerability* and 20.1 km^2 of that does not have any *Adaptive Capacity* at all (Figure 4.10 and Figure 4.11). *Adaptive Capacity* approximately equals *Potential Impact* for 18.8 km^2 (11%) of regularly-flooded estuarine marsh within the San Francisco Bay Delta. The remaining 47.1 km^2 (29%) of regularly-flooded estuarine marsh within the San Francisco Bay Delta has more *Adaptive Capacity* than *Potential Impact* from five feet of sea level rise (Figure 4.11). However, in terms of numbers of locations rather than area, there are 669 analytic units containing regularly-flooded estuarine marsh with *lower Vulnerability* that hold the potential to not only maintain regularly-flooded estuarine marsh in the San Francisco Bay Delta, but also to naturally expand regularly-flooded marsh area in response to sea level rise.

Of the remaining 14% of the regularly-flooded estuarine marsh, 7.4 km^2 is in the North Coast ecoregion, 11.2 km^2 is in the Central Coast ecoregion, and 8.2 km^2 is in the South Coast ecoregion (Figure 4.11). Of this cumulative 26.8 km^2, only 0.3 km^2 has no *Adaptive Capacity* in response to five feet of sea level rise (Figure 4.11). In the Central Coast ecoregion, 57% of the area of regularly-flooded estuarine marsh has *high Vulnerability*, whereas 46% of the area of regularly-flooded estuarine marsh has *high Vulnerability* in the South Coast ecoregion. In the North Coast ecoregion, 32% of the area of regularly-flooded estuarine marsh has *high Vulnerability*. However, each of the three outer-coast ecoregions have four to eight times more analytic units that contain regularly-flooded estuarine marsh with *lower Vulnerability* than analytic units with *high Vulnerability* (Figure 4.10 and Figure 4.11). These areas may act as established patches of resilient habitat able to expand in area, without managers needing to prepare and plant new locations for this habitat.

Figure 4.10 *Vulnerability* of regularly-flooded estuarine marsh to five feet of sea level rise within each analytic unit for the three ecoregions of coastal California.

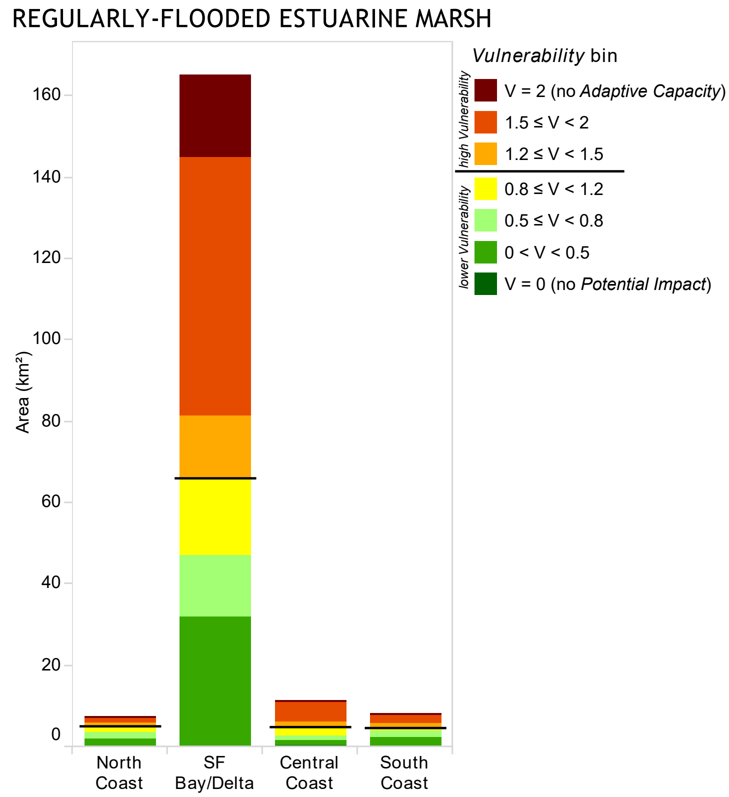
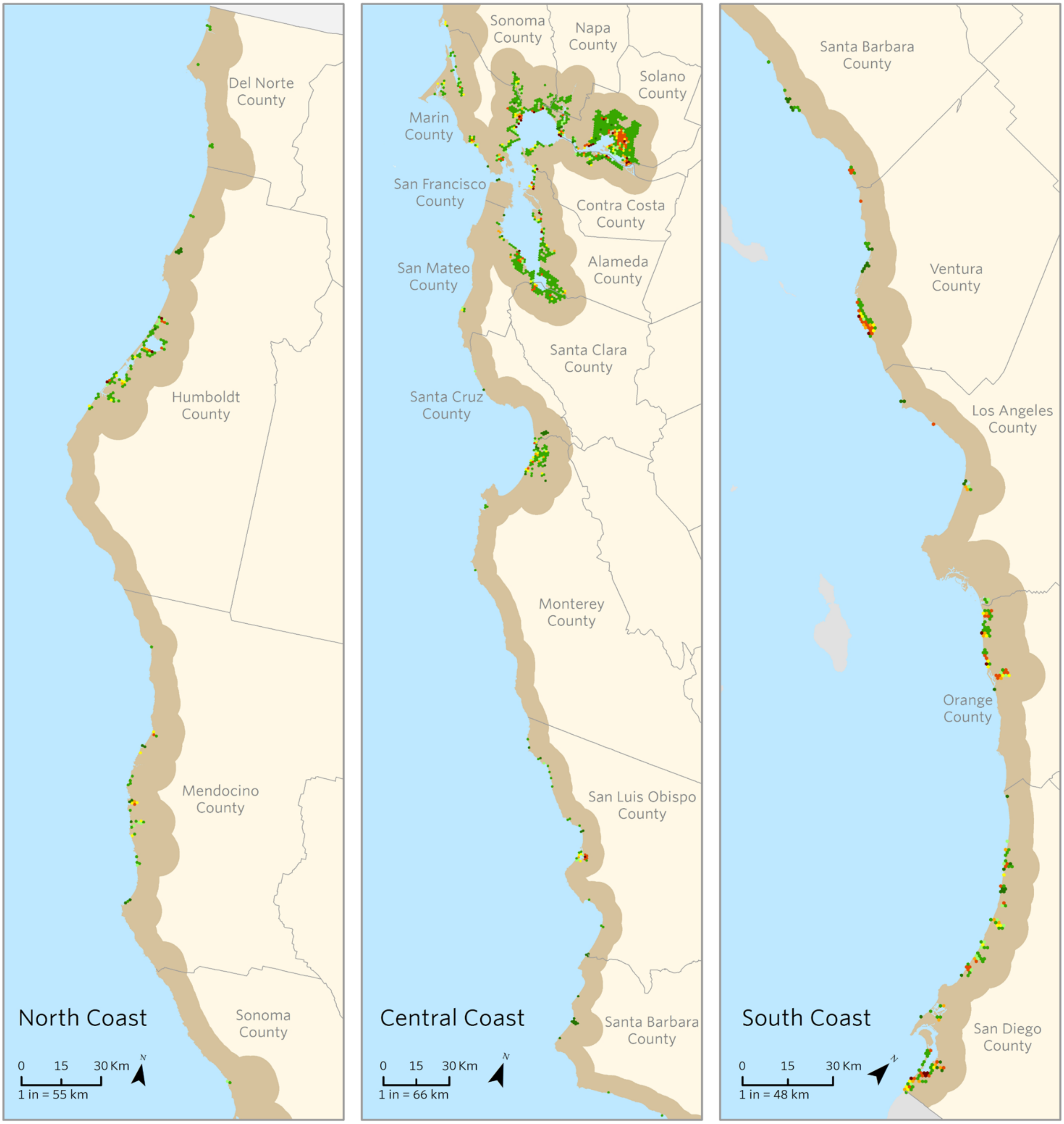


Figure 4.11 *Vulnerability* of regularly-flooded estuarine marsh to five feet of sea level rise by ecoregion.

IRREGULARLY-FLOODED ESTUARINE MARSH

VULNERABILITY, 5FT SEA LEVEL RISE

ECOREGION



Vulnerability

2	No Adaptive Capacity, Highest Vulnerability
1.5 - 1.9	Potential Impact is greater than Adaptive Capacity
1.2 - 1.5	
0.8 - 1.2	Potential Impact is approximately equal to Adaptive Capacity
0.5 - 0.8	Potential Impact is less than Adaptive Capacity
0.0 - 0.5	
0	No Potential Impact

Irregularly-flooded Estuarine Marsh

Irregularly-flooded estuarine marsh is found at the upper edge of the intertidal range, or associated with seasonally closed estuaries. As a transitional habitat from intertidal to upland it has a relatively high *Sensitivity* to tidal inundation. Further, at this higher transitional margin, irregularly-flooded estuarine marsh may also have limited *Adaptive Capacity* in response to rising sea levels, either because of encroachment of the built environment or due to topographic constraint. Irregularly-flooded estuarine marsh is thought to be particularly vulnerable to sea level rise because regularly-flooded estuarine marsh and tidal flat and salt panne will likely move into the narrow, remaining band of irregularly-flooded estuarine marsh, and irregularly-flooded estuarine marsh itself may not be able to move inland because either the unique physical conditions it requires may not be there, or it is constrained by the built environment or agriculture (Stralberg *et al.* 2011; Veloz *et al.* 2012; Schile *et al.* 2014; Goals Project 2015). Accordingly, a large proportion of this habitat has *high Vulnerability* (V≥1.2; Figure 4.12 and Figure 4.13).

Irregularly-flooded estuarine marsh is relatively uncommon, with only 35.5 km² found within the analytic zone statewide (Appendix C.1). Like other estuarine wetland types, the largest amount of this habitat is found in the San Francisco Bay Delta (38%), however, unlike other estuarine wetland types, nearly the same area is found in the South Coast ecoregion (37%) (Appendix C.1 and Figure 4.13).

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Figure 4.12 *Vulnerability* of irregularly-flooded estuarine marsh to five feet of sea level rise within each analytic unit for the three ecoregions of coastal California.

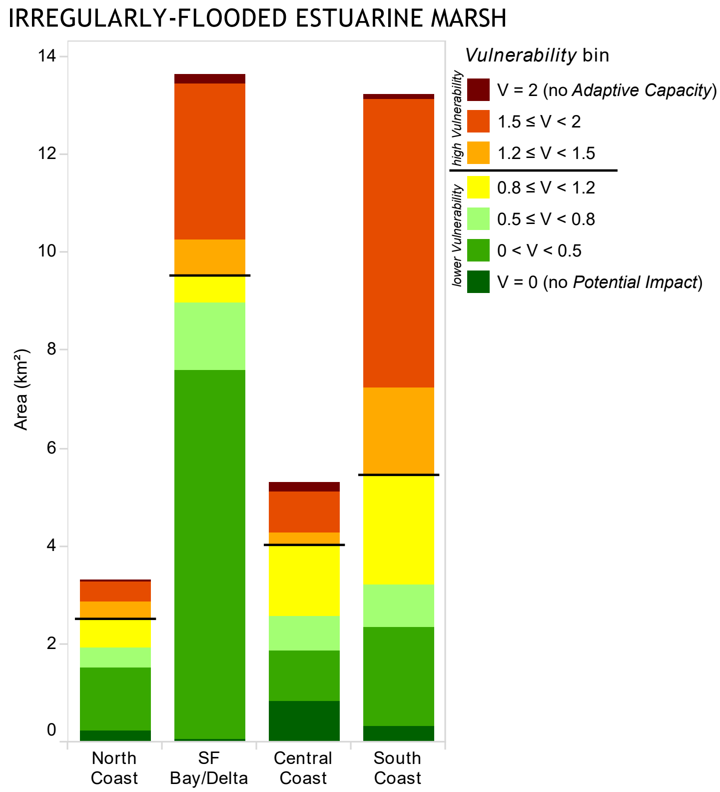


Figure 4.13 *Vulnerability* of irregularly-flooded estuarine marsh to five feet of sea level rise by ecoregion.

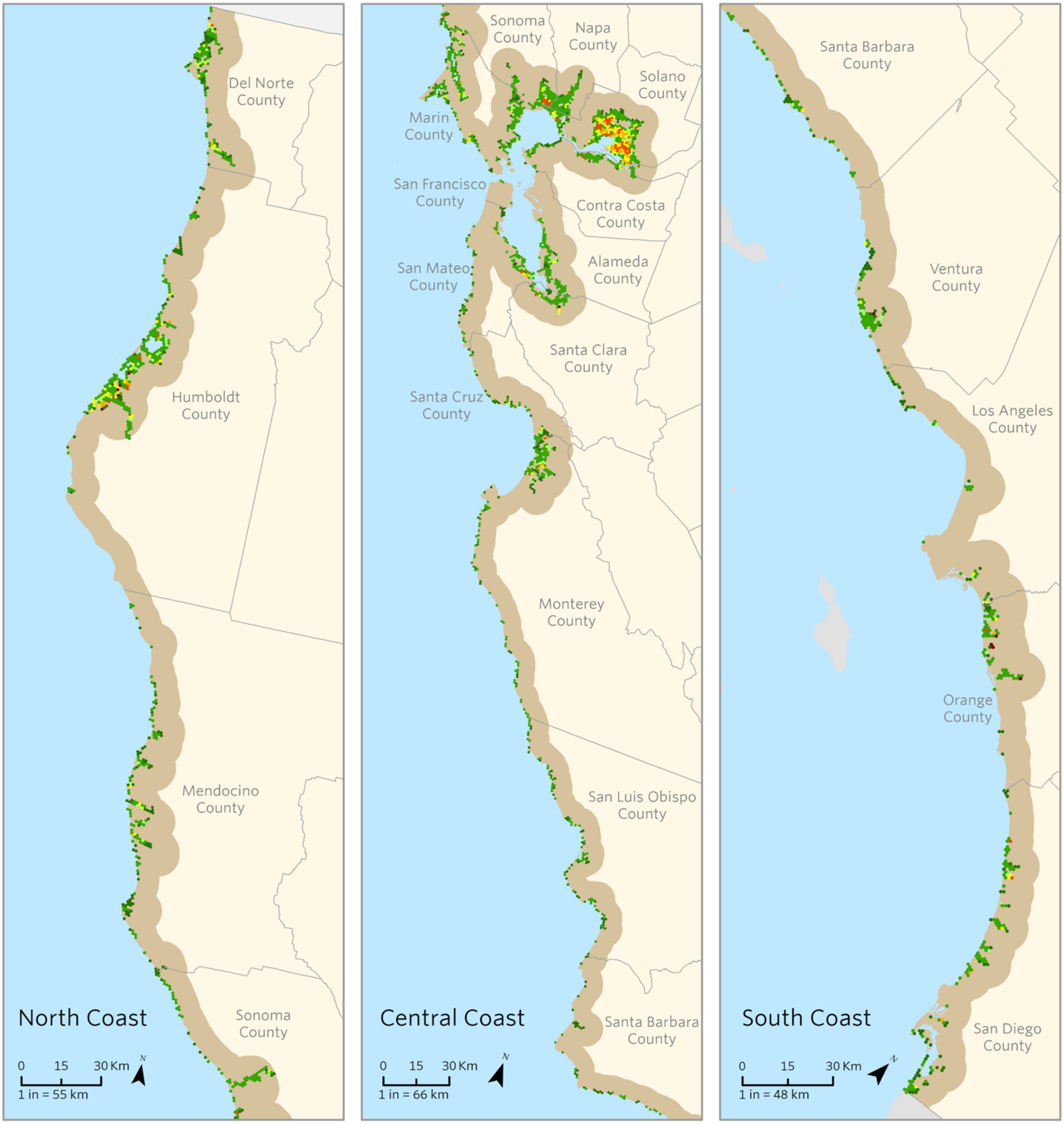
A majority (70%) of the irregularly-flooded estuarine marsh in the San Francisco Bay Delta has *lower Vulnerability* (V <1.2; Figure 4.13). Similarly, over seventy-five percent of the irregularly-flooded estuarine marsh in the North and Central Coast ecoregions also have *lower Vulnerability* (V<1.2; Figure 4.13). These two ecoregions hold nine and fifteen percent of the state's irregularly-flooded estuarine marsh, respectively (Appendix C.2). However, nearly 60% of the 13.2 km² of irregularly-flooded estuarine marsh in the South Coast ecoregion has *high Vulnerability* (V≥1.2; Figure 4.13).

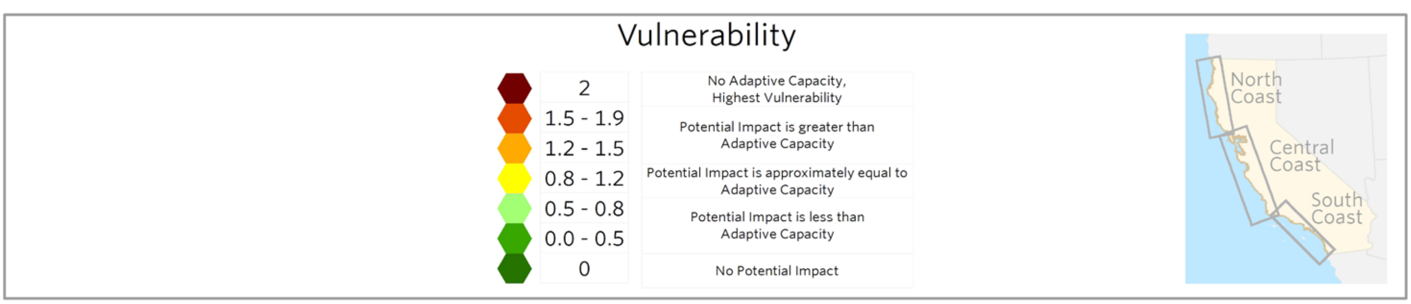
While there is more area of irregularly-flooded estuarine marsh with *high Vulnerability* (V≥1.2) in the South Coast, there are nearly twice the number of analytic units containing some irregularly-flooded estuarine marsh with *lower Vulnerability* (V<1.2). This pattern of having more analytic units containing *lower Vulnerability* irregularly-flooded estuarine marsh than those with *high Vulnerability* holds true for the other ecoregions as well, providing established patches of resilient habitat able to expand in area without managers needing to prepare and plant new locations for this habitat (Figure 4.12 and Figure 4.13).

FRESHWATER WETLAND HABITATS

VULNERABILITY, 5FT SEA LEVEL RISE

ECOREGION





FRESHWATER WETLANDS

For this analysis, freshwater wetlands represent the lumping of six freshwater wetland habitat types. The freshwater wetlands category is composed of: freshwater marsh (7%), seasonal freshwater marsh (74%), tidal freshwater marsh (2%), tidal freshwater forested/shrub (1%), inland shore (6%), and riparian forest and shrub (10%). Consequently, the freshwater wetlands category has the largest extent of the habitat categories summarized in this section, with 262.7 km^2 within the analytic zone statewide (Appendix C.1 and Figure 4.14). Because the sensitivities of the six freshwater wetland habitats vary (Table 2.4), we mapped an area-weighted *Vulnerability* score for the freshwater wetlands habitat group (Figure 4.14). Below we summarize aggregated areas of freshwater wetland *Vulnerability* using habitat specific *Vulnerability* results (Figure 4.15).

Approximately 35% of freshwater wetlands throughout the study area are within the analytic zone statewide (Appendix C.1). Two categories, vernal pool and rare riparian forest and shrub, are not found within the analytic zone, and therefore are not vulnerable to sea level rise. While only 6% of riparian forest and shrub is found within the vulnerability analytic zone, this 6% is likely uniquely adapted to coastal conditions. The remaining five freshwater wetland categories all have at least 61%, and up to 86%, of their study area-wide distribution found within the vulnerability analytic zone. For further details of freshwater wetland habitat-specific *Vulnerability*, see Appendix C.2.

Seventy-three percent of the freshwater wetlands within our analytic zone are found within the San Francisco Bay Delta (Appendix C.1 and Figure 4.14). Of those 191.3 km^2, 64% have a *high Vulnerability* (V≥1.2) and 9% have no *Adaptive Capacity* (V=2; Figure 4.15).

Fourteen percent of the freshwater wetlands in the analytic zone are found in the North Coast ecoregion, with six and seven percent in the Central and South Coast ecoregions respectively (Appendix C.1). Less than one percent of freshwater wetlands in the outer coast ecoregions have no *Adaptive Capacity* (Figure 4.15). *High Vulnerability* scores

Figure 4.14 Area-weighted *Vulnerability* of freshwater wetland habitats to five feet of sea level rise within each analytic unit for the three ecoregions of coastal California.

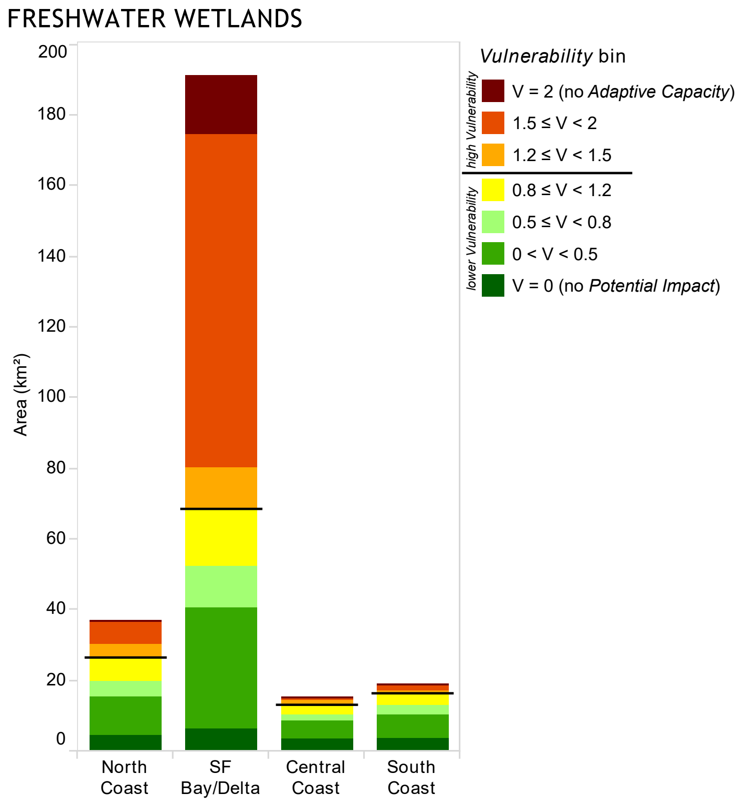


Figure 4.15 Aggregated area of habitat specific *Vulnerability* for all freshwater wetland habitats to five feet of sea level rise by ecoregion.

(V≥1.2) were calculated for 28% of North Coast ecoregion freshwater wetlands, but only 16% and 15% for the Central and South Coast ecoregions, respectively (Figure 4.15).

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TERRESTRIAL HABITATS

VULNERABILITY, 5FT SEA LEVEL RISE

ECOREGION

TERRESTRIAL HABITATS

For this summary of vulnerability, we lumped eighteen terrestrial habitat types. While the habitat and ecological function vary among these eighteen types, they all share one common characteristic: no tolerance (*Sensitivity* = 10) to tidal or subtidal inundation. Of this diverse and extensive group of habitats, 17 habitat types covering a total of 110.5 km² are found within the vulnerability analytic zone (Appendix C.1, Figure 4.16, and Figure 4.17). Only rare serpentine systems are not found within the vulnerability analytic zone. Because these habitats are typically well above mean higher high water and may be patchy in their distribution, most habitats within terrestrial systems have less than 1% of their distribution within the analytic zone, except for coastal prairie, perennial grassland, coastal dune, and rare coastal scrub. There are 3.7 km² of coastal dune within our vulnerability analytic zone (7% of its extent according to existing mapping). For details of terrestrial habitat-specific *Vulnerability*, see Appendix C.2. Collectively, 64% of terrestrial habitat area within the analytic zone will be exposed to intertidal or subtidal waters with five feet of sea level rise (Appendix C.1). We mapped an area-weighted *Vulnerability* score for the terrestrial habitat group (Figure 4.16). Below we summarize aggregated areas of terrestrial habitat *Vulnerability* using habitat specific *Vulnerability* results (Figure 4.17).

Sixty-eight percent of the terrestrial systems within our analytic zone are found within the San Francisco Bay Delta. Of the 74.7 km² of terrestrial systems within the San Francisco Bay Delta, half have *high Vulnerability* (V≥1.2) and 4% have no *Adaptive Capacity* (V=2; Figure 4.17).

The remaining 32% of terrestrial systems are evenly distributed among the outer-coast ecoregions. In the three outer-coast ecoregions 13–28% of terrestrial systems have *high Vulnerability* (V≥1.2; Figure 4.17).

Figure 4.16 Area-weighted *Vulnerability* of terrestrial habitats to five feet of sea level rise within each analytic unit for the three ecoregions of coastal California.

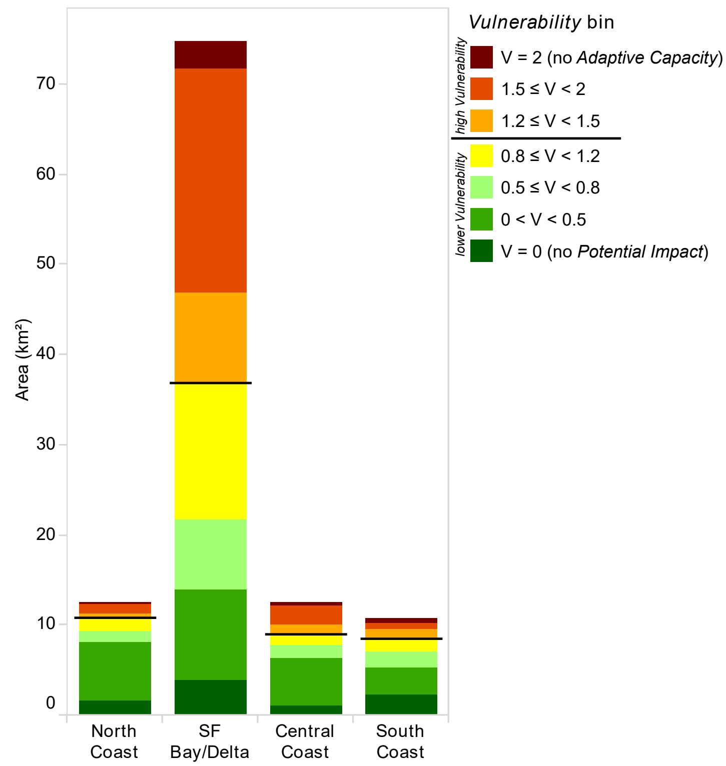
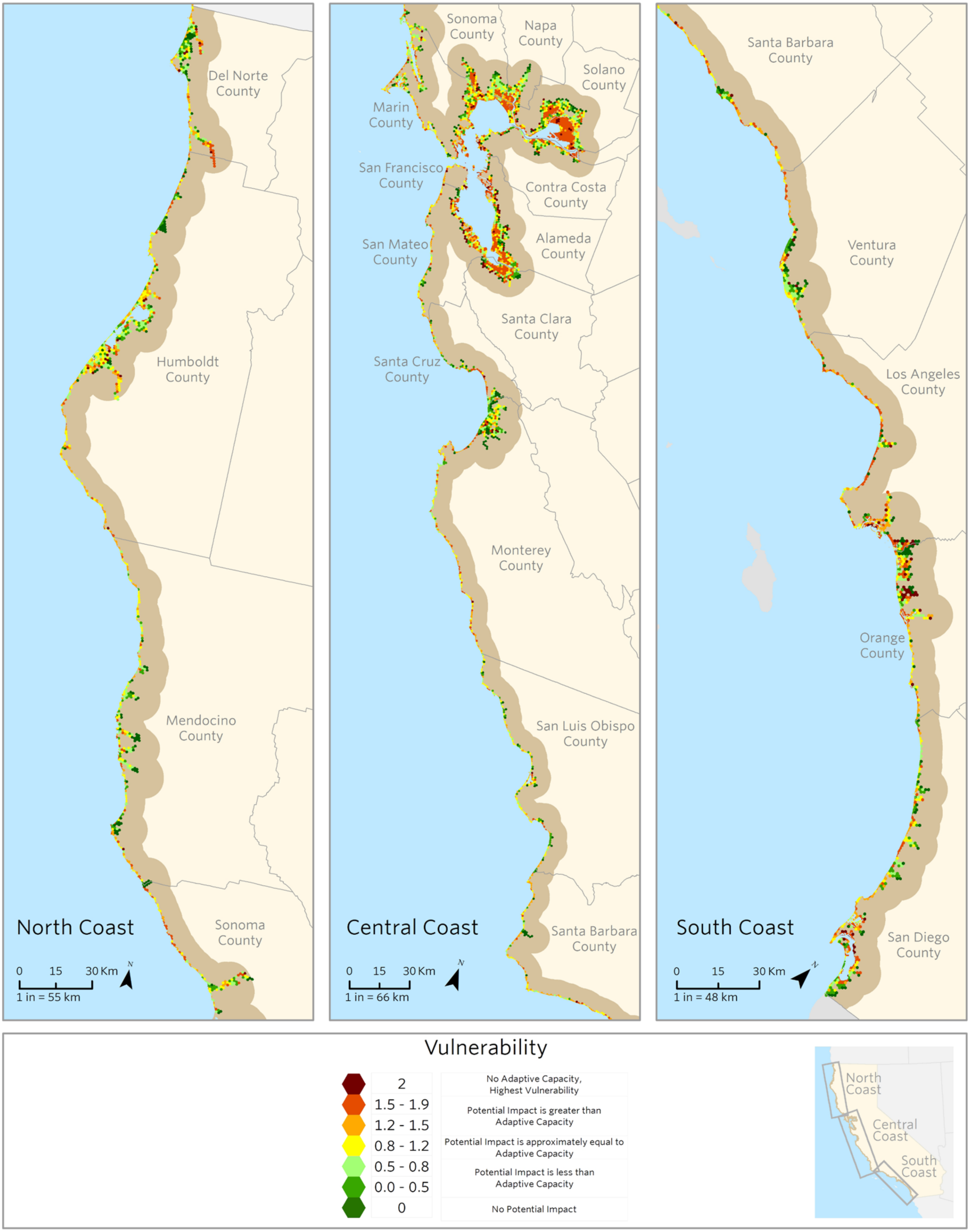


Figure 4.17 Aggregated area of habitat specific *Vulnerability* for all terrestrial habitats to five feet of sea level rise by ecoregion.

INDEX OF VULNERABILITY OF HABITATS
5FT SEA LEVEL RISE

ECOREGION



4.2 Habitat Vulnerability Index

The *Vulnerability Index* is an area weighted average of the *Vulnerability* of all habitats within an analytic unit and thereby provides a relative index of nature's ability to adapt to sea level rise. The *Vulnerability Index* allows consideration of a species' use of an area that may not be limited to a specific habitat type (e.g., marine mammal haul-outs; Section 4.3), or the fate of areas of conservation significance (e.g., Audubon Important Bird Areas; Section 4.3) or conservation lands (Section 4.6). We also used the *Vulnerability Index* to direct conservation investments and strategies at a landscape scale (Section 5).

In interpreting the *Vulnerability Index*, it is useful to first understand where the areas of natural habitat are at present to set the context for this vulnerability. Within the analytic zone, the San Francisco Bay Delta contains 68% of California's coastal habitats (Figure 4.18). The North Coast ecoregion contains 147.91 km² (13%) of California's coastal habitats within the analytic zone. The Central Coast and South Coast ecoregions each contain less than 10% of California's coastal habitats within the analytic zone.

Because it contains more than twice the amount of coastal habitat than along the entire outer coast, the relative vulnerability of the 766 km² of habitat throughout San Francisco Bay Delta is of great importance. For example, like the outer-coast ecoregions, only 4% of the natural habitat area in San Francisco Bay Delta has no *Adaptive Capacity* (V_i=2; Figure 4.18). However, this 4% represents 29 km², a much greater area than the other ecoregions. A majority (62%) of the San Francisco Bay Delta has *Vulnerability Index* scores of greater than 1.2, indicating 472.6 km² of natural habitat with more *Potential Impact* than *Adaptive Capacity* (Figure 4.18 and Figure 4.19).

Ninety-seven km² (66%) of the area of natural habitat within the North Coast ecoregion has a *lower Vulnerability Index* (Figure 4.18 and Figure 4.19). This pattern holds true for the Central Coast (62%) and the South Coast (67%) ecoregions, with 63 km² and 69.7 km² respectively of natural habitat with *lower Vulnerability Index* scores (Figure 4.18 and Figure 4.19).

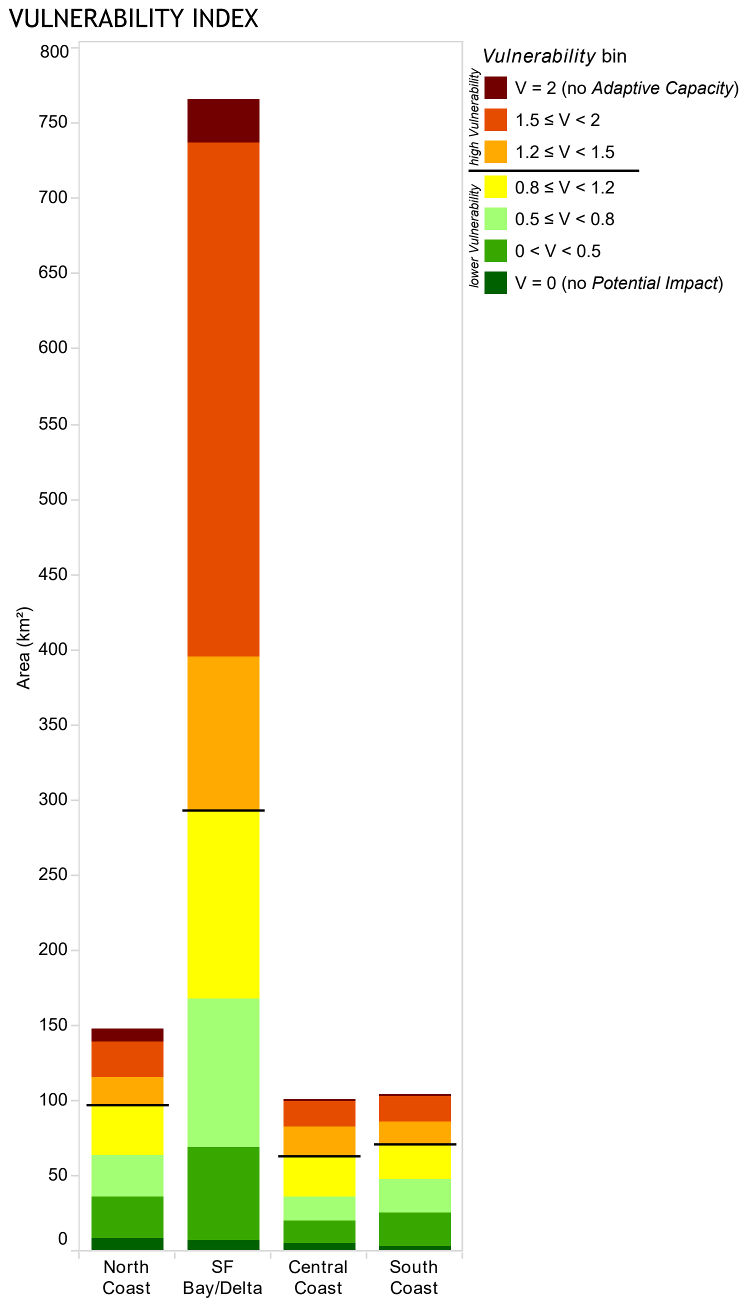


Figure 4.18 *Vulnerability Index* score for five feet of sea level rise by ecoregion.

Figure 4.19 Index of *Vulnerability* to five feet of sea level rise for all habitats within a given analytic unit.

4.3 Vulnerability of Critical Habitats for Focal Marine Mammals, Seabirds, and Shorebirds

Approximately half of the analytic units that contained pinniped occurrences had *high Vulnerability Index* scores (e.g., 53% for Pacific harbor seals, 51% for California sea lions, 46% for Steller sea lions, and two of four Northern elephant seal haul-outs). These findings are supported by our habitat-specific results which found a majority of rocky intertidal and upper beach habitat along California's coast having *high Vulnerability* (Figure 4.3 and Figure 4.7). Many of the marine mammal occurrences (Figure 3.4) fell outside of our analytic zone, most likely due to locational error associated with the occurrence data, but also perhaps because they were observed on nearshore rocks which are not included in this assessment. While pinnipeds have adapted to changing coasts for millions of years, the fact that half of the current pinniped occurrences are within *high Vulnerability* coastal habitats is of concern for these protected species in a time of rapid human-induced environmental change.

Of the 52 analytic units containing one or more observations of black oystercatchers (Figure 3.5), 24 (46%) have *high Vulnerability Index* scores. This is not surprising, considering that 60% of rocky intertidal habitat on which this species depends is of *high Vulnerability*. While black oystercatchers currently are widespread and reasonably common, they nest and feed exclusively in rocky shores which are vulnerable to sea level rise (Figure 4.3).

Approximately 40% of the analytic units containing occurrences of or critical habitat for western snowy plovers, have *high Vulnerability* (V≥1.2). Twenty-two percent of the 18 analytic units with occurrences of, and 42% of the 206 analytic units with critical habitat for California least terns, have *high Vulnerability Index* scores. Having approximately 40% of critical habitat with *high Vulnerability* represents a conservation concern for these two species that are managed under the Endangered Species Act.

There are 43 Audubon Important Bird Areas totaling 5,881 km^2 that have a cumulative 1,691 km^2 within our analytic zone. This is a fraction of the total area of Audubon Important Bird Areas throughout California, but these coastal areas contain unique habitats such as coastal prairie, coastal scrub, coastal dunes, estuarine habitats such as tidal flat and salt panne, regularly-flooded estuarine marsh, and irregularly-flooded

estuarine marsh, all of which provide unique services to a diversity of birds (Box 3.2). Forty-six percent of the 1,691 km^2 of coastal Audubon Important Bird Areas have a *high Vulnerability Index* score (V_i≥1.2; Appendix C.3). The coastal habitats contained within these Audubon Important Bird Areas may be critically important for migratory birds flying along the coastal section of the Pacific Flyway.

4.4 Potential Impact of Sea Level Rise to Imperiled Species

Of the 159 imperiled species with documented presence in our study area, 62 species have at least one occurrence in the projected footprint of five feet of sea level rise (Table 4.1). Many of these species have high proportions of their occurrences within projected five feet of sea level rise. For example: 39 species have at least 20% of their occurrences, 24 species have at least 50% of their occurrences, and eight species have 100% of their occurrences within projected five feet of sea level rise (Appendix C.4).

Table 4.1 Number of rare and imperiled species in the study area and within projected 5ft of sea level rise.

Taxonomic group	Number of species	Number of species within 5ft sea level rise
Plants	109	30
Invertebrates	21	10
Herps	8	6
Birds	11	11
Mammals	10	5

Plants are generally constrained by growing conditions and dispersal abilities, raising concern of potential impacts from sea level rise. A high proportion of the records of imperiled species are of plants, due to their habitat specificities and geographic restrictions. There are 23 plant species that have at least 20% of their occurrences within projected five feet of sea level rise. Six plants have 100% of their occurrences within projected five feet of sea level rise including plants like coastal dunes milk-vetch found only within coastal dunes, or California seablite, Suisun thistle, and two species of bird's beak found only in regularly-flooded and irregularly-flooded estuarine marsh (Box 3.2 and Appendix C.4). These imperiled plants depend on the resilience of these coastal habitats, which are already reduced in area from their historic ranges (Figure 4.11, Figure 4.13, and Figure 4.17).

Some of the imperiled animal species with occurrences within projected sea level rise such as bank swallow (*Riparia riparia*) and lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*), are highly mobile and may be able to use different habitats in response to changes resulting from sea level rise. Others, like Morro shoulderband snail (*Helminthoglypta walkeriana*) and saltmarsh harvest mouse *(Reithrodontomys raviventris)* are not only less mobile, but also rely on very specific coastal habitats that may be vulnerable to sea level rise, such as estuarine marsh for the mouse and coastal dune for the snail (Figure 4.11 and Figure 4.17).

Five of the seven imperiled bird species are found only within specific coastal habitats and have over 80% of their occurrences within projected five feet of sea level rise. The California Ridgway's rail, California black rail, and light-footed clapper rail are each only found in regularly-flooded and irregularly-flooded estuarine marsh (Box 3.2), and rely upon the resilience of these habitats into the future (Figure 4.11 and Figure 4.13). Similarly, western snowy plover and California least tern rely on relatively undisturbed upper beach (Box 3.1) to remain resilient in the face of sea level rise (Figure 4.6 and Figure 4.7).

4.5 Land Cover and Projected Inundation

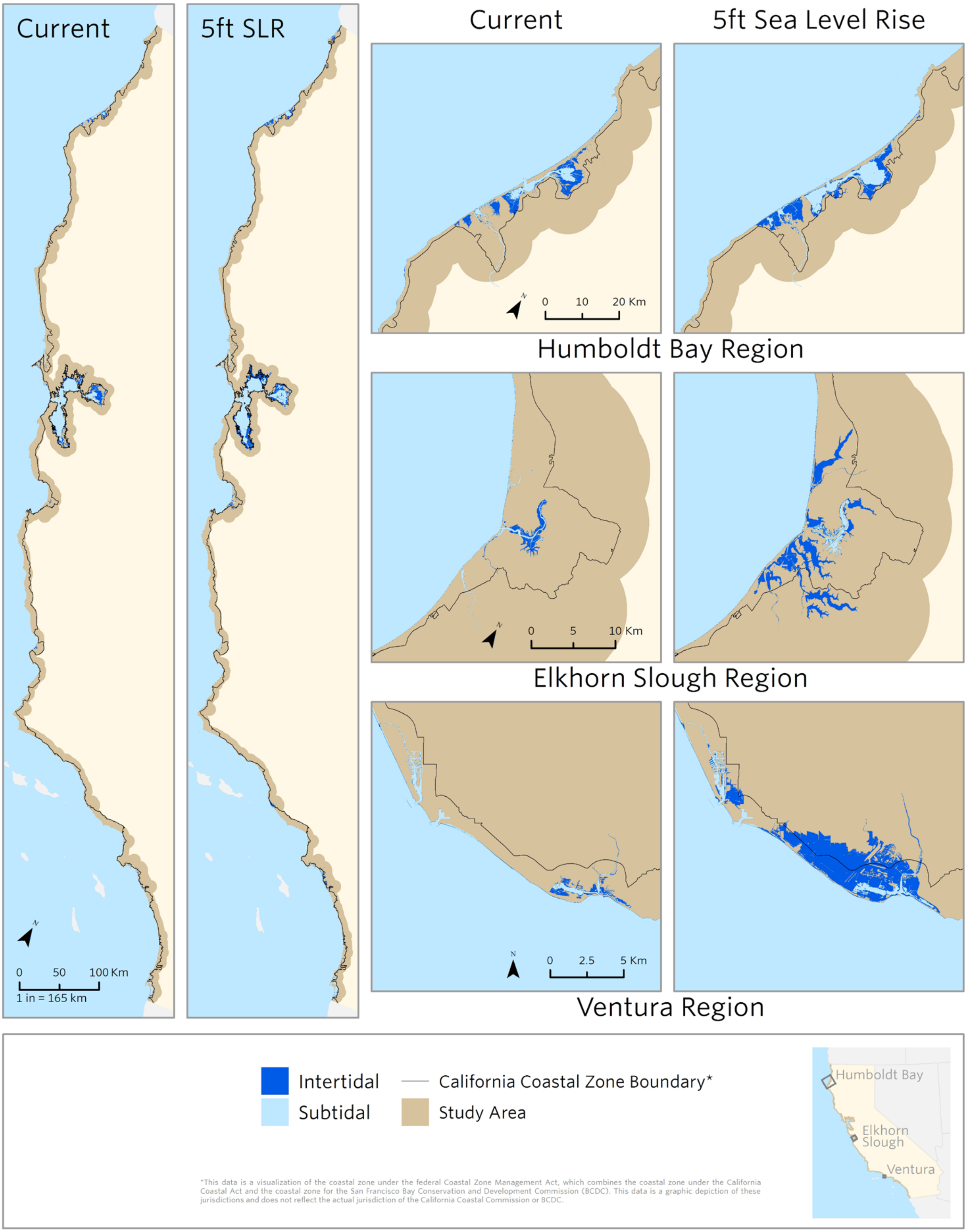
Patterns of exposure for the three land-use types: natural, agricultural, and developed, provide context for the impact of sea level rise to natural systems, as well as information on important social drivers of conservation opportunities to mitigate the impacts of sea level rise to nature. For example, natural lands will experience more exposure to sea level rise than agricultural or developed areas (Table 4.2). Agricultural and developed lands are typically devalued by tidal exposure, potentially enhancing conservation or restoration opportunities on those lands (Sections 5.4–5.5).

Table 4.2 Area (km^2) within the study area, and within projected sea level rise (SLR) by land cover type.

		NATURAL			AGRICULTURE			DEVELOPED		
Ecoregion/County	**Total (study area)**	**Study Area**	**Area exposed 2ft SLR**	**Area exposed 5ft SLR**	**Study Area**	**Area exposed 2ft SLR**	**Area exposed 5ft SLR**	**Study Area**	**Area exposed 2ft SLR**	**Area exposed 5ft SLR**
North Coast	**5,501.0**	5,069.2	71.3	109.3	264.1	41.2	58.8	167.6	1.9	6.5
SF Bay/Delta	**4,657.0**	2,295.1	671.6	734.0	406.0	51.0	63.3	1955.9	68.6	200.4
Central Coast	**5,847.8**	4,596.7	55.6	77.2	635.1	2.5	19.4	616.1	1.0	9.8
South Coast	**4,388.6**	1,733.7	41.7	71.4	241.1	0.01	6.3	2413.9	9.7	48.2
Statewide	**20,394.3**	**13,694.7**	**840.2**	**991.9**	**1546.3**	**94.7**	**147.8**	**5153.4**	**81.3**	**264.9**

COASTAL ZONE BOUNDARY

CURRENT CONDITIONS AND 5FT SEA LEVEL RISE



*This data is a visualization of the coastal zone under the federal Coastal Zone Management Act, which combines the coastal zone under the California Coastal Act and the coastal zone for the San Francisco Bay Conservation and Development Commission (BCDC). This data is a graphic depiction of these jurisdictions and does not reflect the actual jurisdiction of the California Coastal Commission or BCDC.

4.6 Conservation Management Status, Ownership, and Inundation

Of the more than 509 km^2 of public lands projected to be inundated, 365 km^2 are highly conserved and 109 km^2 are conserved, which together represent 93% of the public lands at risk. Of the 474 km^2 of highly conserved and conserved lands, 312 km^2 are projected to become intertidal, while 162 km^2 are projected to be lost to subtidal exposure. Seventy-three percent of the total exposure (345 km^2) is projected to occur within the San Francisco Bay Delta (Appendix C.6).

Three public land managers stand out as having the greatest proportion of their coastal land vulnerable to sea level rise: U. S. Fish and Wildlife Service, California State Lands Commission[1], and California Department of Fish and Wildlife.

California Department of Fish and Wildlife lands will experience the most inundation, with 156.7 out of 270.2 km^2 of lands within the study area projected to be inundated by five feet of sea level rise. Of this, 65.8 km^2 is projected to be lost to subtidal exposure, while the remaining 90.9 km^2 will be subject to intertidal exposure. Eighty-two percent of this exposure is projected to occur within the San Francisco Bay Delta (Appendix C.7).

U. S. Fish and Wildlife Service lands will experience the greatest proportional change (79%), with 133.9 of 168.9 km^2 projected to be inundated by five feet of sea level rise. Of this, 25 km^2 is projected to be lost to subtidal exposure, while the remaining 93 km^2 will be subject to intertidal exposure. Eighty-eight percent of the overall exposure is projected to occur within the San Francisco Bay Delta (Appendix C.7).

A projected 68.4 km^2 of California State Lands Commission's 93.1 km^2 of non-tidal lands will become tidal areas with five feet of sea level rise. Of this, 29 km^2 are projected to be lost to subtidal exposure, while the remaining 39 km^2 will be subject to intertidal exposure. Sixty-eight percent of this shift is projected to occur within the San Francisco Bay Delta, 14% along the North Coast, and the remainder split between the Central and South Coast ecoregions (Appendix C.7).

The lands of other land managers will also be affected by sea level rise. For example, 44 km^2 of Department of Defense lands are projected to be inundated by five feet of sea level rise, 93% of which is projected to be intertidal, and most of which is in the San Francisco Bay Delta or South Coast ecoregion. While California State Parks manages 939.9 km^2, the greatest extent of public land within our study area, only 21.6 km^2 of these lands are projected to be inundated by five feet of sea level rise. However, 29% of this inundation is projected to be lost to subtidal exposure.

Sea level rise will potentially reduce the area of non-tidal lands within the California Coastal Commission's Coastal Zone by approximately 215 km^2 statewide (Figure 4.20). The reduction in area of the Coastal Zone varies county by county from as little as 0.2 km^2 to as much as 68 km^2 (Appendix C.5). This results in a 1% to 16% reduction in jurisdictional oversight of coastal habitats by the Coastal Commission. Furthermore, there are areas totaling 37 km^2 for which sea level rise is projected to extend inland beyond the existing Coastal Zone boundary. Orange, Ventura, and Monterey Counties stand out as having the largest areas in which the 'landward' Coastal Zone boundary would in fact be seaward of the future shoreline (Appendix C.5). These areas would therefore lack Coastal Commission oversight of development.

As dry land becomes intertidal or subtidal, it becomes tidelands, subject to Public Trust protection administered by the State Lands Commission. Cumulatively, 1,200 km^2 along the outer coast and within San Francisco Bay Delta would experience this transition to Public Trust land with five feet of sea level rise.

1 In addition to tide and submerged lands, California State Lands Commission administers other public lands in the study area, including school lands, swamp and overflowed lands, other federal land grants to California, and rancho, pueblo, presidio, and mission lands.

Figure 4.20 The landward Coastal Zone Boundary for the California Coastal Commission (CCC) and the Bay Conservation and Development Commission (BCDC) and intertidal and subtidal waters for current conditions and projected five feet of sea level rise.

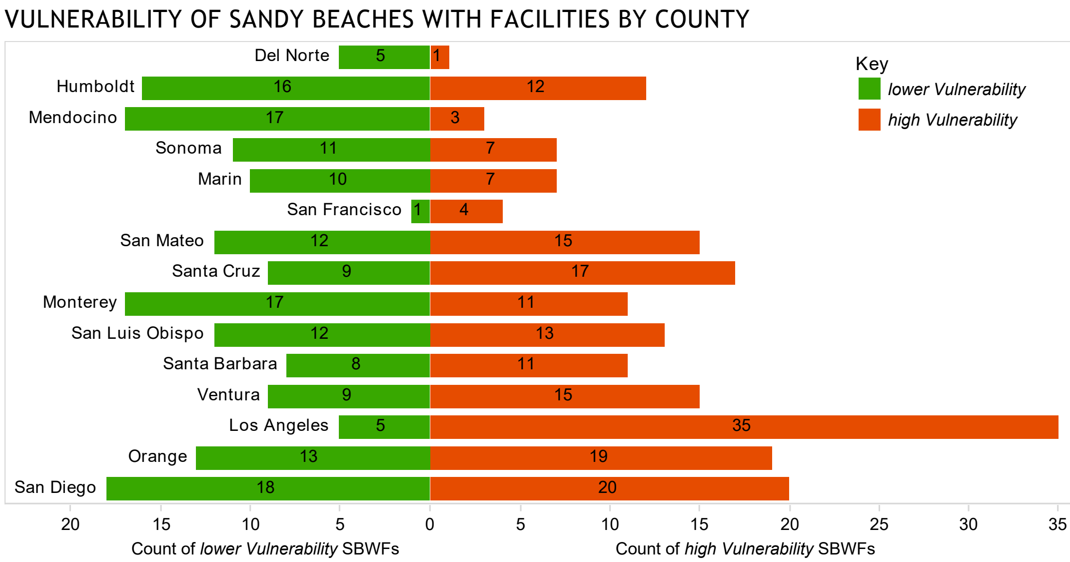


Figure 4.21 *Vulnerability of sandy beaches with facilities (SBWFs) to five feet of sea level rise by county.*

4.7 Vulnerability of Public Access to Sea Level Rise

Sea level rise will diminish coastal access opportunities throughout the state by reducing beach widths, submerging rocky intertidal areas, and flooding coastal beach infrastructure. Overall, California's sandy beaches with facilities are quite vulnerable. The upper beach at more than half of these sites statewide does not have the *Adaptive Capacity* needed to compensate for the *Potential Impact* of sea level rise (Table 4.3). The North Coast has fewer sandy beaches with facilities than the other ecoregions, and a smaller proportion of them have *high Vulnerability*; still, three out of every 10 sites have *high Vulnerability* (V≥1.2). *Vulnerability* is greater along the Central and South Coasts, with half of the Central Coast's sandy beaches with facilities, and nearly seven out of every 10 sandy beaches with facilities in the South Coast with *high Vulnerability* (V≥1.2).

At least half of the sandy beaches with facilities have *high Vulnerability* in nine out of the 15 outer-coastal counties, including all of the most heavily populated counties (Los Angeles, San Diego, San Francisco, San Mateo, Orange & Ventura; Figure 4.21). Los Angeles County tops the list with 88% of sandy beaches with facilities having *high Vulnerability* (Figure 4.21). The population of these counties is expected to grow, as will the demand for public coastal access. These results suggest that without intervention, the portfolio of sandy beaches with facilities and the services they provide will be reduced.

Table 4.3 *Vulnerability* of sandy beaches with facilities (SBWFs) to five feet of sea level rise by ecoregion.

Ecoregion	Lower Vulnerability SBWFs	High Vulnerability SBWFs	Total SBWFs	Percent vulnerable
North Coast	48	19	**67**	28%
Central Coast	63	72	**135**	53%
South Coast	52	99	**151**	66%
Total (state)	**163**	**190**	**353**	**54%**

5.0 | How Can We Conserve California's Coast into the Future?

California's coastal habitats, imperiled species, and conservation lands are highly vulnerable to sea level rise and we must begin now to conserve our future coastline. Sustained and concerted efforts are necessary, ranging from new conservation approaches to policy focused on maintaining a natural, functioning coastline. Conservation and management frameworks need to embrace the realities of a dynamic coastline and allow for natural processes to act at multiple scales. At a local scale, these adaptive frameworks need to inform actions to provide habitats the space necessary for coastal processes such as erosion, accretion, transgression, and transition. At regional scales, these frameworks need to inform conservation and restoration of natural flows and transport of water, materials, and, importantly, sediments from upper watersheds to estuaries and coasts, as well as along nearshore coastal waters through littoral sediment transport. Management and conservation in the face of sea level rise must consider regional habitat representation and composition in order to maintain the extent and function of coastal habitats and species, understanding that while habitats or species are vulnerable in one location, conditions may arise to support that habitat or species in other locations. By using habitat vulnerability results in combination with other data, we identify five key strategies organized under two larger themes:

CONSERVE AND MANAGE FOR RESILIENCE

We can build upon California's strong coastal conservation legacy to ensure that resilient strongholds persist into the future in the face of sea level rise. To do this, we need to ensure that our existing conservation lands are maintained and managed for resilience and that we invest in new conservation lands to remove the risk that the habitat value of these lands could be destroyed by land use changes and future development. Accordingly, we present spatially explicit opportunities for the application of the following three strategies to conserve coastal habitats in the face of sea level rise:

Maintain Existing Resilient Conservation Lands (Section 5.1)—we identified resilient patches of conservation lands that should be managed to maintain both their conservation management status as well as the resilience of the habitats within these areas.

Conserve Resilient Landscapes (Section 5.2)—we identified resilient patches of habitat that are not yet conserved which represent opportunities to invest in conserving habitats that will be resilient in the face of sea level rise.

Manage in Place for Resilience (Section 5.3)—we identified vulnerable habitats on conserved lands that may need additional management actions to enhance their resilience to keep pace with sea level rise.

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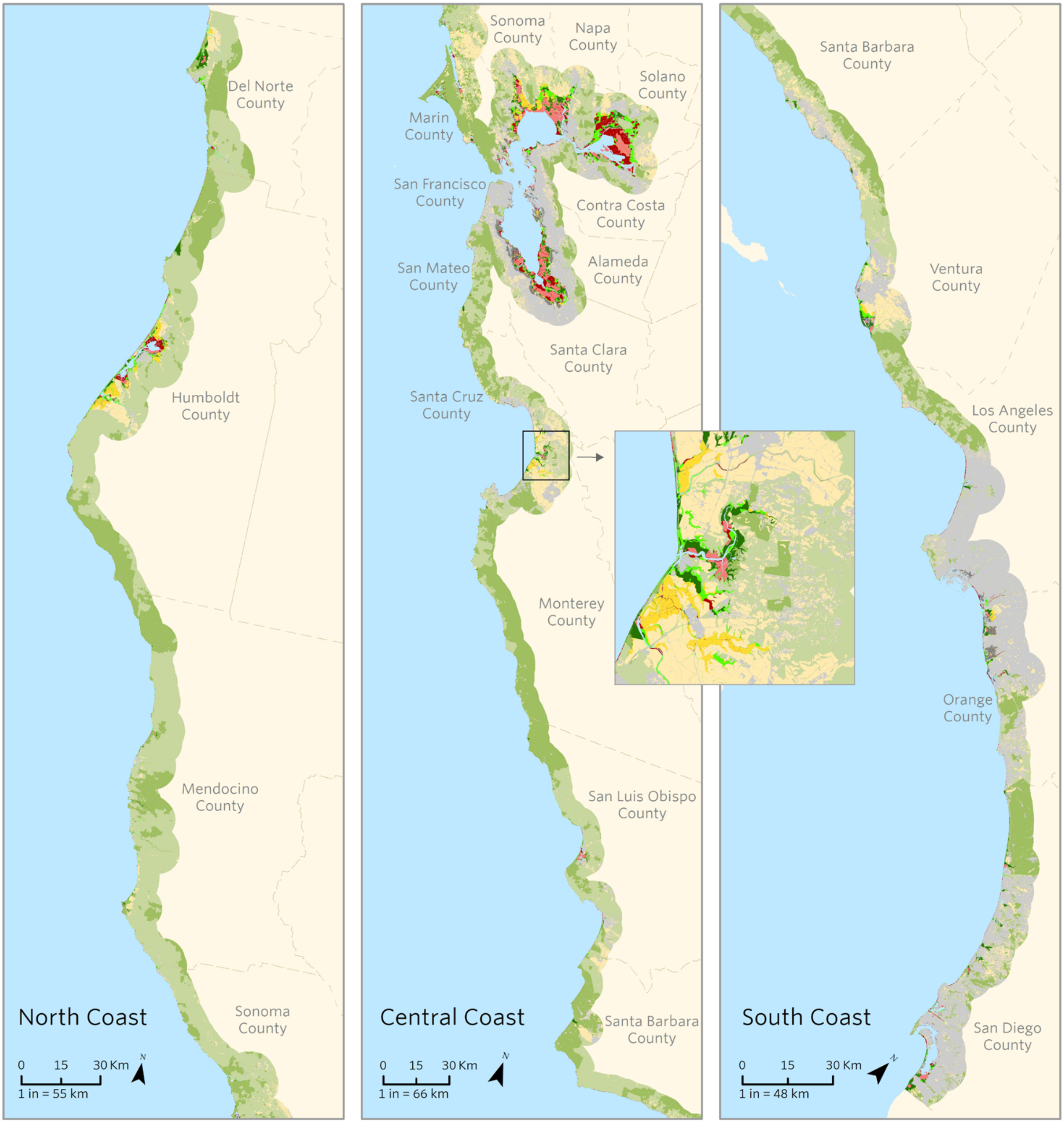
CALIFORNIA COASTAL CONSERVATION ASSESSMENT

ECOREGION



Resilient Conserved Habitat
Maintain the resilience and conservation status of existing conservation land.

Resilient Non-conserved Habitat
Invest in conserving resilient landscapes.

Vulnerable Conserved Habitat
Manage in place for resilience to help habitat keep pace with sea level rise.

Vulnerable Non-conserved Habitat
Mitigate potential losses by adapting adjacent built environment and/or investing in potential future habitat.

Potential Future Habitat
Invest in conservation and management that allows vulnerable habitat to transgress inland.

Exposed Built Environment
Adapt the built environment to enhance habitat area and function.

Study Area
- Conserved Habitat
- Non-conserved Habitat
- Undeveloped Uplands
- Built Environment

MITIGATE POTENTIAL LOSSES OF VULNERABLE HABITATS

Some of California's coastal habitats will be lost to sea level rise and we need to mitigate those potential losses. We present spatially explicit recommendations for the application of two strategies that are both essential to mitigating potential losses of vulnerable habitats:

Conserve Potential Future Habitat Areas (Section 5.4)—we identified undeveloped uplands that are projected to become tidal and/or are adjacent to vulnerable habitats, that could be conserved and restored to coastal habitat.

Increase Adaptive Capacity (Section 5.5)—we identified areas where adapting or retreating vulnerable components of the built environment could enhance the *Adaptive Capacity* of natural habitats.

Given that 55% of the 1,121 km^2 of coastal habitats we assessed were highly vulnerable to sea level rise, we need concerted investment in each of the five sea level rise strategies outlined above to conserve California's coastal habitats into the future. To make spatially explicit recommendations for the application of these strategies, we combined our *Vulnerability Index* with conservation management status and land use data to identify areas appropriate for each strategy in one single map (Figure 5.1). Below we describe each strategy and opportunities for its application across the landscapes within each ecoregion.

Figure 5.1 Opportunities for conserving California's habitat and managed lands in the face of sea level rise. The inset shows the level of detail which may also be observed by zooming in to any area of interest in the high resolution report, or by viewing interactive maps online at CoastalResilience.org/CoastalAssessment.

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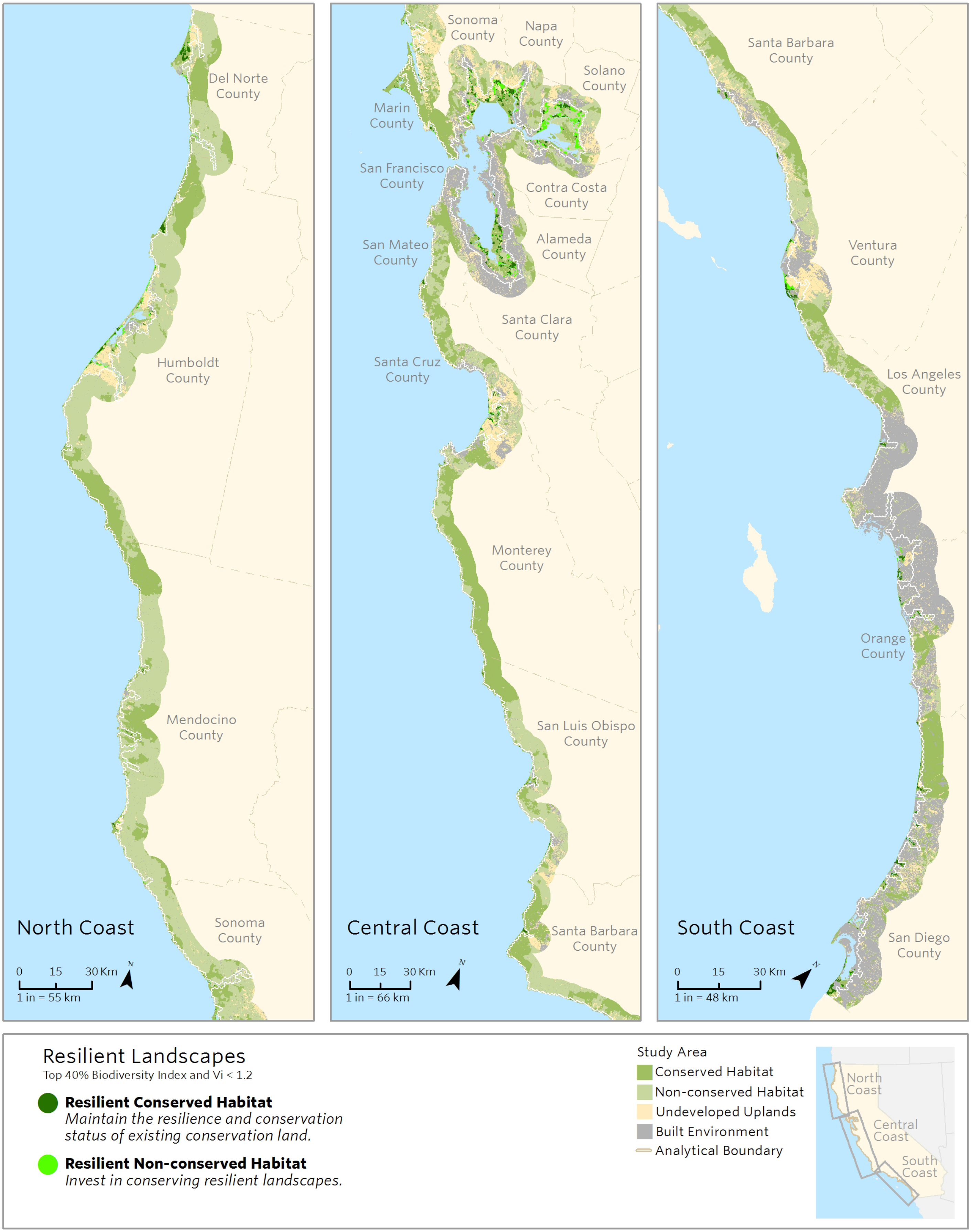
RESILIENT LANDSCAPES

ECOREGION



5.1 Maintain Existing Resilient Conservation Lands

Approximately half of the habitat area within tracts of conserved lands along the California coast are resilient to sea level rise. Maintaining resilient conservation lands means maintaining the conservation status of the landscape as well as taking management steps to ensure that coastal habitats remain resilient to sea level rise. Strong management is needed to ensure that ecological processes remain intact and human actions do not interfere with the adaptive capacity of the landscape to preserve the extent and composition of coastal habitats. Maintaining the conservation management status of our conservation lands is important to preserving the goods and services these intact habitats provide to nature and people (Barbier *et al.* 2011). This strategy highlights the need for sea level rise threats to be incorporated into management plans for conserved lands, to ensure that any planned human use and infrastructure will not lessen the resilience of these core habitats to sea level rise.

Maintaining large areas of resilient landscapes free from development allows for the continuation of natural coastal processes such as erosion, accretion, habitat transition, and habitat transgression. This is critical for species to adapt to these and other changes associated with climate change and sea level rise. Conserved resilient landscapes are important platform sites for monitoring how physical settings and ecosystem conditions change with climate change and sea level rise, and how habitats and species respond to these changes. Conserved resilient landscapes also provide important reference sites for habitat restoration throughout the coast.

We used the *Vulnerability Index* and conservation management status to highlight the 253 km^2 of resilient conserved landscapes throughout the state and illustrate how they relate to the landscape of conservation strategies and other land uses along the coast (Figure 5.1). We also prioritized those resilient conserved landscapes using a biodiversity filter (Figure 5.2) to identify important landscapes in each ecoregion.

Figure 5.2 Priority habitat areas that are resilient to sea level rise, and strategies to maintain them. Details may be observed by zooming in to any area of interest in the high resolution report, or by viewing interactive maps online at CoastalResilience.org/CoastalAssessment.

NORTH COAST

The North Coast ecoregion contains 20% of the state's resilient conserved habitat. Of this 50 km^2 of resilient conserved habitat, 32% is freshwater wetlands, 32% is tidal flat and salt panne, and 13% is terrestrial.

SAN FRANCISCO BAY DELTA

The San Francisco Bay Delta contains 49% of the state's resilient conserved habitat. Of this 123 km^2 of resilient conserved habitat, 26% is regularly-flooded estuarine marsh, 24% is freshwater wetlands, and 20% is tidal flat and salt panne.

CENTRAL COAST

A majority of the resilient landscapes of the Central Coast ecoregion are already conserved, accounting for 14% of the state's resilient conserved habitat. Of this 36.4 km^2, 22% is freshwater wetlands, 19% is tidal flat and salt panne, 17% is terrestrial habitats, and 11% is regularly-flooded estuarine marsh.

SOUTH COAST

A majority of the resilient landscapes of the South Coast ecoregion are already conserved, accounting for 17% of the state's resilient conserved habitat. Of the 44 km^2 of resilient conserved habitat in the South Coast, 26% is freshwater wetlands, 22% is tidal flat and salt panne, 12% is terrestrial habitats, and 12% is irregularly-flooded estuarine marsh. Maintaining the conservation status and resilience of the nearly 5 km^2 of resilient conserved irregularly-flooded estuarine marsh in the South Coast is important for the maintenance of this habitat for the region and the state.

5.2 Conserve Resilient Landscapes

There are portions of the coast that are resilient to sea level rise, but are not yet conserved or protected from human alteration or development. Conserving these resilient landscapes will be critical to maintaining the extent and composition of coastal habitats along the entire coast. Investing in the conservation of resilient landscapes will also preserve many ecosystem services to people—buffering against storm damage, fisheries production, cleaning coastal waters, sequestering carbon, and opportunities for recreation that even small patches of coastal habitats provide (Barbier *et al.* 2011). Conserving resilient landscapes will not only preserve the resilience of habitats within these areas, but also contribute to the resilience of habitats and human assets at regional scales—by preserving natural processes such as erosion, accretion, and littoral sediment transport.

Investing in the conservation of resilient strongholds throughout California's coast in a network of large areas connected by corridors and buffered from other land-uses, is important to maintain California's coastal biodiversity. Large patches of resilient conserved habitats can act as refuges to help maintain populations of rare and imperiled species. Conserving a diversity of physical conditions in a well-connected network will be critical to the maintenance of biodiversity as climates change and sea levels rise (Lawler *et al.* 2015). Large tracts of conservation lands will allow natural processes to occur, the physical setting to change, and habitats and species to adapt and respond to these changes. Linking conservation lands in a network will facilitate current migration patterns and allow the movement of populations as conditions shift with changes in climate and sea level rise.

We stress, however, that conserving habitats *regardless* of vulnerability will be important if we are to maintain California's coast as over 60% natural habitat. Habitats under current conditions may be critical to the maintenance of populations of rare or imperiled species at present and while sea levels rise and habitats change. Further, conserving habitat area with any level of vulnerability will allow for natural processes, including the transition of habitats as sea levels rise. To be clear, we find lasting importance in habitat conservation regardless of assessed vulnerability to sea level rise. However, the conservation of habitats resilient to sea level rise will be critical to the maintenance of the extent of each habitat type and regional composition as sea levels rise.

We used the *Vulnerability Index* and conservation management status to highlight non-conserved resilient landscapes and how they relate to the landscape of conservation lands and other land uses (Figure 5.1). Cumulatively there is an opportunity to double the overall area of resilient strongholds California-wide (Figure 5.1). Many of the patches of resilient non-conserved habitat are located between existing resilient conserved or vulnerable conserved habitats (Figure 5.1). The conservation of these areas would fill key gaps, preserve habitat corridors, and establish a well-connected network of conserved coastal habitats throughout California. To strategize among the many opportunities to invest in conserving resilient landscapes throughout each ecoregion, we prioritized those resilient landscapes with the highest conservation value using the RWRI (Figure 5.2). Using habitat-specific vulnerability in relation to conservation management status, we summarize those coastal habitats for which this strategy will be particularly important by ecoregion below.

NORTH COAST

The North Coast ecoregion contains 17% of the state's resilient non-conserved habitat. Of this 47 km^2 of resilient non-conserved habitat in the North Coast ecoregion, 27% is freshwater wetlands, 21% is tidal flat and salt panne, and 11% is terrestrial habitats. There are 9 km^2 of resilient tidal flat and salt panne, nearly 3.5 km^2 of resilient upper beach, and 12 km^2 of resilient freshwater wetlands that are not yet conserved on the North Coast. There are also opportunities to nearly double the area of conserved resilient regularly-flooded estuarine marsh and irregularly-flooded estuarine marsh within this ecoregion (Figure 5.3). Highly biodiverse and resilient landscapes stand out near Point St. George, as well as the beaches, dunes, and estuarine wetlands along Arcata and Humboldt Bay, and the Eel River estuary (Figure 5.2). Conserving the large patches of resilient, biodiverse, yet non-conserved coastal habitats among these existing resilient strongholds (Figure 5.2) would fill gaps in an existing landscape of conserved habitats and preserve the values these habitats provide to people and nature.

FOCAL HABITAT VULNERABILITY AND CONSERVATION MANAGEMENT STATUS

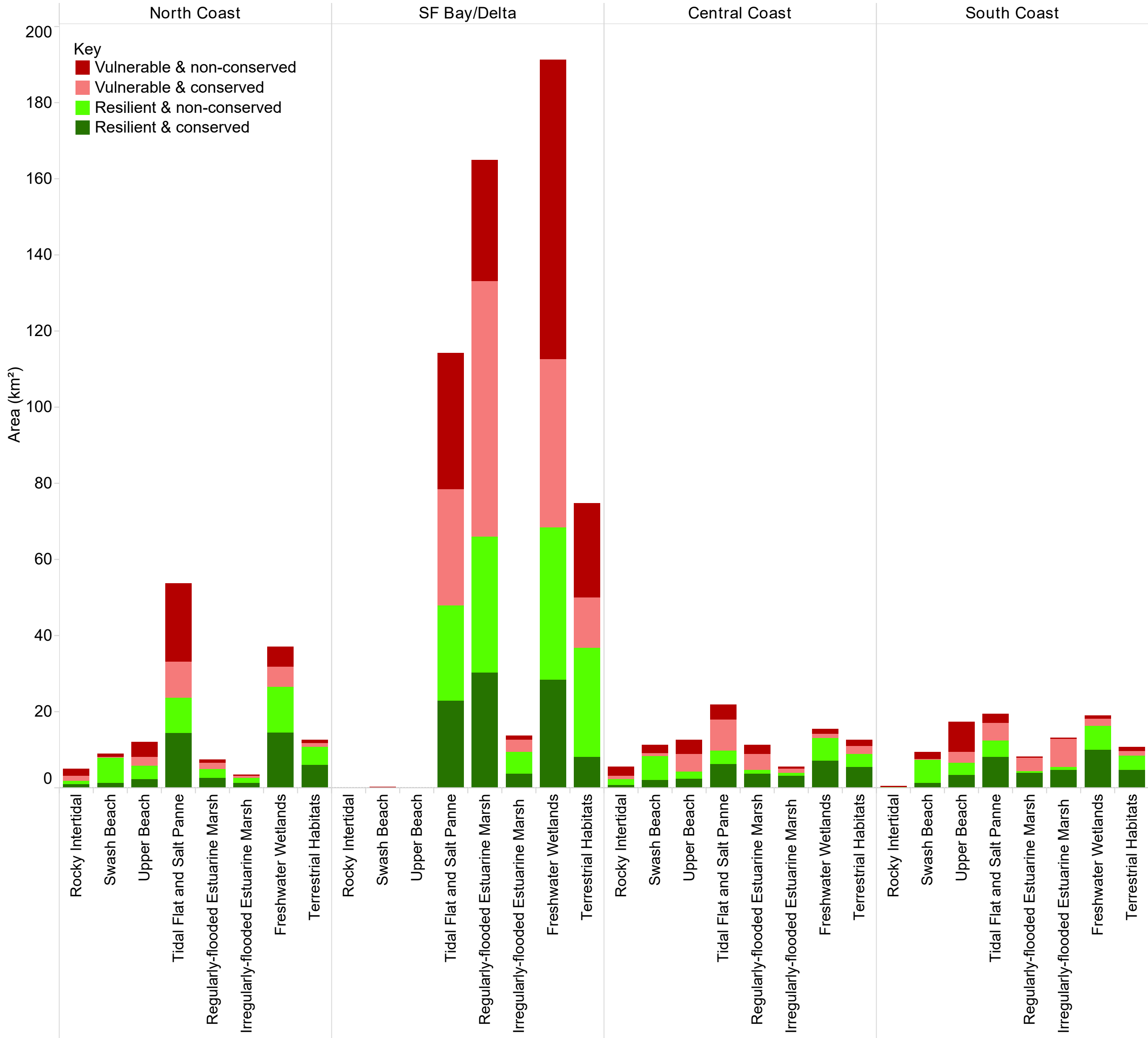
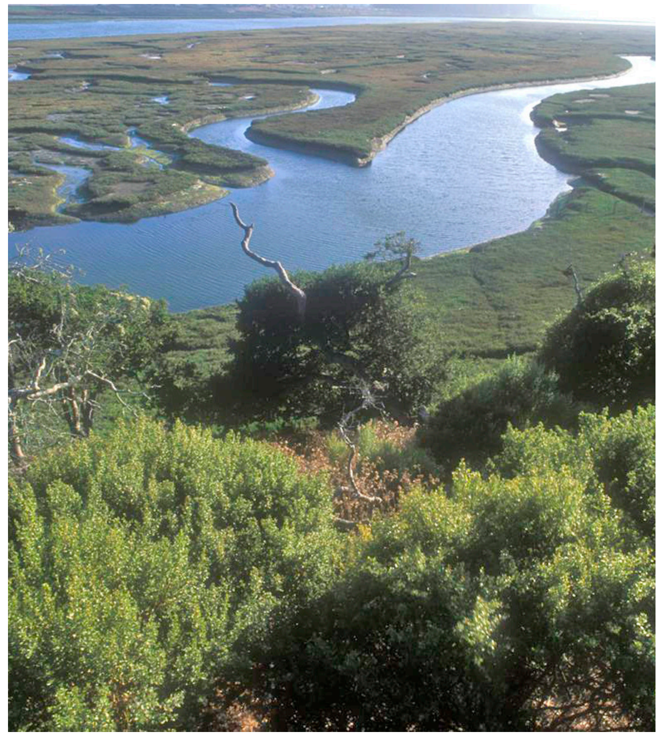


Figure 5.3 Area (km²) for each of eight coastal habitats by ecoregion categorized by vulnerability and conservation management status.

© Ian Shive



© Elkhorn Slough National Estuarine Research Reserve

SAN FRANCISCO BAY DELTA

The San Francisco Bay Delta contains 63% of the state's resilient non-conserved habitat. Of this 171 km^2, 24% is freshwater wetlands, 21% is regularly-flooded estuarine marsh, 17% is terrestrial habitats, and 15% is tidal flat and salt panne. These three habitats are three of the most vulnerable habitats in the San Francisco Bay Delta, so efforts to conserve any resilient patches of these three habitats could be critical to maintaining these habitats in this important region. The substantial gains from conserving the 35.7 km^2 of resilient regularly-flooded estuarine marsh could prove critical to maintaining regularly-flooded estuarine marsh statewide, as well as the rare and imperiled species that rely on this habitat. There are large aggregations of resilient non-conserved habitats with high biodiversity value in Suisun Bay and San Pablo Bay (Figure 5.2).

CENTRAL COAST

The Central Coast ecoregion contains 10% of the state's resilient non-conserved habitat. A majority of the resilient landscapes in the Central Coast are already conserved, and these are dispersed throughout the ecoregion (Figure 5.1). Conserving the 27 km^2 of non-conserved resilient landscapes throughout the Central Coast would fill gaps in a relatively well-conserved stretch of California's coastline. Of this 27 km^2, 22% is freshwater wetlands, 13% is terrestrial habitats, and 12% is tidal flat and salt panne. Patches of resilient non-conserved lands with high biodiversity lie within a matrix of conserved lands along the Marin headlands, as well as throughout the Pajaro River and Salinas River areas surrounding Elkhorn Slough in the center of the Monterey Bay (Figure 5.2). Conserving these resilient tracts of natural habitats would not only fill gaps in the existing conservation landscape, but also create resilient strongholds adjacent to the vulnerable estuarine, beach, and dune habitats of this area. Such strategic conservation investments will likely prove critical to maintaining regional representation of habitat and species diversity, as well as to avoiding habitat fragmentation that may result from sea level rise. The Central Coast holds 26% of the state's resilient beaches and 51% of the state's resilient rocky intertidal (Figure 5.3), so working to ensure their conservation into the future is important for these two habitats.

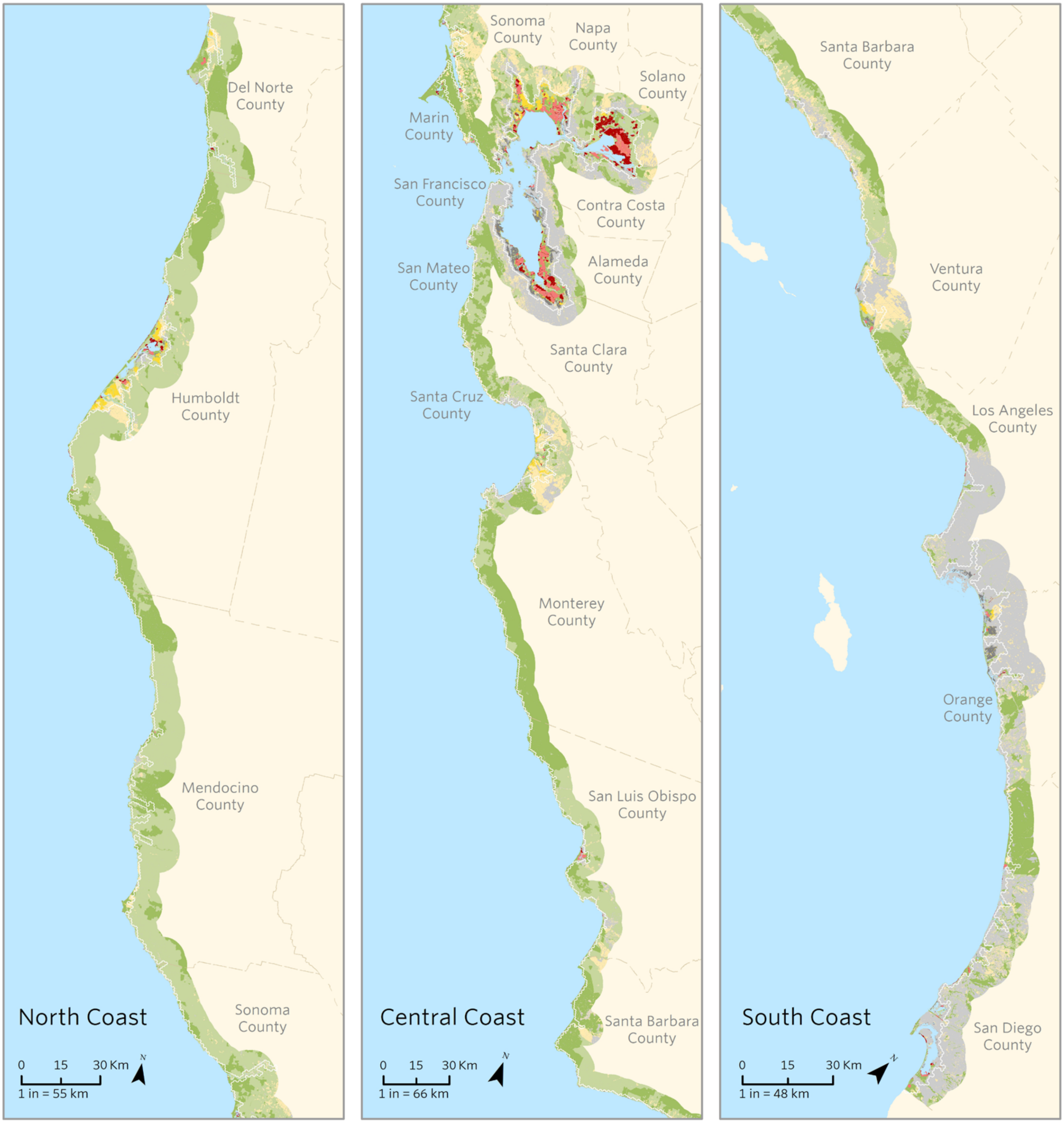
© Walter Heady/The Nature Conservancy

SOUTH COAST

The South Coast ecoregion contains 10% of the state's resilient non-conserved habitat in large tracts dispersed throughout the ecoregion—many of which fill gaps within the existing conservation landscape (Figure 5.1 and Figure 5.2). Collectively these provide an opportunity for significant conservation gains. Of this 26 km^2, 22% is freshwater wetlands, 15% is tidal flat and salt panne, 14% is terrestrial habitats, and 12% is upper beach. Over one-third of the state's irregularly-flooded estuarine marsh is found within the South Coast, so it is important to invest in the protection of the 8.8 km^2 of resilient, non-conserved, irregularly-flooded estuarine marsh. The South Coast holds 39% of the state's resilient upper beaches, and only half of them are conserved (Figure 5.3). In a region noted for the vulnerability of its beaches (Section 4.1.1; Vitousek *et al.* 2017, Dugan 2008 and 2017), the conservation of the 3.3 km^2 of resilient beaches should be a high priority.

VULNERABLE LANDSCAPES

ECOREGION



Vulnerable Landscapes

Top 40% Biodiversity Index and Vi ≥ 1.2

Vulnerable Conserved Habitat
Manage in place for resilience to help habitat keep pace with sea level rise.

Vulnerable Non-conserved Habitat
Mitigate potential losses by adapting adjacent built environment and/or investing in potential future habitat.

Potential Future Habitat
Invest in conservation and management that allows vulnerable habitat to transgress inland.

Exposed Built Environment
Adapt the built environment to enhance habitat area and function.

Study Area
- Conserved Habitat
- Non-conserved Habitat
- Undeveloped Uplands
- Built Environment
- Analytical Boundary

5.3 Manage in Place for Resilience

Some important coastal habitats do not have the adaptive capacity to transgress inland due to topography or the built environment, so to maintain habitat area and function it is critical to manage these vulnerable habitats in place for resilience. Many coastal habitats have adapted to changing sea levels through the accretion of sediments and growing vertically to keep pace with rising seas. Unfortunately, the very habitats that lack areas to transgress into, often also lack sufficient sediment supply and delivery to result in vertical accretion. In response, there is a growing set of tools that coastal land managers can apply to manage habitats in place for resilience over a variety of time horizons. For example, managers can add sediments to habitats to help them keep pace with sea level rise, or restore water and sediment flow throughout the site to help facilitate accretion. Managing in place for resilience is a strategy that can assist habitats to persist in place, thereby helping to maintain the extent and function of coastal habitats.

The fact that coastal accretion rates are often not high enough to keep pace with sea level rise is not only due to accelerated sea level rise, but often due to an unnatural disconnection of sediment supply and delivery. This may arise when the upstream landscape is altered by damming, channelizing or armoring streams, constructing storm drains or other features of the built environment. In the marine or estuarine environment, hard infrastructure or practices such as dredging may limit sediment supplies or change littoral sediment dynamics. We must consider the cumulative impacts of these stressors on coastal habitats at regional scales, and managing in place for resilience may mean addressing source stressors elsewhere. Managers are becoming increasingly aware of the complex and dynamic impacts to sediment and water flow dynamics in coastal habitats, and are developing creative management strategies to mitigate these impacts. Examples of practices to manage in place for resilience range from the manual placement of sediments, thin-layer sediment augmentation, the removal of levees around estuarine marshes or dams upstream, improving flushing and sediment dynamics on a marsh, to restoring the flow and sediment processes in the estuary or watershed upstream. There is no single approach to managing in place for resilience, and the best approach will incorporate both local dynamics and the regional context.

Figure 5.6 Priority habitat areas that are vulnerable to sea level rise, and strategies to manage in place and mitigate potential loss. Details may be observed by zooming in to any area of interest in the high resolution report, or by viewing interactive maps online at CoastalResilience.org/CoastalAssessment.

With approximately half of the statewide habitat area of conserved lands being vulnerable to sea level rise, managing in place for resilience is an important strategy to maintain habitat extent and composition regionally and statewide (Figure 5.1). Statewide, efforts to manage in place for resilience can be prioritized by conservation value (Figure 5.6). Most of the highly vulnerable conservation lands in need of management in place for resilience are found in the San Francisco Bay Delta. Considering the existing work to manage San Francisco Bay Delta's habitats for resilience in place lends confidence to the persistence of the largest extent of estuarine marsh habitat in the state, and for the scalability of this approach statewide.

NORTH COAST

The North Coast ecoregion contains 6% of the state's vulnerable conserved habitat that could be managed in place for resilience. These are evenly divided among federal, state, and regional managers (Table 5.1) throughout the North Coast (Figure 5.1). Of the 18.2 km^2 of vulnerable conserved habitat in the North Coast ecoregion, 42% is tidal flat and salt panne, 24% is freshwater wetlands, and 10% is upper beach. Because these are three of the most vulnerable habitats in the North Coast (Figure 4.1), managing these conserved habitats for resilience is essential to protecting our investment in these habitats. Managing in place for resilience for the 18.2 km^2 of vulnerable conserved habitat in the North Coast could potentially add to the existing 50 km^2 of currently conserved resilient landscapes.

© Andrea Pickart/U.S. Fish and Wildlife Service

Table 5.1 Area (km^2) of conserved natural lands with high vulnerability index and their ownership by ecoregion.

Ecoregion	Total Vulnerable Conserved	Vulnerable Conserved and Federally managed	Vulnerable Conserved and State managed	Vulnerable Conserved and Regionally/Locally managed	Vulnerable Conserved with Other managers
North Coast	**18.22**	5.25	6.35	5.24	1.38
SF Bay/Delta	**249.90**	99.72	136.84	9.19	4.15
Central Coast	**19.46**	3.92	12.37	2.2	0.97
South Coast	**16.76**	8.02	6.95	1.67	0.13
Total (state)	**304.33**	**116.91**	**162.5**	**18.3**	**6.61**

SAN FRANCISCO BAY DELTA

The San Francisco Bay Delta contains 82% of the state's highly vulnerable areas of conservation lands dispersed throughout the region (Table 5.1 and Figure 5.1). Most of these are state-managed lands, but a high proportion are also federally-managed (Table 5.1). The forces interacting to give rise to the *high Vulnerability* of these conservation lands vary throughout the San Francisco Bay Delta and the approaches to managing in place for resilience will not only vary spatially, but also by the habitats of interest. Of the 250 km^2 of vulnerable conserved habitat in the San Francisco Bay Delta, 26% is regularly-flooded estuarine marsh, 17% is freshwater wetlands, and 12% is tidal flat and salt panne. This includes most of the state's highly vulnerable regularly-flooded estuarine marsh, tidal flat and salt panne, and freshwater wetlands, much of which is on conserved land. These three habitats were identified as having more area of *high Vulnerability* than area of *lower Vulnerability* in the San Francisco Bay Delta (Figure 4.1). Managing in place for resilience for these three wetland habitats could include enhancing on-site accretion rates, as well as addressing source sediment supply problems associated with the high degree of urbanization of bay tributaries, high number of dams on the Sacramento and San Joaquin Rivers, and associated water and sediment management. Management of these highly important local habitat patches is not only of state significance, but also involves statewide management decisions and coordination. There are 13 km^2 of vulnerable conserved terrestrial habitats throughout the San Francisco Bay Delta. Managing in place for resilience will also be important for the 3 km^2 of irregularly-flooded estuarine marsh throughout the San Francisco Bay Delta.

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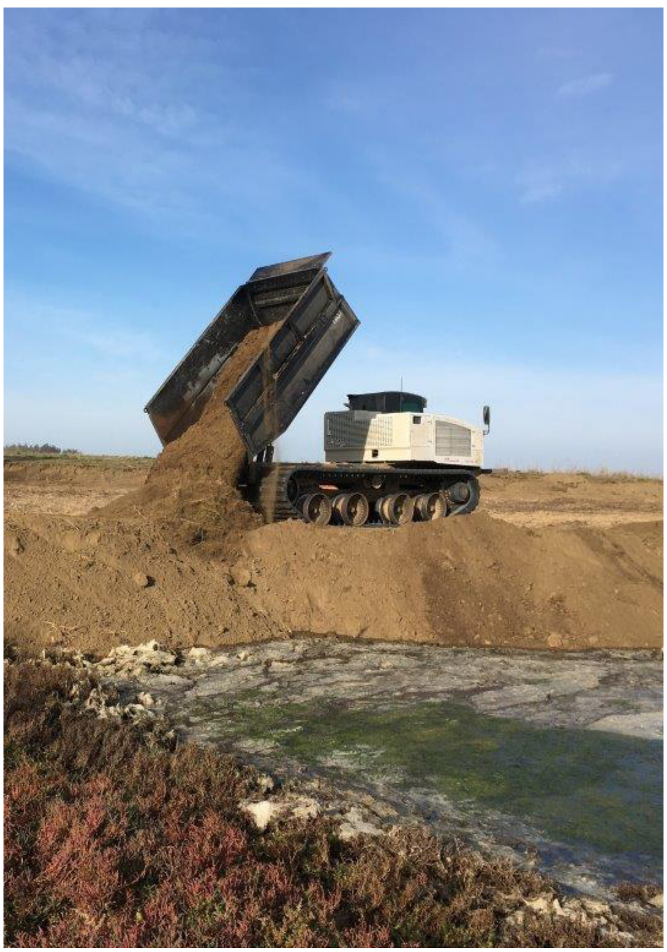
CENTRAL COAST

The Central Coast ecoregion holds 6.4% of the state's vulnerable conserved lands. There are large areas of vulnerable conservation lands along Point Reyes and the Marin headlands (Figure 5.1). There are also large and continuous expanses of vulnerable conservation lands in Morro Bay (Figure 5.1). Of the 19.4 km² of vulnerable conserved habitat throughout the state, 35% is tidal flat and salt panne, 21% is upper beach, and 18% is regularly-flooded estuarine marsh. *High Vulnerability* regularly-flooded estuarine marsh occurs on conservation lands within Tomales Bay, Drakes Estero Marine Conservation Area, Elkhorn Slough National Estuarine Research Reserve, and Morro Bay State Marine Reserve (Figure 5.1). To a large extent, the *Adaptive Capacity* of these well-conserved vulnerable habitats is constrained by topography rather than the built environment. Accordingly, managers should consider measures to increase resilience in place for these regularly-flooded estuarine marshes to ensure the persistence of these important habitats and the species they support in these key areas.



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SOUTH COAST

The South Coast ecoregion contains 16.8 km² of vulnerable conservation lands, accounting for 5.5% of the state's total (Table 5.1). Most of these vulnerable areas are on federal and state managed lands and are aggregated in larger patches throughout the ecoregion (Table 5.1 and Figure 5.1). Of the 16.8 km² of vulnerable conserved habitat in the South Coast, 33% is irregularly-flooded estuarine marsh. This represents approximately 20% of the statewide distribution of irregularly-flooded estuarine marsh (Table 3.1). Thus, managing in place for resilience is an important strategy for irregularly-flooded estuarine marshes, which are an important habitat for the many seasonally closed estuaries in the South Coast. Furthermore, 21% of the 16.8 km² of vulnerable conserved habitat in the South Coast is tidal flat and salt panne, 15% is regularly-flooded estuarine marsh, and 13% is upper beach. Forty-two percent of the state's *high Vulnerability* upper beach is found within the South Coast ecoregion, and only 2.9 km² of this is conserved. Given the *high Vulnerability* of beaches throughout the ecoregion, managing in place for resilience may be needed, yet sediment augmentation, or nourishment, should be considered with caution due to the negative ecological impacts (Speybroeck *et al.* 2006, Schlacher *et al.* 2012, Viola *et al.* 2014). Given the regional scale of vulnerability, managing in place for beach resilience might best be addressed by mitigating the impacts of anthropogenic structures and practices that disrupt sediment supply and transport throughout the region.

© Richard Nye/U.S. Fish and Wildlife Service

AREA OF BUILT ENVIRONMENT LIMITING ADAPTIVE CAPACITY BY ECOREGION

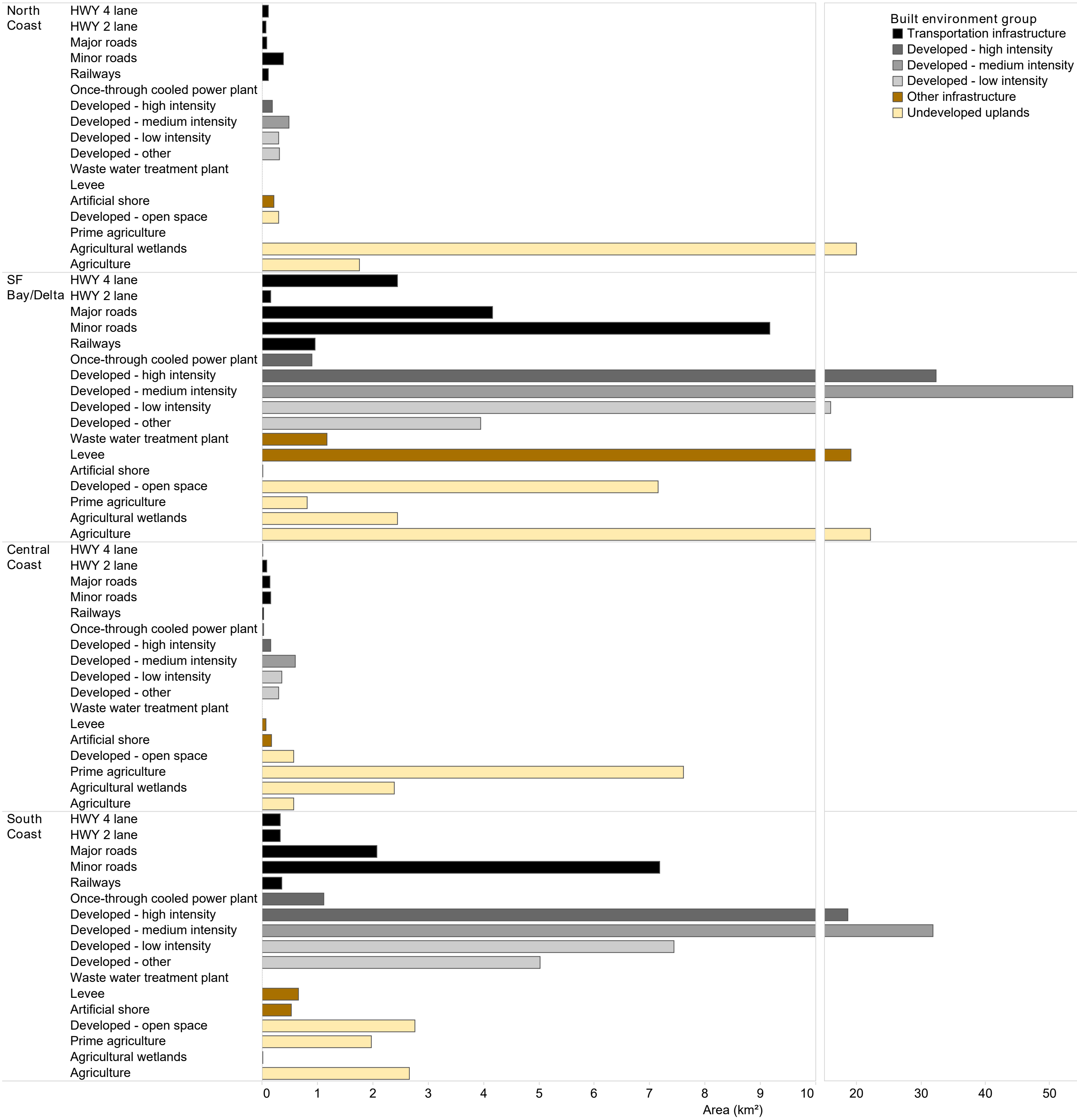


Figure 5.4 Area (km^2) of all 17 built environment categories within the analytic zone in analytic units with high vulnerability index scores (note change in scale of x-axis after break).

5.4 Conserve Potential Future Habitat Areas

It will be critical to conserve, restore, and manage the areas with the potential to become coastal habitat in the future to enable that shoreward transgression of habitats as sea levels rise. Without this important investment, we will be unable to maintain coastal habitat extent and function in the face of sea level rise. Thus, conserving potential future habitat is an important conservation strategy to maintain regional assemblages and extent of coastal habitats throughout each ecoregion (Figure 5.1). With a majority of the area of coastal habitats vulnerable to sea level rise (Figure 4.1), conserving resilient strongholds and managing conserved habitats in place for resilience will not be enough to maintain the current extent of coastal habitats in the face of sea level rise. In order to maintain extent and representation of coastal habitats, we must invest in increasing habitat area to mitigate potential regional habitat losses. Thus, potential future habitat will play an important role in conserving California's coastal habitats in the face of sea level rise.

We define 'undeveloped uplands' as lands with limited or no hard structures, that represent opportunities to restore natural habitats and processes with less effort relative to built landscapes. The types of land use within undeveloped uplands vary by ecoregion (Figure 5.4). For example, developed open space comprises a large portion of undeveloped uplands in the San Francisco Bay Delta and South Coast, whereas in the North Coast and Central Coast, undeveloped uplands are dominated by agriculture (Figure 5.4). The largest extent of undeveloped uplands within the analytic zone of vulnerable analytic units, are within the North Coast and Central Coast (Figure 5.5). Much of what we characterize as undeveloped uplands were established on historic wetlands and coastal habitats, therefore intrinsic site characteristics as well as future conditions with sea level rise will facilitate restoration. In fact, 81 km^2 of agricultural lands within our analytic zone are presently characterized as wetlands by the NWI (termed 'agricultural wetlands' in this assessment), constituting nearly one third of the undeveloped uplands, primarily in the North Coast (Figure 5.4).

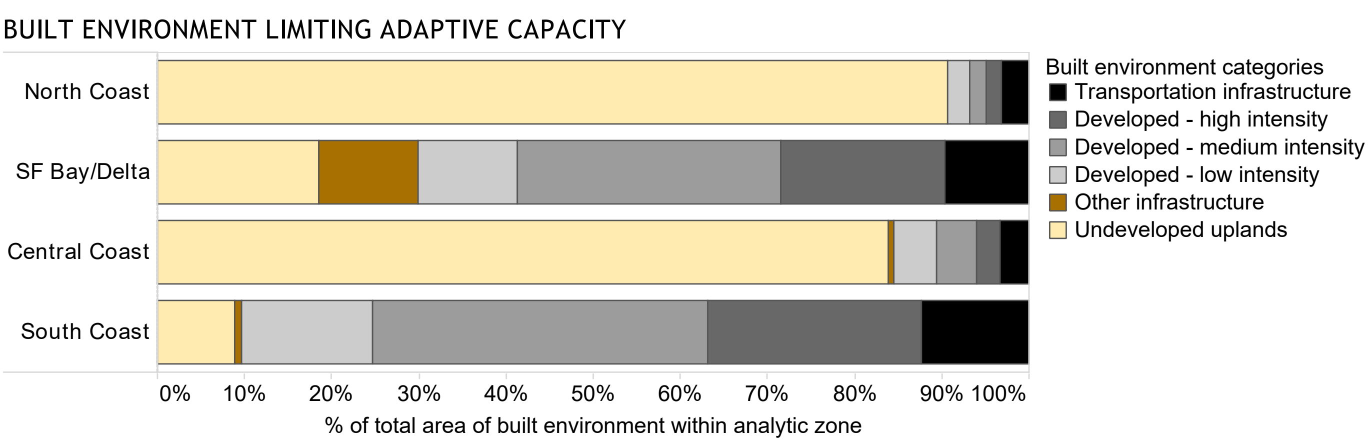


Figure 5.5 Relative composition of six built environment groups within the analytic zone in analytic units with high vulnerability index scores.

Clockwise from left: © Sylvia Busby; © Yuki Shimazu/Creative Commons; © Walter Heady/The Nature Conservancy

We characterize 'potential future habitats' as that subset of undeveloped uplands and levees that are currently wetlands, are projected to be exposed to sea level rise, and/or are adjacent to vulnerable habitats. These conditions are considered to be indicators of suitability for habitat restoration, as well as future habitat value, and are therefore prioritized under this strategy. It is important to note that the subset of undeveloped uplands that meet the potential future habitat criteria is small relative to the overall extent of undeveloped uplands. However, managing these small proportions of agriculture and developed open space along the coast to become our habitat stock of the future will be critical to maintain the extent and representation of coastal habitats throughout California.

Potential future habitats could provide mitigation for the loss of a wide range of habitat types, depending on regional needs and local conditions. For example, they could provide area for the restoration of estuarine habitats, from mudflat through estuarine marsh, and into the transitional or upland habitats to buffer marshes. Similarly, potential future habitats could provide area for the restoration of marine intertidal habitats—creating habitat for beaches to transgress into, creating habitat for dunes to form or transgress into as beaches evolve landward, or creating wetland and upland habitats landward of dunes. In this regard, potential future habitats could be restored to accommodate changing habitat conditions with climate change and maintain representation of habitat assemblages at regional scales. With 53% of natural habitat areas vulnerable to sea level rise (Figure 4.18, Figure

5.1, and Figure 5.3), it is critical to invest in potential future habitats. The restoration of potential future habitats could be used to mitigate losses to vulnerable habitats nearby (Figure 5.1), and could be further prioritized by the biodiversity value of those vulnerable habitats (Figure 5.6).

NORTH COAST

The North Coast ecoregion holds the largest extent of potential future habitat relative to potential loss of coastal habitat areas (Figure 5.1). The 61 km² of potential future habitat throughout the North Coast ecoregion could be critical to mitigate the potential loss of tidal flat and salt panne, upper beach, and of freshwater wetlands. There are patches of potential future habitat throughout the North Coast ecoregion to mitigate regional potential loss of habitats at local scales (Figure 5.1). There are large aggregations of potential future habitat in the Smith River estuary, Eel River estuary, and Humboldt Bay, which could prove important to maintaining extent and composition of estuarine habitats (Figure 5.1). Much of the potential future habitat within Humboldt Bay is agricultural wetlands, which would require relatively little restoration effort to regain habitat function, value, and extent.

SAN FRANCISCO BAY DELTA

The San Francisco Bay Delta has the highest extent (100.5 km²) of potential future habitat. However, this extent is lower relative to the extent of *high Vulnerability* areas and potential loss of coastal habitats for this region, suggesting that it may be a challenge to maintain the extent of coastal habitats in this ecoregion based on this strategy alone (Figure 5.1). Conserving potential future habitats could prove crucial to maintaining the extent of tidal flat and salt panne, regularly-flooded estuarine marsh, and freshwater wetlands—each calculated as having more area of *high Vulnerability* than area of *lower Vulnerability* within this ecoregion (Figure 4.1). The large amount of potential future habitat in San Pablo Bay could be used to maintain extents of freshwater and estuarine marshes for the region (Figure 5.1). Adapting the vast extent of levees throughout the San Francisco Bay Delta (Figure 5.4) to restore habitat function, value, and extent could significantly contribute to the potential for future estuarine and freshwater wetland habitat for this region, and the services these habitats provide to nature and people.

CENTRAL COAST

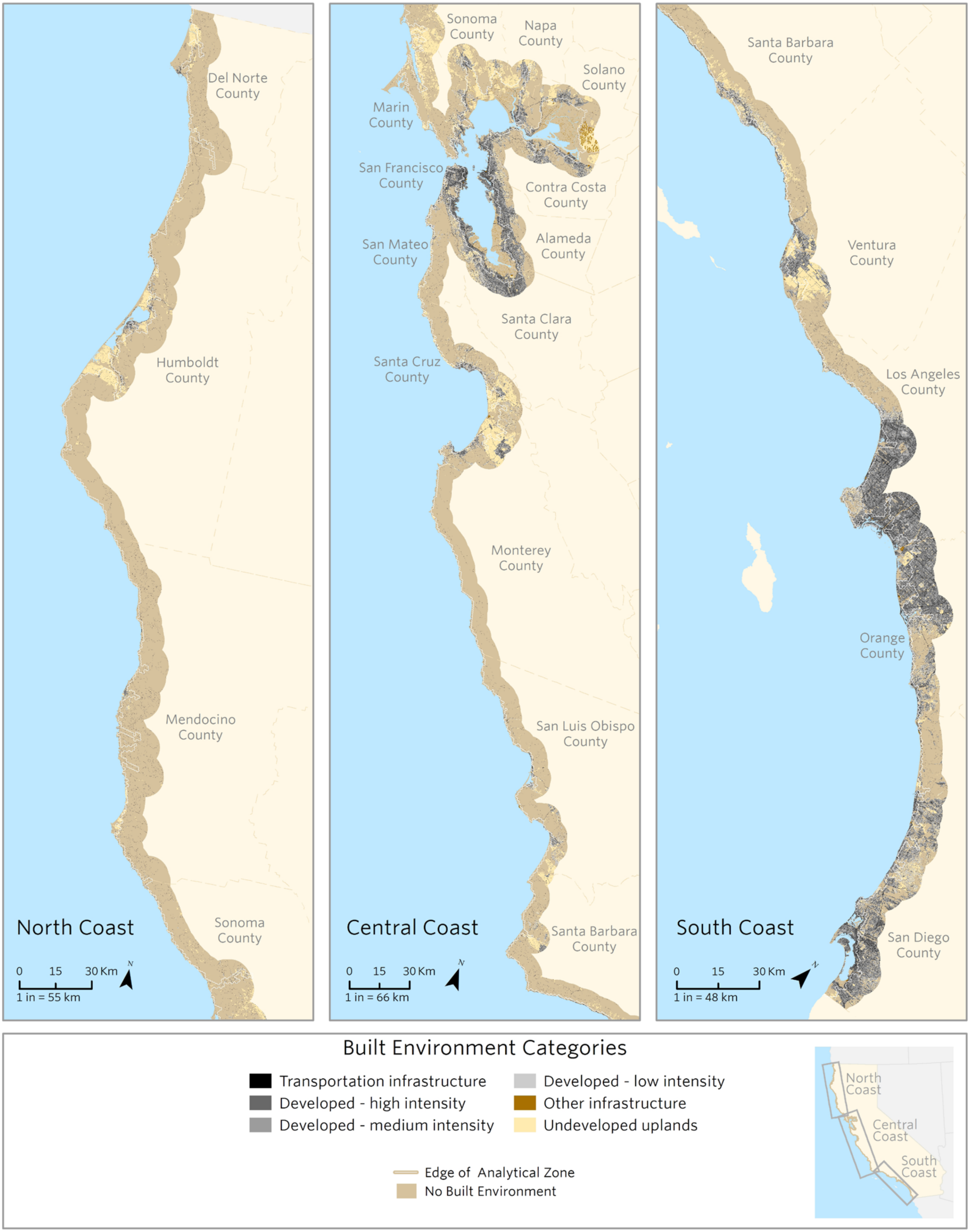
Much of the human alteration of the landscape that reduces *Adaptive Capacity* in the Central Coast ecoregion is classified as agriculture (Figure 5.4). Collectively there are 24 km² of potential future habitat throughout the Central Coast. There are significant patches of potential future habitat to mitigate local potential habitat losses in Tomales Bay and Morro Bay, however, the largest extent exists in the Pajaro River and Salinas River areas surrounding Elkhorn Slough (Figure 5.1). Conserving potential future habitat could prove critical to offsetting the potentially high loss of estuarine habitats (Figure 4.1) constrained by topography in these well conserved landscapes. Similarly, conserving potential future habitat could be indirectly important for the maintenance of the extent of upper beach. For example, conserving potential future habitat inland of the extensive dune networks throughout southern Monterey Bay would allow dunes to transgress inland, providing area for beaches to transgress inland, as well as a reliable source of sand to maintain them (Figure 5.1).

SOUTH COAST

The 13.6 km² of potential future habitat throughout the South Coast ecoregion (Figure 5.1) could provide gains critical to maintaining extent and composition of coastal habitats for the region. This strategy could be applied to restoring potential future upper beach and irregularly-flooded estuarine marsh, both projected to suffer extensive potential loss to sea level rise for the region. Both habitats are also regionally important for a diversity of species and culturally important to humans. However, a significant portion of potential future habitat is classified as prime agriculture (Figure 5.4), and the economic value of these areas are high, posing a challenge to implementing this conservation strategy. Thus, it will be important to minimize the degree of hardening in these potential future habitat areas until conditions become more conducive to conservation, either due to saline intrusion, sea level rise exposure, or socio-political shifts. Potential future habitats are dispersed throughout the South Coast ecoregion, providing the potential to maintain local habitat extent as well as regional assemblages, however a vast majority are aggregated in the Oxnard Plain and Mugu Wetland complex (Figure 5.1).

BUILT ENVIRONMENT CATEGORIES

ECOREGION



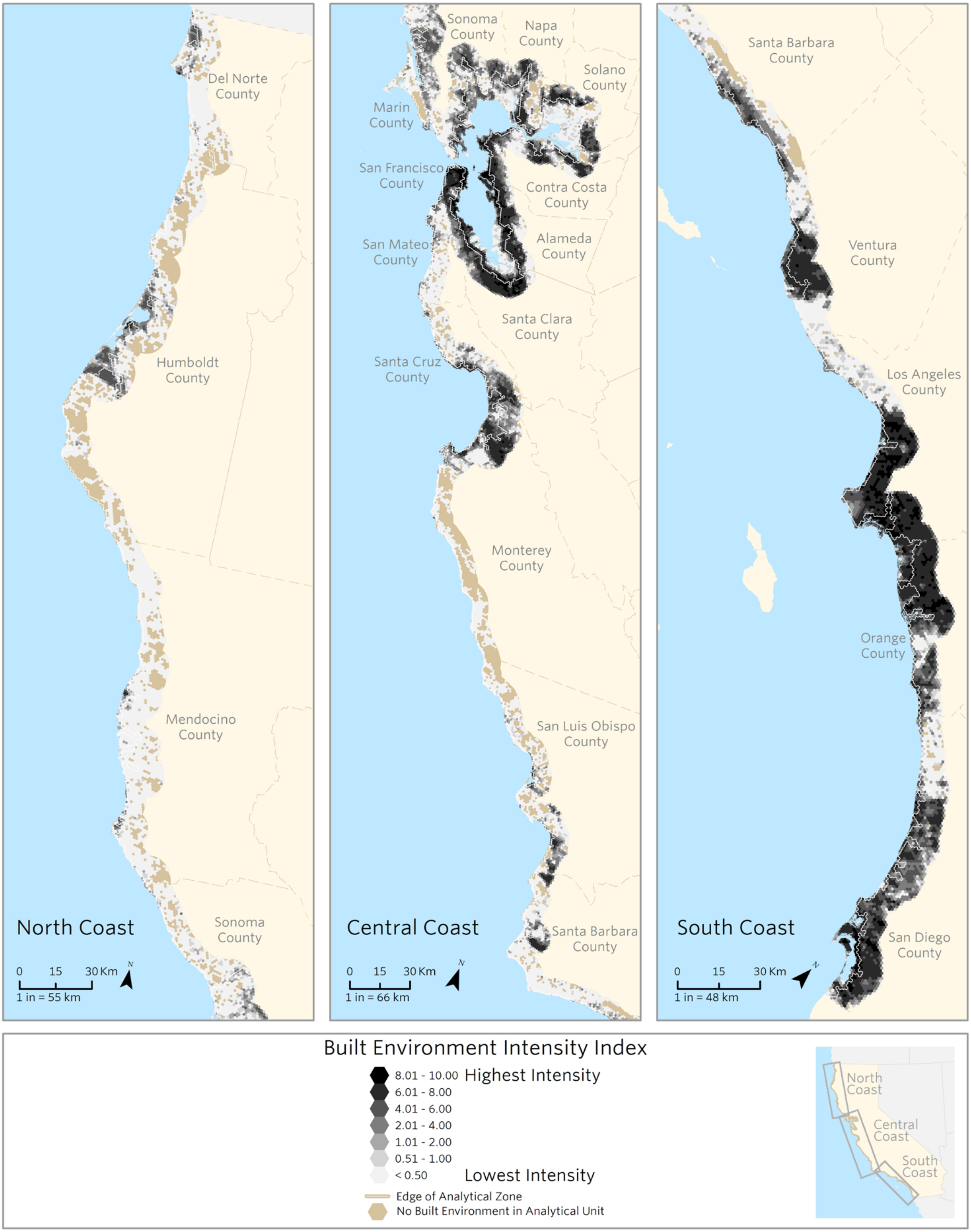
5.5 Increase Adaptive Capacity through Adapting the Built Environment

Often what reduces *Adaptive Capacity* for California's coastal habitats are the many categories of built environment (Figure 5.1, Figure 5.4, Figure 5.5, and Figure 5.7). Much of the built environment itself will be exposed to sea level rise (Table 4.2). Therefore, there are many win-win opportunities throughout California, where adapting vulnerable built environment features will directly benefit coastal habitats by either increasing hydrologic connectivity and function, or enabling direct restoration and habitat enhancement. Investment in such adaptation will yield dividends, both through increased resilience of the built environment, as well as through the protective services provided by coastal habitats. Using coastal habitats as natural infrastructure to protect the built environment provides other co-benefits, such as improving water quality, sequestering carbon, enhancing fisheries, and providing recreation (Barbier *et al.* 2011).

Figure 5.7 Six categories of built environment for the three ecoregions of coastal California.

BUILT ENVIRONMENT INTENSITY INDEX

ECOREGION



The types of built environment within the analytic zone vary among and within ecoregions (Figure 5.4, Figure 5.5, Figure 5.7, and Appendix D). The cost of adapting or retreating built environment features will depend on the type of built feature, as well as local factors such as property values, land use policy, and community values. The *Built Environment Intensity Index* provides an index of relative cost to remove or adapt that built environment category (Table 2.1 and Figure 5.8). The details of what habitats would benefit from adapting the built environment depend on a multitude of local factors, but vulnerable built environment features are often themselves the subjects of adaptation action, and represent an opportunity to increase the resilience of otherwise vulnerable coastal habitats. Here we summarize adaptation for five different categories of built environment: low intensity development, medium intensity development, high intensity development, other infrastructure, and transportation infrastructure (undeveloped uplands are summarized separately in Section 5.3), with examples to highlight the benefits to people and nature from this strategy.

Low intensity and medium intensity development vary in the percent of the area that is composed of impermeable surfaces and thus differ in their landscape development intensity index (Brown and Vivas 2005; Table 2.1) and resulting cost of adaptation. Adaptation opportunities for vulnerable built environment features within these two classes include floodplain buy-outs that serve flood mitigation and habitat enhancement goals simultaneously (Calil and Newkirk 2017). While there are opportunities in all ecoregions, the largest potential conservation gains from adapting low and medium intensity development are within San Francisco Bay Delta and the South Coast ecoregion (Figure 5.4 and Figure 5.5).

At the other end of the development intensity spectrum is high intensity development. This category of built environment is often overlooked in terms of retreat and adaptation because it is considered to be permanent. However, coastal industrial development can not only be highly vulnerable to sea level rise, but also technologically obsolete. Once-through cooled power plants in the coastal zone are an example of this (Melius *et al.* 2017). By state policy, these power plants are required to either change their cooling infrastructure or shut down by year 2024. Furthermore, several once-through cooled power plants no longer significantly contribute to power generation for the state. Two such power plants located on the coast in Ventura County will therefore be shut down, and if removed and restored could contribute dramatically to the extent and function of coastal habitats (Melius *et al.* 2017).

For the purposes of this assessment, other infrastructure includes components such as wastewater treatment plants. By being on the coastline, these critical components are vulnerable to sea level rise impacts. By collecting freshwater from sewers and storm drains and piping this water out to sea, wastewater treatment plants also interrupt the freshwater cycle of coastal ecosystems critical to maintaining coastal habitats. Scientists and managers are considering creative solutions that rethink how wastewater treatment plants treat water. Instead of being piped out to sea, the water could be released through coastal wetlands that could act as 'tertiary treatment plants.' These tertiary treatment wetlands could provide natural infrastructure to protect otherwise vulnerable treatment plants from rising seas and storm damage. There are extensive opportunities to adapt other infrastructure within San Francisco Bay Delta, which could provide extensive conservation gains while providing significant benefits to people (Figure 5.1, Figure 5.4, and Figure 5.5).

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Figure 5.8 Built environment intensity index adapted from Brown and Vivas (2005).

With few exceptions, there is generally some degree of transportation infrastructure within the sea level rise analytic zone along California's coast (Figure 5.7). Transportation infrastructure could obstruct the ability of coastal habitats to transgress inland. Bridges, culverts, or the road itself could impede the natural flow of fresh, estuarine, or marine waters and the important associated physical and ecological functions. Transportation infrastructure provides a unique opportunity, where infrastructure adaptation, rather than retreat, may best provide resilience for both the infrastructure in question, and nature.

An important component of coastal adaptation is the use of natural infrastructure. The dynamic properties of natural habitats can provide resilience to sea level rise and has been shown to be effective at reducing storm damage (Möller *et al.* 2014, Spalding *et al.* 2014, Narayan *et al.* 2016). Prioritizing natural infrastructure along California's coast could thereby provide resilience to rising seas while also effectively enhancing the area and function of coastal habitats. Natural infrastructure overcomes many of the shortcomings of coastal armoring by working with—rather than against—natural coastal processes. Natural infrastructure may include but is not limited to: oyster reefs, seagrass beds, sand dunes, cobble berms, tidal benches, and marsh sills. In addition, these systems provide important co-benefits for coastal communities (Arkema *et al.* 2013). Natural infrastructure can serve as protective buffers against sea level rise and storm events while continuing to provide access, recreation opportunities, wildlife habitat, and other social benefits. Prioritizing natural infrastructure would not only increase the extent and function of coastal habitats throughout California, but also increase public awareness of and appreciation for coastal habitats and the many services they provide, thereby fueling conservation momentum (Morrison 2015).

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6.0 | Conclusion

With rising sea levels and increasing human populations along our coast, there is a pressing need for new conservation and management strategies to conserve California's unique coastal habitats and the high biodiversity they support. Unlike traditional conservation, the threat of climate change requires us to look beyond existing conditions and envision the coast of the future. Yet, we need to adapt our management and conservation practices today to achieve that vision of tomorrow.

A majority of California's coastal habitat area, like beaches, rocky intertidal, and estuarine marshes, are highly vulnerable to sea level rise. This vulnerability puts California's coastal biodiversity at risk and jeopardizes the many services to people we enjoy. Many species are found only within California's coastal habitats and nowhere else in the world, further highlighting the need for conservation, as well as the need to consider sea level rise impacts in the population management of these already imperiled species. Half of California's marine mammal pupping sites along the mainland coast are highly vulnerable, indicating clear risks to these species and potential cascading effects throughout the Pacific Ocean. Our assessment found that one quarter of the conservation management lands within our analytic zone will become subtidal waters—illuminating an urgent need for managers to develop and implement sea level rise management plans. Furthermore, nearly half the extent of the Audubon Important Bird Areas we analyzed was found to have *high Vulnerability*—which not only highlights potential impacts to birds already suffering from climate change impacts along the Pacific Flyway, but also highlights the global significance of conserving California's coast in the face of sea level rise. With this level of vulnerability comes a clear need for strategic conservation actions now and into the future.

Conservation in the face of sea level rise requires an adaptive process that embraces the reality of a dynamic coastline. These habitats need space for coastal processes such as erosion, accretion, transgression, and transition, if they are to survive. This assessment identified opportunities for five conservation and adaptation strategies (Figure 5.1) organized under two larger themes:

Conserve and Manage for Resilience

We need to ensure that our existing conservation lands are maintained and managed for resilience and that we invest in new conservation by investing in the following three strategies:

MAINTAIN EXISTING RESILIENT CONSERVATION LANDS

Approximately half of the habitat area within tracts of conserved lands along the California coast are resilient to sea level rise. Preserving the natural coastal processes and resilient habitats contained within these conservation lands will be important to maintaining the natural character of our coast as well as to maintaining the goods and services that these existing resilient conserved habitats provide to people.

CONSERVE RESILIENT LANDSCAPES

Investing in the conservation of non-conserved resilient habitats could double the area of resilient conservation lands. Conserving large tracts of natural coast in resilient strongholds will provide space for coastal processes to occur, as well as allow habitats and species to adapt and shift with physical and climatic changes. These resilient strongholds can preserve biodiversity and ecological function, and act as a network of well-connected reserves throughout California's coast. The benefits of conserving resilient strongholds will also contribute to the coastal resilience of habitats and human assets at regional scales by preserving natural processes such as erosion, accretion, and littoral sediment transport.

MANAGE IN PLACE FOR RESILIENCE

Some habitats lack both area to transgress into as well as coastal processes such as accretion to keep pace with sea level rise. Managers of these vulnerable habitats can help increase resilience by augmenting sediment supply or adding sediments to allow habitats to keep pace with sea level rise. However, we also need to consider cumulative impacts occurring elsewhere that may be interrupting sediment delivery or coastal processes and address these source problems to improve overall coastal resilience and benefit vulnerable habitats.

Mitigate Potential Losses of Vulnerable Habitats

Some of California's coastal habitats will be lost to sea level rise and we need to mitigate those potential losses. Two strategies will be essential to mitigating potential losses of vulnerable habitats:

CONSERVE AND RESTORE POTENTIAL FUTURE HABITAT AREAS

It is critical to manage the areas that have the potential to become our habitat stock of the future to enable that transition. Without doing so, we will be unable to maintain coastal habitat extent and function in the face of sea level rise. Only a thin strip of coastal agriculture and minimally developed land is necessary to allow this transition, and these lands themselves are projected to become intertidally inundated. Each ecoregion has substantial opportunities to invest in potential future habitat, collectively representing close to 200 km^2 statewide that could be restored to mitigate potential habitat losses to sea level rise.

ADAPT THE BUILT ENVIRONMENT

One of the most serious impediments to long-term habitat resilience is the built environment. We need to simultaneously protect human community assets and enhance the extent and resilience of coastal habitats by managing our infrastructure with natural processes in mind. For example, adapting the small proportion of vulnerable transportation infrastructure could provide dividends of resilience to the state's roadways and coastal habitats. Using coastal habitats as natural infrastructure to protect the built environment provides other co-benefits, such as improving water quality, sequestering carbon, enhancing fisheries, and recreation.

With each of these strategies, coastal practitioners, scientists, and decision makers need to embrace an adaptive framework to decision making and management of coastal resources—one that does not constrain future adaptation options and actively evaluates and responds to changing conditions.

Implementing these five sea level rise adaption and conservation strategies will be challenging and require difficult decisions. We ought to balance the conservation of habitat with preserving our legacy of coastal agricultural food production. In addition, we should balance the protection of vulnerable human infrastructure with the recognition that we cannot defend certain assets in-place forever, and that protecting built assets with hard armoring can reduce habitat function and the benefits that habitats provide. We need to research, demonstrate, and fund the deployment of natural infrastructure along California's diverse coastline and work with uncommon partners across geographies to address source impacts in watersheds and coastlines that reduce the resilience of coastal habitats and processes. We must also strategically communicate about the extraordinary benefits—economic, cultural, and ecological—that coastal habitats provide to nature and people, to spur the required investment in each of the five conservation and adaption strategies described.

The results of this spatially explicit assessment provide a foundation of information to support immediate action to conserve habitats and biodiversity in the face of sea level rise. However, additional research, data collection, monitoring, and focal investigations are essential to further advance our understanding of how our coast, its habitats, and species will respond to sea level rise. We identified a need to increase the extent, resolution, and frequency of updating spatial data for coastal habitats, armoring, levees, and the built environment to keep pace with a changing coast and to better inform management decisions. In addition, regional or local assessments benefit from locally-collected information and knowledge, providing much needed site-level detail that can be used to enhance the regional level patterns highlighted in this assessment. We encourage linking results of this statewide effort to more localized assessments. Furthermore, the alignment of results from assessments using different methods and/or conducted at different scales will emphasize the importance of these findings, and a clear need for action.

With so much of California's coastal habitats, imperiled species, and managed lands at risk from sea level rise, immediate collective action is necessary to conserve these natural resources into the future. The decisions made now by state legislators, land managers, regional planners, and local communities will establish the direction we take in our sea level rise response—these day-to-day choices could move us toward long-term conservation of California's habitats and biodiversity in the face of sea level rise, or away from it. Only a concerted, sustained initiative—guided by the science foundation presented by this effort and others like it—will support the legacy of conservation along California's magnificent coast and ensure that future generations can enjoy and benefit from the same biodiversity, ecosystems services, and natural character as we do.

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Appendices

APPENDIX A: LIST OF DATA SOURCES

	Description	Source	Type
Sea Level Rise	Tidal inundation (2 and 5 feet)	NOAA Digital Coast	Polygon
Land Cover	Shore Armoring	California Coastal Commission	Line
	Coastal Structures	UCSC	Polygon
	Land Cover: Developed; Agriculture; Natural	CALVEG, ReGAP, NLCD	Polygon
	Ownership / Management Status	CPAD, CCED, USFS, BLM, TNC	Polygon
	Infrastructure: Roads	Esri	Line
	Infrastructure: Once-through cooled power-plants; Developed areas	TNC	Point, Line, Polygon
Habitats and Species	Upland dominant vegetation habitat classes	CALVEG, TNC	Polygon
	Wetland habitat classes	NWI, TNC	Polygon
	Dune habitats	CALVEG, ReGAP, CNDDB, TNC	Polygon
	Designated critical habitat for threatened and endangered species	USFWS for T&E species	Line, Polygon
	Marine Mammal: Haul-outs and rookeries	CDFW BIOS, NOAA, TNC	Point
	Seabird: Rookeries, nesting, feeding, resting	CDFW BIOS, CNDDB	Point
	Important Bird Areas	Audubon	Point, Polygon
	Endangered, Threatened, and Rare Species	CNDDB (1-2)	Polygon
Coastal Access	Coastal access and recreation opportunities	California Coastal Commission	Point

** All data are statewide in extent with exception of CALVEG which is absent for San Luis Obispo County, for which we used ReGAP, CNDDB, and other sources previously compiled by TNC (The Nature Conservancy 2006).*

APPENDIX B.1: IMPERILED SPECIES WITHIN STUDY AREA

Taxonomic group	Scientific name	Common name	Observations statewide	Observations within study area	% of observations within study area
Herps	*Rana draytonii*	California red-legged frog	1324	582	44%
Herps	*Ambystoma californiense*	California tiger salamander	960	131	14%
Herps	*Thamnophis gigas*	giant garter snake	255	2	1%
Herps	*Masticophis lateralis euryxanthus*	Alameda whipsnake	125	44	35%
Herps	*Anaxyrus californicus*	arroyo toad	122	9	7%
Herps	*Thamnophis sirtalis tetrataenia*	San Francisco garter snake	33	30	91%
Herps	*Ambystoma macrodactylum croceum*	Santa Cruz long-toed salamander	19	19	100%
Herps	*Chelonia mydas*	green turtle	2	2	100%
Bird	*Polioptila californica californica*	coastal California gnatcatcher	713	209	29%
Bird	*Vireo bellii pusillus*	least Bell's vireo	377	99	26%
Bird	*Riparia riparia*	bank swallow	194	11	6%
Bird	*Laterallus jamaicensis coturniculus*	California black rail	153	67	44%
Bird	*Brachyramphus marmoratus*	marbled murrelet	97	56	58%
Bird	*Rallus longirostris obsoletus*	California clapper rail	69	69	100%
Bird	*Coccyzus americanus occidentalis*	western yellow-billed cuckoo	63	3	5%
Bird	*Empidonax traillii extimus*	southwestern willow flycatcher	63	6	10%
Bird	*Sternula antillarum browni*	California least tern	30	30	100%
Bird	*Charadrius alexandrinus nivosus*	western snowy plover	27	21	78%
Bird	*Rallus longirostris levipes*	light-footed clapper rail	24	24	100%
Invertebrate	*Desmocerus californicus dimorphus*	valley elderberry longhorn beetle	197	5	3%
Invertebrate	*Branchinecta sandiegonensis*	San Diego fairy shrimp	110	56	51%
Invertebrate	*Streptocephalus woottoni*	Riverside fairy shrimp	65	26	40%

Taxonomic group	Scientific name	Common name	Observations statewide	Observations within study area	% of observations within study area
Invertebrate	*Branchinecta conservatio*	Conservancy fairy shrimp	40	11	28%
Invertebrate	*Euphilotes enoptes smithi*	Smith's blue butterfly	33	25	76%
Invertebrate	*Syncaris pacifica*	California freshwater shrimp	17	11	65%
Invertebrate	*Helminthoglypta walkeriana*	Morro shoulderband (=banded dune) snail	14	14	100%
Invertebrate	*Speyeria zerene myrtleae*	Myrtle's silverspot butterfly	11	11	100%
Invertebrate	*Polyphylla barbata*	Mount Hermon (=bar-bate) June beetle	11	11	100%
Invertebrate	*Plebejus icarioides missionensis*	Mission blue butterfly	10	10	100%
Invertebrate	*Euphydryas editha bayensis*	Bay checkerspot butterfly	10	1	10%
Invertebrate	*Cicindela ohlone*	Ohlone tiger beetle	6	6	100%
Invertebrate	*Elaphrus viridis*	Delta green ground beetle	6	6	100%
Invertebrate	*Speyeria callippe callippe*	callippe silverspot butterfly	6	6	100%
Invertebrate	*Euphilotes battoides allyni*	El Segundo blue butterfly	4	4	100%
Invertebrate	*Speyeria zerene hippolyta*	Oregon silverspot butterfly	3	3	100%
Invertebrate	*Callophrys mossii bayensis*	San Bruno elfin butterfly	3	3	100%
Invertebrate	*Trimerotropis infantilis*	Zayante band-winged grasshopper	3	3	100%
Invertebrate	*Glaucopsyche lygdamus palosverdesensis*	Palos Verdes blue butterfly	2	2	100%
Invertebrate	*Apodemia mormo langei*	Lange's metalmark butterfly	1	1	100%
Invertebrate	*Speyeria zerene behrensii*	Behren's silverspot butterfly	1	1	100%
Mammal	*Corynorhinus townsendii*	Corynorhinus townsendii	424	43	10%
Mammal	*Vulpes macrotis mutica*	San Joaquin kit fox	382	4	1%
Mammal	*Pekania pennanti*	Pekania pennanti	360	6	2%
Mammal	*Dipodomys stephensi*	Stephens' kangaroo rat	107	3	3%
Mammal	*Reithrodontomys raviventris*	salt-marsh harvest mouse	86	86	100%
Mammal	*Aplodontia rufa nigra*	Point Arena mountain beaver	35	35	100%

Taxonomic group	Scientific name	Common name	Observations statewide	Observations within study area	% of observations within study area
Mammal	*Martes caurina humboldtensis*	Humboldt marten	18	3	17%
Mammal	*Perognathus longimembris pacificus*	Pacific pocket mouse	7	7	100%
Mammal	*Enhydra lutris nereis*	southern sea otter	2	1	50%
Mammal	*Leptonycteris yerbabuenae*	lesser long-nosed bat	2	1	50%
Vascular Plant	*Lilaeopsis masonii*	Lilaeopsis masonii	183	64	35%
Vascular Plant	*Brodiaea filifolia*	thread-leaved brodiaea	113	67	59%
Vascular Plant	*Gratiola heterosepala*	Boggs Lake hedge-hyssop	78	5	6%
Vascular Plant	*Acanthomintha ilicifolia*	San Diego thorn-mint	58	21	36%
Vascular Plant	*Navarretia fossalis*	spreading navarretia	54	16	30%
Vascular Plant	*Astragalus agnicidus*	Humboldt milk-vetch	52	25	48%
Vascular Plant	*Eryngium aristulatum var. parishii*	San Diego button-celery	52	31	60%
Vascular Plant	*Deinandra increscens ssp. villosa*	Gaviota tarplant	45	45	100%
Vascular Plant	*Deinandra conjugens*	Otay tarplant	37	19	51%
Vascular Plant	*Arctostaphylos glandulosa ssp. crassifolia*	Del Mar manzanita	35	28	80%
Vascular Plant	*Ambrosia pumila*	San Diego ambrosia	34	5	15%
Vascular Plant	*Astragalus brauntonii*	Braunton's milk-vetch	33	6	18%
Vascular Plant	*Limnanthes vinculans*	Limnanthes vinculans	33	1	3%
Vascular Plant	*Chorizanthe pungens var. pungens*	Monterey spineflower	32	31	97%
Vascular Plant	*Pentachaeta lyonii*	Lyon's pentachaeta	32	5	16%
Vascular Plant	*Neostapfia colusana*	Colusa grass	31	4	13%
Vascular Plant	*Orcuttia californica*	California Orcutt grass	28	8	29%
Vascular Plant	*Gilia tenuiflora ssp. arenaria*	Monterey gilia	25	25	100%
Vascular Plant	*Piperia yadonii*	Yadon's rein orchid	25	25	100%
Vascular Plant	*Orcuttia inaequalis*	San Joaquin Valley Orcutt grass	24	1	4%

Taxonomic group	Scientific name	Common name	Observations statewide	Observations within study area	% of observations within study area
Vascular Plant	*Cordylanthus rigidus ssp. littoralis*	seaside bird's-beak	21	19	90%
Vascular Plant	*Hesperolinon congestum*	Marin western flax	21	21	100%
Vascular Plant	*Pleuropogon hooverianus*	North Coast semaphore grass	21	2	10%
Vascular Plant	*Cirsium fontinale var. obispoense*	San Luis Obispo fountain thistle	20	16	80%
Vascular Plant	*Lasthenia conjugens*	Contra Costa goldfields	19	19	100%
Vascular Plant	*Baccharis vanessae*	Encinitas baccharis	19	8	42%
Vascular Plant	*Blennosperma bakeri*	Sonoma sunshine	18	2	11%
Vascular Plant	*Deinandra minthornii*	Deinandra minthornii	18	4	22%
Vascular Plant	*Holocarpha macradenia*	Santa Cruz tarplant	18	18	100%
Vascular Plant	*Chloropyron molle ssp. molle*	soft salty bird's-beak	17	17	100%
Vascular Plant	*Layia carnosa*	beach layia	17	17	100%
Vascular Plant	*Lupinus tidestromii*	Tidestrom's lupine	17	17	100%
Vascular Plant	*Erysimum menziesii*	Menzies' wallflower	16	16	100%
Vascular Plant	*Monardella viminea*	willowy monardella	15	2	13%
Vascular Plant	*Dithyrea maritima*	beach spectaclepod	14	10	71%
Vascular Plant	*Chorizanthe robusta var. robusta*	robust spineflower	14	14	100%
Vascular Plant	*Dudleya cymosa ssp. marcescens*	marcescent dudleya	14	12	86%
Vascular Plant	*Lilium occidentale*	western lily	13	13	100%
Vascular Plant	*Plagiobothrys diffusus*	San Francisco popcornflower	13	13	100%
Vascular Plant	*Suaeda californica*	California seablite	12	12	100%
Vascular Plant	*Trifolium polyodon*	Pacific Grove clover	12	12	100%
Vascular Plant	*Cirsium scariosum var. loncholepis*	La Graciosa thistle	12	10	83%
Vascular Plant	*Clarkia speciosa ssp. immaculata*	Pismo clarkia	12	11	92%
Vascular Plant	*Limnanthes douglasii ssp. sulphurea*	Point Reyes meadowfoam	12	12	100%

Taxonomic group	Scientific name	Common name	Observations statewide	Observations within study area	% of observations within study area
Vascular Plant	*Mimulus fremontii var. vandenbergensis*	Vandenberg monkeyflower	12	9	75%
Vascular Plant	*Blennosperma nanum var. robustum*	Blennosperma nanum var. robustum	11	11	100%
Vascular Plant	*Pogogyne nudiuscula*	Otay Mesa mint	11	3	27%
Vascular Plant	*Chloropyron maritimum ssp. maritimum*	salt marsh bird's-beak	10	10	100%
Vascular Plant	*Sanicula maritima*	Sanicula maritima	10	10	100%
Vascular Plant	*Cirsium rhothophilum*	surf thistle	9	9	100%
Vascular Plant	*Eriogonum crocatum*	conejo buckwheat	9	3	33%
Vascular Plant	*Pogogyne abramsii*	San Diego mesa mint	9	8	89%
Vascular Plant	*Oenothera deltoides ssp. howellii*	Antioch Dunes evening-primrose	8	5	63%
Vascular Plant	*Alopecurus aequalis var. sonomensis*	Sonoma alopecurus	8	7	88%
Vascular Plant	*Arctostaphylos pallida*	pallid manzanita	8	8	100%
Vascular Plant	*Castilleja affinis var. neglecta*	Tiburon paintbrush	8	6	75%
Vascular Plant	*Dudleya verityi*	Verity's dudleya	7	7	100%
Vascular Plant	*Chorizanthe orcuttiana*	Orcutt's spineflower	6	6	100%
Vascular Plant	*Erysimum teretifolium*	Santa Cruz wallflower	6	6	100%
Vascular Plant	*Trifolium trichocalyx*	Monterey clover	6	5	83%
Vascular Plant	*Ceanothus masonii*	Mason's ceanothus	5	5	100%
Vascular Plant	*Chorizanthe pungens var. hartwegiana*	Ben Lomond spineflower	5	4	80%
Vascular Plant	*Dudleya brevifolia*	short-leaved dudleya	5	5	100%
Vascular Plant	*Hazardia orcuttii*	Orcutt's hazardia	5	5	100%
Vascular Plant	*Hesperocyparis abramsiana var. abramsiana*	Santa Cruz cypress	5	4	80%
Vascular Plant	*Cirsium hydrophilum var. hydrophilum*	Suisun thistle	4	4	100%
Vascular Plant	*Chorizanthe howellii*	Howell's spineflower	4	4	100%
Vascular Plant	*Cirsium fontinale var. fontinale*	Crystal Springs fountain thistle	4	4	100%

Taxonomic group	Scientific name	Common name	Observations statewide	Observations within study area	% of observations within study area
Vascular Plant	*Cordylanthus tenuis ssp. capillaris*	Pennell's bird's-beak	4	3	75%
Vascular Plant	*Delphinium bakeri*	Delphinium bakeri	4	2	50%
Vascular Plant	*Delphinium luteum*	golden larkspur	4	4	100%
Vascular Plant	*Dudleya stolonifera*	Laguna Beach dudleya	4	4	100%
Vascular Plant	*Eriodictyon altissimum*	Indian Knob mountainbalm	4	4	100%
Vascular Plant	*Lupinus nipomensis*	Nipomo Mesa lupine	4	4	100%
Vascular Plant	*Arctostaphylos morroensis*	Morro manzanita	3	3	100%
Vascular Plant	*Arenaria paludicola*	marsh sandwort	3	3	100%
Vascular Plant	*Fritillaria roderickii*	Roderick's fritillary	3	1	33%
Vascular Plant	*Trifolium amoenum*	two-fork clover	3	3	100%
Vascular Plant	*Acanthomintha duttonii*	San Mateo thorn-mint	3	3	100%
Vascular Plant	*Amsinckia grandiflora*	large-flowered fiddleneck	3	1	33%
Vascular Plant	*Chorizanthe robusta var. hartwegii*	Scotts Valley spineflower	3	3	100%
Vascular Plant	*Chorizanthe valida*	Sonoma spineflower	3	3	100%
Vascular Plant	*Clarkia franciscana*	Presidio clarkia	3	3	100%
Vascular Plant	*Erysimum capitatum var. angustatum*	Contra Costa wallflower	3	3	100%
Vascular Plant	*Lessingia germanorum*	San Francisco lessingia	3	3	100%
Vascular Plant	*Pedicularis dudleyi*	Pedicularis dudleyi	3	2	67%
Vascular Plant	*Tuctoria mucronata*	Crampton's tuctoria or Solano grass	3	1	33%
Vascular Plant	*Ceanothus maritimus*	Ceanothus maritimus	2	2	100%
Vascular Plant	*Dudleya cymosa ssp. ovatifolia*	Santa Monica dudleya	2	2	100%
Vascular Plant	*Eriophyllum latilobum*	San Mateo woolly sunflower	2	2	100%
Vascular Plant	*Hesperocyparis goveniana*	Gowen cypress	2	2	100%
Vascular Plant	*Polygonum hickmanii*	Scotts Valley polygonum	2	2	100%

Taxonomic group	Scientific name	Common name	Observations statewide	Observations within study area	% of observations within study area
Vascular Plant	*Potentilla hickmanii*	Hickman's cinquefoil	2	2	100%
Vascular Plant	*Rosa minutifolia*	small-leaved rose	2	2	100%
Vascular Plant	*Streptanthus glandulosus ssp. niger*	Tiburon jewelflower	2	2	100%
Vascular Plant	*Verbesina dissita*	big-leaved crownbeard	2	2	100%
Vascular Plant	*Astragalus tener var. titi*	coastal dunes milk-vetch	1	1	100%
Vascular Plant	*Arctostaphylos bakeri ssp. bakeri*	Arctostaphylos bakeri ssp. bakeri	1	1	100%
Vascular Plant	*Arctostaphylos franciscana*	Franciscan manzanita	1	1	100%
Vascular Plant	*Arctostaphylos hookeri ssp. hearstiorum*	Hearsts' manzanita	1	1	100%
Vascular Plant	*Arctostaphylos imbricata*	San Bruno Mountain manzanita	1	1	100%
Vascular Plant	*Arctostaphylos montana ssp. ravenii*	Presidio manzanita	1	1	100%
Vascular Plant	*Arctostaphylos pacifica*	Pacific manzanita	1	1	100%
Vascular Plant	*Astragalus pycnostachyus var. lanosissimus*	Ventura Marsh milk-vetch	1	1	100%
Vascular Plant	*Calochortus tiburonensis*	Tiburon mariposa-lily	1	1	100%
Vascular Plant	*Nasturtium gambelii*	Gambel's water cress	1	1	100%
Vascular Plant	*Ornithostaphylos oppositifolia*	Baja California birdbush	1	1	100%
Vascular Plant	*Pentachaeta bellidiflora*	white-rayed pentachaeta	1	1	100%
Vascular Plant	*Thermopsis macrophylla*	Santa Ynez false lupine	1	1	100%

APPENDIX B.2: IMPORTANT BIRD AREAS WITHIN STUDY AREA

Region	IBA Name (Audubon Top 50 Refugia in bold)	P Criteria[1]	L Criteria[2]	S Criteria[3]	W Criteria[4]	Total Area of IBA (km^2)	Area of IBA within study area (km^2)	% within study area
North Coast	**Bodega Harbor***	no	no	yes	yes	29.7	0.2	1%
North Coast	**Cape Mendocino Grasslands**	no	yes	no	no	893.2	597.7	67%
North Coast	Del Norte Coast	yes	yes	yes	yes	101.7	97.4	96%
North Coast	Humboldt Bay	yes	yes	yes	yes	328.7	274.2	83%
North Coast	Humboldt Lagoons	yes	no	no	yes	280.7	271.3	97%
North Coast	Mendocino Coast	no	yes	no	no	217.2	213.0	98%
SF Bay/Delta	**Alameda Naval Air Station**	yes	no	no	no	4.1	2.4	58%
SF Bay/Delta	Benicia State Recreation Area	yes	yes	no	no	2.4	2.3	94%
SF Bay/Delta	**Brooks Island Regional Preserve**	no	no	no	no	0.9	0.7	71%
SF Bay/Delta	Byron Area	yes	no	no	yes	173.0	1.9	1%
SF Bay/Delta	**Concord Marshes**	yes	yes	no	yes	33.6	31.9	95%
SF Bay/Delta	**Corte Madera Marsh**	yes	no	yes	no	2.9	2.6	90%
SF Bay/Delta	East Diablo Range	no	yes	no	no	2288.3	21.8	1%
SF Bay/Delta	**Eastshore Wetlands**	yes	no	yes	yes	6.4	5.5	86%
SF Bay/Delta	Jepson Grasslands	yes	yes	no	no	171.6	108.0	63%
SF Bay/Delta	North Richmond Wetlands	yes	yes	no	yes	19.4	17.7	91%
SF Bay/Delta	**Richardson Bay**	no	no	no	yes	12.7	2.9	23%
SF Bay/Delta	Sacramento-San Joaquin Delta	yes	no	yes	yes	863.2	60.6	7%
SF Bay/Delta	**San Francisco Bay–South**	yes	yes	yes	yes	282.2	251.6	89%
SF Bay/Delta	San Pablo Bay Wetlands	yes	yes	yes	yes	315.7	288.3	91%

1 P Criteria: Supports over 1% of the global or 10% of the California population of one or more sensitive taxa.
2 L Criteria: Supports more than 9 sensitive species.
3 S Criteria: 10,000 or more observable shorebirds in one day.
4 W Criteria: 5,000 or more observable waterfowl in one day.
* Bodega Harbor is split between the North and Central Coast ecoregions and thus appears twice in this list.

Region	IBA Name (Audubon Top 50 Refugia in bold)	P Criteria[1]	L Criteria[2]	S Criteria[3]	W Criteria[4]	Total Area of IBA (km^2)	Area of IBA within study area (km^2)	% within study area
SF Bay/Delta	Suisun Marsh	yes	yes	yes	yes	267.5	255.6	96%
Central Coast	**Año Nuevo Area**	no	yes	no	no	163.1	125.6	77%
Central Coast	**Big Sur Area**	yes	yes	no	no	159.3	158.2	99%
Central Coast	**Bodega Harbor***	no	no	yes	yes	29.7	10.8	36%
Central Coast	**Bolinas Lagoon**	no	no	yes	yes	4.7	3.3	70%
Central Coast	**Elkhorn Slough**	yes	yes	yes	yes	38.7	36.4	94%
Central Coast	**Morro Bay**	yes	yes	yes	yes	23.5	21.5	92%
Central Coast	Pt. Reyes-Outer	no	no	yes	yes	33.8	20.1	59%
Central Coast	**Salinas River-Lower**	no	yes	no	yes	17.2	16.3	95%
Central Coast	**San Antonio Valley**	no	yes	no	no	781.1	20.5	3%
Central Coast	**Santa Lucia Peaks**	yes	no	no	no	24.4	23.4	96%
Central Coast	**Santa Maria River Valley**	yes	no	no	no	64.2	64.4	100%
Central Coast	**Santa Ynez River Valley**	yes	yes	no	no	20.4	0.7	4%
Central Coast	**Tomales Bay**	yes	no	yes	yes	40.8	15.3	38%
Central Coast	**Vandenberg AFB**	yes	yes	no	no	381.4	321.7	84%
Central Coast	**Carmel River/Point Lobos**	no	yes	no	no	131.1	72.2	55%
South Coast	**Ballona Valley**	yes	no	no	no	5.1	3.5	69%
South Coast	**Camp Pendleton**	yes	yes	no	no	684.0	260.0	38%
South Coast	**Goleta Coast**	yes	no	no	no	8.3	8.1	97%
South Coast	**Lake Casitas Area**	no	yes	no	yes	38.3	13.9	36%
South Coast	**Lower Los Angeles River**	no	no	yes	no	3.0	1.6	52%
South Coast	**Mission Bay**	yes	yes	no	yes	12.0	4.7	39%
South Coast	**North San Diego Lagoons**	yes	yes	no	no	19.0	16.5	87%
South Coast	**Orange Coast Wetlands**	yes	yes	yes	yes	32.4	29.0	90%

Region	IBA Name (Audubon Top 50 Refugia in bold)	P Criteria[1]	L Criteria[2]	S Criteria[3]	W Criteria[4]	Total Area of IBA (km^2)	Area of IBA within study area (km^2)	% within study area
South Coast	**Pt. Mugu Area**	yes	yes	yes	yes	20.2	18.8	93%
South Coast	**San Diego Bay**	yes	yes	yes	yes	32.7	13.5	41%
South Coast	**San Diego NWR-East**	yes	yes	no	no	31.0	0.5	2%
South Coast	**San Joaquin Hills**	yes	yes	no	no	78.8	74.5	94%
South Coast	**San Pasqual Valley**	yes	yes	no	yes	45.3	1.2	3%
South Coast	**Santa Clara River Valley**	yes	yes	no	no	137.6	10.3	7%
South Coast	**Santa Ynez River-Upper**	yes	yes	no	yes	705.0	26.1	4%
South Coast	**Southern Orange County**	yes	yes	no	no	217.1	19.6	9%
South Coast	**Terminal Island Tern Colony**	yes	no	no	no	0.1	0.1	100%
South Coast	**Tijuana River Reserve**	yes	yes	no	no	11.6	11.3	97%

APPENDIX C.1: AREA OF FOCAL HABITAT AND SEA LEVEL RISE INUNDATION. Area reported in units of km^2.

Region	Habitat type	Area in analytic zone 5ft SLR[1]	Subtidal area			Intertidal area			Non-tidal area		
			Current conditions	2ft SLR	5ft SLR	Current conditions	2ft SLR	5ft SLR	Current conditions	2ft SLR	5ft SLR
North Coast	*Irregularly-flooded Estuarine Marsh*	3.3	0.0	0.0	0.1	0.4	1.2	2.4	2.9	2.0	0.7
	Regularly-flooded Estuarine Marsh	7.4	0.0	0.0	0.5	1.9	6.4	6.8	5.4	0.9	0.2
	Rocky Intertidal	4.9	0.0	1.0	2.7	3.2	2.7	1.8	1.7	1.2	0.5
	Swash Beach	8.9	0.0	1.7	6.5	8.9	7.1	2.4	0.0	0.0	0.0
	Terrestrial	12.5	0.0	0.0	0.2	0.4	0.8	4.1	12.2	11.6	8.2
	Tidal Flat and Salt Panne	53.6	0.0	12.2	34.0	35.4	24.8	13.2	18.2	16.6	6.4
	Upper Beach	12.1	0.0	0.0	0.0	0.0	2.4	6.8	12.1	9.7	5.3
	Freshwater Wetlands	36.9	0.0	0.0	1.7	3.5	7.5	21.0	33.4	29.3	14.3
SF Bay/ Delta	*Irregularly-flooded Estuarine Marsh*	13.6	0.0	0.0	4.3	5.7	9.9	8.2	7.9	3.7	1.1
	Regularly-flooded Estuarine Marsh	165.1	0.0	1.8	19.3	50.7	155.5	145.2	114.4	7.7	0.5
	Rocky Intertidal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Swash Beach	0.2	0.0	0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.0
	Terrestrial	74.7	0.0	0.1	8.2	13.5	41.2	48.6	61.2	33.4	17.9
	Tidal Flat and Salt Panne	114.1	0.0	64.9	101.1	106.6	47.2	12.9	7.5	2.0	0.1
	Upper Beach	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0
	Freshwater Wetlands	191.3	0.0	4.6	80.8	125.5	173.4	105.0	65.8	13.3	5.5

1 The analytic zone is the area between current mean lower low water and a contour line drawn at an elevation twice that of projected sea level rise. See Section 2.1.

Region	Habitat type	Area in analytic zone 5ft SLR[1]	Subtidal area			Intertidal area			Non-tidal area		
			Current conditions	2ft SLR	5ft SLR	Current conditions	2ft SLR	5ft SLR	Current conditions	2ft SLR	5ft SLR
Central Coast	*Irregularly-flooded Estuarine Marsh*	5.3	0.0	0.0	0.2	0.6	2.1	4.0	4.7	3.2	1.1
	Regularly-flooded Estuarine Marsh	11.2	0.0	0.6	5.2	7.7	9.4	5.3	3.6	1.3	0.7
	Rocky Intertidal	5.6	0.0	1.7	3.5	3.9	2.7	1.6	1.8	1.2	0.5
	Swash Beach	11.4	0.0	4.2	9.9	11.4	7.2	1.5	0.0	0.0	0.0
	Terrestrial	12.5	0.0	0.2	0.7	1.1	1.9	5.2	11.5	10.4	6.6
	Tidal Flat and Salt Panne	21.9	0.0	7.6	16.7	17.1	11.3	4.1	4.7	3.0	1.0
	Upper Beach	12.6	0.0	0.0	0.1	0.0	3.0	7.6	12.6	9.7	4.9
	Freshwater wetlands	15.5	0.0	0.0	0.2	0.7	2.6	8.2	14.8	12.8	7.1
South Coast	*Irregularly-flooded Estuarine Marsh*	13.2	0.0	0.0	0.8	1.7	6.2	10.9	11.5	7.0	1.5
	Regularly-flooded Estuarine Marsh	8.2	0.0	0.1	3.2	4.2	6.8	4.7	4.0	1.3	0.2
	Rocky Intertidal	0.5	0.0	0.1	0.3	0.3	0.3	0.2	0.2	0.1	0.1
	Swash Beach	9.6	0.0	3.4	9.3	9.6	6.2	0.3	0.0	0.0	0.0
	Terrestrial	10.7	0.0	0.0	0.2	0.2	0.5	3.7	10.5	10.3	6.9
	Tidal Flat and Salt Panne	19.5	0.0	3.8	9.9	10.3	9.0	6.5	9.3	6.7	3.1
	Upper Beach	17.3	0.0	0.0	0.1	0.0	2.3	6.9	17.3	15.0	10.4
	Freshwater wetlands	19.0	0.0	0.0	0.4	0.5	1.3	9.8	18.5	17.7	8.8
State total	*Irregularly-flooded Estuarine Marsh*	35.5	0.0	0.1	5.5	8.4	19.4	25.6	27.0	16.0	4.4
	Regularly-flooded Estuarine Marsh	191.8	0.0	2.5	28.2	64.5	178.1	162.0	127.4	11.2	1.7
	Rocky Intertidal	11.1	0.0	2.8	6.5	7.4	5.7	3.5	3.7	2.5	1.1
State total	*Swash Beach*	30.0	0.0	9.4	25.8	30.0	20.6	4.2	0.0	0.0	0.0
	Terrestrial	110.5	0.0	0.3	9.4	15.1	44.5	61.6	95.4	65.8	39.6
	Tidal Flat and Salt Panne	209.1	0.0	88.5	161.7	169.4	92.3	36.8	39.7	28.3	10.6
	Upper Beach	42.2	0.0	0.0	0.2	0.0	7.7	21.4	42.2	34.5	20.6
	Freshwater wetlands	262.7	0.0	4.6	83.1	130.2	184.9	143.9	132.5	73.2	35.7

APPENDIX C.2: HABITAT SPECIFIC VULNERABILITY. Area reported in units of km².

Habitat type	STATEWIDE					
	Area in study area	Area in analytic zone 5ft SLR[1]	Resilient Area	Vulnerable Area	Count of AUs[2] with Resilient Habitat	Count of AUs[3] with Vulnerable Habitat
Alkaline Marsh	0.32	0.18	0.16	0.02	71	6
Annual Grassland	2839.82	79.86	42.39	37.47	1677	540
Aquatic Bed	0.34	0.31	0.15	0.16	29	8
Artificial Salt Pond	110.28	109.65	6.35	103.30	91	209
Barren	47.37	12.41	8.22	4.19	805	254
Chaparral	1186.56	2.32	1.97	0.35	294	47
Coastal Conifer Forest and Woodlands	3889.76	0.61	0.51	0.10	167	14
Coastal Dune	54.88	3.73	2.77	0.96	413	92
Coastal Prairie	0.76	0.08	0.08	0.00	13	0
Coastal Scrub	1333.22	4.26	3.46	0.80	807	79
Estuarine forested/shrub wetland	1.07	0.83	0.81	0.02	59	3
Freshwater Marsh	27.97	17.18	11.94	5.24	713	111
Inland Shore	20.52	16.38	12.82	3.56	230	12
Invertebrate reef	0.46	0.46	0.03	0.43	4	11
Irregularly-flooded Estuarine Marsh	38.51	35.48	21.53	13.95	1219	219
Lakes / Ponds	157.94	81.52	39.06	42.46	1403	682
Mixed Evergreen Forests and Woodlands	1076.67	1.52	1.48	0.05	236	13
Oak Forests and Woodlands	848.24	0.95	0.85	0.10	267	16
Other	0.63	0.60	0.40	0.20	252	57
Perennial Grassland	78.31	2.78	1.91	0.86	217	25
Rare Chaparral	43.24	0.05	0.05	0.00	12	0

1 The analytic zone is the area between current mean lower low water and a contour line drawn at an elevation twice that of projected sea level rise. See Section 2.1.
2 AU = Analytic Unit
3 AU = Analytic Unit

Habitat type	STATEWIDE					
	Area in study area	Area in analytic zone 5ft SLR[1]	Resilient Area	Vulnerable Area	Count of AUs[2] with Resilient Habitat	Count of AUs[3] with Vulnerable Habitat
Rare Coastal Conifer Forest and Woodlands	218.36	0.42	0.37	0.06	157	19
Rare Coastal Scrub	16.68	0.47	0.27	0.21	134	43
Rare Mixed Evergreen Forests and Woodlands	104.67	0.01	0.01	0.00	16	0
Rare Oak Forests and Woodlands	18.18	0.07	0.06	0.01	12	1
Rare Riparian Forest and Shrub	0.13		0.00	0.00	0	0
Rare Serpentine systems	46.89		0.00	0.00	0	0
Rare Vegetated Dune	55.35	0.37	0.33	0.04	84	8
Regularly-flooded Estuarine Marsh	203.57	191.85	80.14	111.71	1065	413
Riparian Forest and Shrub	433.19	25.99	20.28	5.70	1264	98
Riverine	208.23	24.97	15.69	9.28	2345	482
Rocky Intertidal	13.83	11.07	4.60	6.47	745	356
Seasonal Freshwater Marsh	258.03	194.08	71.86	122.22	1313	302
Swash Beach	29.99	29.99	23.99	6.01	1689	293
Tidal Channel	9.45	9.38	9.27	0.11	930	13
Tidal Flat and Salt Panne	238.44	209.06	93.71	115.35	1743	625
Tidal Freshwater Forested/Shrub	3.71	2.63	2.18	0.45	165	10
Tidal Freshwater Marsh	7.50	6.42	4.90	1.52	178	16
Upper Beach	62.12	42.23	16.91	25.32	1033	917
Vernal Pool	0.22		0.00	0.00	0	0

APPENDIX C.3: IMPORTANT BIRD AREAS, SEA LEVEL RISE INUNDATION, AND VULNERABILITY. All area reported in units of km^2.

Region	IBA Name	IBA total area	Area of IBA in study area	Area Inundated 2ft SLR	Area inundated 5ft SLR	Area lower vulnerability 5ft SLR	Area higher vulnerability 5ft SLR	Count of AUs[1] w/lower vulnerability	Count of AUs w/higher vulnerability	Count of AUs outside analytic zone 5ft SLR[2]
North Coast	Bodega Harbor*	29.7	0.2	0.0	0.1	7.2	3.7	28	15	2
North Coast	Cape Mendocino Grasslands	893.2	597.7	0.9	2.6	35.3	33.3	67	65	604
North Coast	Del Norte Coast	101.7	97.4	0.7	21.0	59.0	15.3	73	34	39
North Coast	Humboldt Bay	328.7	274.2	47.7	102.6	127.3	81.1	188	134	90
North Coast	Humboldt Lagoons	280.7	271.3	0.3	1.2	27.8	9.9	35	24	261
North Coast	Mendocino Coast	217.2	213.0	1.0	3.2	66.3	11.8	87	30	163
SF Bay/Delta	Alameda Naval Air Station	4.1	2.4	0.1	1.2	0.0	0.0	0	1	0
SF Bay/Delta	Benicia State Recreation Area	2.4	2.3	0.9	1.2	0.8	1.5	2	5	1
SF Bay/Delta	Brooks Island Regional Preserve	0.9	0.7	0.3	0.5	0.0	0.7	0	5	0
SF Bay/Delta	Byron Area	173.0	1.9	0.0	0.0	0.0	0.0	0	0	7
SF Bay/Delta	Concord Marshes	33.6	31.9	19.5	25.8	13.0	18.9	41	50	0
SF Bay/Delta	Corte Madera Marsh	2.9	2.6	1.9	2.4	0.7	1.9	2	6	0
SF Bay/Delta	East Diablo Range	2288.3	21.8	0.0	0.0	0.0	0.0	0	0	38
SF Bay/Delta	Eastshore Wetlands	6.4	5.5	2.1	3.5	1.8	3.7	8	21	0
SF Bay/Delta	Jepson Grasslands	171.6	108.0	0.1	0.8	7.0	4.2	13	7	122
SF Bay/Delta	North Richmond Wetlands	19.4	17.7	7.1	9.6	8.3	8.6	17	30	2
SF Bay/Delta	Richardson Bay	12.7	2.9	1.6	2.3	0.4	2.5	2	22	0
SF Bay/Delta	Sacramento-San Joaquin Delta	863.2	60.6	0.0	0.5	0.4	3.2	1	9	72
SF Bay/Delta	San Francisco Bay-South	282.2	251.6	152.8	199.6	89.1	161.0	149	243	0
SF Bay/Delta	San Pablo Bay Wetlands	315.7	288.3	185.4	248.8	140.4	147.7	219	215	3
SF Bay/Delta	Suisun Marsh	267.5	255.6	61.5	195.3	88.1	167.6	145	225	0

1 AU = Analytic Unit
2 IBAs are often large and extend inland beyond our analytic zone. This column shows the number of Analytic Units of the portion of the IBA within our study area but beyond potential impact from sea level rise.
* Bodega Harbor is split between the North and Central Coast ecoregions and thus appears twice in this list.

Region	IBA Name	IBA total area	Area of IBA in study area	Area Inundated 2ft SLR	Area inundated 5ft SLR	Area lower vulnerability 5ft SLR	Area higher vulnerability 5ft SLR	Count of AUs[1] w/lower vulnerability	Count of AUs w/higher vulnerability	Count of AUs outside analytic zone 5ft SLR[2]
Central Coast	Ano Nuevo Area	163.1	125.6	0.3	0.7	6.1	3.7	11	9	140
Central Coast	Big Sur Area	159.3	158.2	0.3	0.8	18.1	11.3	32	25	163
Central Coast	Bodega Harbor*	29.7	10.8	1.0	2.7	7.2	3.7	28	15	2
Central Coast	Bolinas Lagoon	4.7	3.3	0.5	2.8	1.3	2.0	9	6	0
Central Coast	Elkhorn Slough	38.7	36.4	5.2	14.9	27.3	4.6	52	9	13
Central Coast	Morro Bay	23.5	21.5	4.9	7.9	8.1	8.5	23	18	13
Central Coast	Pt. Reyes-Outer	33.8	20.1	2.3	6.4	6.7	11.5	40	55	10
Central Coast	Salinas River-Lower	17.2	16.3	0.4	1.8	9.9	2.0	25	8	15
Central Coast	San Antonio Valley	781.1	20.5	0.0	0.0	0.0	0.0	0	0	36
Central Coast	Santa Lucia Peaks	24.4	23.4	0.0	0.0	0.0	0.0	0	0	52
Central Coast	Santa Maria River Valley	64.2	64.4	0.1	0.4	5.4	7.3	8	17	73
Central Coast	Santa Ynez River Valley	20.4	0.7	0.0	0.0	0.0	0.0	0	0	4
Central Coast	Tomales Bay	40.8	15.3	3.3	7.5	7.8	6.8	40	34	5
Central Coast	Vandenberg AFB	381.4	321.7	0.7	1.6	26.0	19.8	44	37	353
Central Coast	Carmel River/Point Lobos	131.1	72.2	0.1	0.5	4.8	0.1	10	3	92
South Coast	Ballona Valley	5.1	3.5	0.5	1.3	3.0	0.4	11	6	2
South Coast	Camp Pendleton	684.0	260.0	0.8	3.0	22.5	4.1	41	11	285
South Coast	Goleta Coast	8.3	8.1	0.4	1.5	5.0	1.6	17	6	19
South Coast	Lake Casitas Area	38.3	13.9	0.0	0.0	0.0	0.0	0	0	25
South Coast	Lower Los Angeles River	3.0	1.6	0.1	0.2	0.3	0.1	7	7	13
South Coast	Mission Bay	12.0	4.7	1.0	2.5	2.2	2.5	11	18	0
South Coast	North San Diego Lagoons	19.0	16.5	2.4	6.2	12.6	1.9	45	9	20
South Coast	Orange Coast Wetlands	32.4	29.0	3.5	13.6	20.3	6.4	48	27	15

APPENDIX C.4: IMPERILED SPECIES AND SEA LEVEL RISE INUNDATION

Taxon	Scientific name	Common name	# Occurrences Statewide	# In Study Area	# In 2ft SLR Zone	% in 2ft SLR zone	# in 5ft SLR Zone	% in 5ft SLR Zone
Herps	*Rana draytonii*	California red-legged frog	1324	582	59	4%	90	7%
Herps	*Ambystoma californiense*	California tiger salamander	960	131	4	0%	5	1%
Herps	*Thamnophis gigas*	giant garter snake	255	2	1	0%	1	0%
Herps	*Masticophis lateralis euryxanthus*	Alameda whipsnake	125	44	0	0%	0	0%
Herps	*Anaxyrus californicus*	arroyo toad	122	9	0	0%	0	0%
Herps	*Thamnophis sirtalis tetrataenia*	San Francisco garter snake	33	30	2	6%	2	6%
Herps	*Ambystoma macrodactylum croceum*	Santa Cruz long-toed salamander	19	19	0	0%	2	11%
Herps	*Chelonia mydas*	green turtle	2	2	2	100%	2	100%
Bird	*Polioptila californica californica*	coastal California gnatcatcher	713	209	20	3%	24	3%
Bird	*Vireo bellii pusillus*	least Bell's vireo	377	99	7	2%	16	4%
Bird	*Riparia riparia*	bank swallow	194	11	9	5%	9	5%
Bird	*Laterallus jamaicensis coturniculus*	California black rail	153	67	62	41%	63	41%
Bird	*Brachyramphus marmoratus*	marbled murrelet	97	56	2	2%	2	2%
Bird	*Rallus longirostris obsoletus*	California clapper rail	69	69	69	100%	69	100%
Bird	*Coccyzus americanus occidentalis*	western yellow-billed cuckoo	63	3	1	2%	1	2%
Bird	*Empidonax traillii extimus*	southwestern willow flycatcher	63	6	0	0%	1	2%
Bird	*Sternula antillarum browni*	California least tern	30	30	25	83%	27	90%
Bird	*Charadrius alexandrinus nivosus*	western snowy plover	27	21	19	70%	20	74%
Bird	*Rallus longirostris levipes*	light-footed clapper rail	24	24	20	83%	20	83%
Invertebrate	*Desmocerus californicus dimorphus*	valley elderberry longhorn beetle	197	5	1	1%	1	1%
Invertebrate	*Branchinecta sandiegonensis*	San Diego fairy shrimp	110	56	1	1%	2	2%
Invertebrate	*Streptocephalus woottoni*	Riverside fairy shrimp	65	26	0	0%	0	0%

Taxon	Scientific name	Common name	# Occurrences Statewide	# In Study Area	# In 2ft SLR Zone	% in 2ft SLR zone	# in 5ft SLR Zone	% in 5ft SLR Zone
Invertebrate	*Branchinecta conservatio*	Conservancy fairy shrimp	40	11	2	5%	2	5%
Invertebrate	*Euphilotes enoptes smithi*	Smith's blue butterfly	33	25	3	9%	3	9%
Invertebrate	*Syncaris pacifica*	California freshwater shrimp	17	11	0	0%	3	18%
Invertebrate	*Helminthoglypta walkeriana*	Morro shoulderband (=banded dune) snail	14	14	6	43%	7	50%
Invertebrate	*Speyeria zerene myrtleae*	Myrtle's silverspot butterfly	11	11	8	73%	8	73%
Invertebrate	*Polyphylla barbata*	Mount Hermon (=barbate) June beetle	11	11	0	0%	0	0%
Invertebrate	*Plebejus icarioides missionensis*	Mission blue butterfly	10	10	1	10%	1	10%
Invertebrate	*Euphydryas editha bayensis*	Bay checkerspot butterfly	10	1	0	0%	0	0%
Invertebrate	*Cicindela ohlone*	Ohlone tiger beetle	6	6	0	0%	0	0%
Invertebrate	*Elaphrus viridis*	Delta green ground beetle	6	6	0	0%	0	0%
Invertebrate	*Speyeria callippe callippe*	callippe silverspot butterfly	6	6	0	0%	0	0%
Invertebrate	*Euphilotes battoides allyni*	El Segundo blue butterfly	4	4	2	50%	2	50%
Invertebrate	*Speyeria zerene hippolyta*	Oregon silverspot butterfly	3	3	1	33%	3	100%
Invertebrate	*Callophrys mossii bayensis*	San Bruno elfin butterfly	3	3	0	0%	0	0%
Invertebrate	*Trimerotropis infantilis*	Zayante band-winged grasshopper	3	3	0	0%	0	0%
Invertebrate	*Glaucopsyche lygdamus palosverdesensis*	Palos Verdes blue butterfly	2	2	0	0%	0	0%
Invertebrate	*Apodemia mormo langei*	Lange's metalmark butterfly	1	1	0	0%	0	0%
Invertebrate	*Speyeria zerene behrensii*	Behren's silverspot butterfly	1	1	0	0%	0	0%
Mammal	*Corynorhinus townsendii*	Corynorhinus townsendii	424	43	8	2%	8	2%
Mammal	*Vulpes macrotis mutica*	San Joaquin kit fox	382	4	0	0%	0	0%
Mammal	*Pekania pennanti*	Pekania pennanti	360	6	0	0%	0	0%
Mammal	*Dipodomys stephensi*	Stephens' kangaroo rat	107	3	0	0%	0	0%
Mammal	*Reithrodontomys raviventris*	salt-marsh harvest mouse	86	86	84	98%	85	99%
Mammal	*Aplodontia rufa nigra*	Point Arena mountain beaver	35	35	1	3%	2	6%

Taxon	Scientific name	Common name	# Occurrences Statewide	# In Study Area	# In 2ft SLR Zone	% in 2ft SLR zone	# in 5ft SLR Zone	% in 5ft SLR Zone
Mammal	*Martes caurina humboldtensis*	Martes caurina humboldtensis	18	3	0	0%	0	0%
Mammal	*Perognathus longimembris pacificus*	Pacific pocket mouse	7	7	0	0%	0	0%
Mammal	*Enhydra lutris nereis*	southern sea otter	2	1	1	50%	1	50%
Mammal	*Leptonycteris yerbabuenae*	lesser long-nosed bat	2	1	1	50%	1	50%
Vascular Plant	*Lilaeopsis masonii*	Lilaeopsis masonii	183	64	46	25%	46	25%
Vascular Plant	*Brodiaea filifolia*	thread-leaved brodiaea	113	67	0	0%	0	0%
Vascular Plant	*Gratiola heterosepala*	Boggs Lake hedge-hyssop	78	5	0	0%	0	0%
Vascular Plant	*Acanthomintha ilicifolia*	San Diego thorn-mint	58	21	0	0%	0	0%
Vascular Plant	*Navarretia fossalis*	spreading navarretia	54	16	0	0%	0	0%
Vascular Plant	*Astragalus agnicidus*	Humboldt milk-vetch	52	25	0	0%	0	0%
Vascular Plant	*Eryngium aristulatum var. parishii*	San Diego button-celery	52	31	0	0%	0	0%
Vascular Plant	*Deinandra increscens ssp. villosa*	Gaviota tarplant	45	45	4	9%	4	9%
Vascular Plant	*Deinandra conjugens*	Otay tarplant	37	19	0	0%	0	0%
Vascular Plant	*Arctostaphylos glandulosa ssp. crassifolia*	Del Mar manzanita	35	28	0	0%	0	0%
Vascular Plant	*Ambrosia pumila*	San Diego ambrosia	34	5	0	0%	0	0%
Vascular Plant	*Astragalus brauntonii*	Braunton's milk-vetch	33	6	0	0%	0	0%
Vascular Plant	*Limnanthes vinculans*	Limnanthes vinculans	33	1	0	0%	0	0%
Vascular Plant	*Chorizanthe pungens var. pungens*	Monterey spineflower	32	31	4	13%	6	19%
Vascular Plant	*Pentachaeta lyonii*	Lyon's pentachaeta	32	5	0	0%	0	0%
Vascular Plant	*Neostapfia colusana*	Colusa grass	31	4	0	0%	0	0%
Vascular Plant	*Orcuttia californica*	California Orcutt grass	28	8	0	0%	0	0%
Vascular Plant	*Gilia tenuiflora ssp. arenaria*	Monterey gilia	25	25	3	12%	3	12%
Vascular Plant	*Piperia yadonii*	Yadon's rein orchid	25	25	0	0%	0	0%
Vascular Plant	*Orcuttia inaequalis*	San Joaquin Valley Orcutt grass	24	1	0	0%	0	0%

Taxon	Scientific name	Common name	# Occurrences Statewide	# In Study Area	# In 2ft SLR Zone	% in 2ft SLR zone	# in 5ft SLR Zone	% in 5ft SLR Zone
Vascular Plant	*Cordylanthus rigidus ssp. littoralis*	seaside bird's-beak	21	19	0	0%	0	0%
Vascular Plant	*Hesperolinon congestum*	Marin western flax	21	21	0	0%	0	0%
Vascular Plant	*Pleuropogon hooverianus*	North Coast semaphore grass	21	2	0	0%	0	0%
Vascular Plant	*Cirsium fontinale var. obispoense*	San Luis Obispo fountain thistle	20	16	0	0%	0	0%
Vascular Plant	*Lasthenia conjugens*	Contra Costa goldfields	19	19	3	16%	4	21%
Vascular Plant	*Baccharis vanessae*	Encinitas baccharis	19	8	0	0%	0	0%
Vascular Plant	*Blennosperma bakeri*	Sonoma sunshine	18	2	0	0%	0	0%
Vascular Plant	*Deinandra minthornii*	Deinandra minthornii	18	4	0	0%	0	0%
Vascular Plant	*Holocarpha macradenia*	Santa Cruz tarplant	18	18	0	0%	0	0%
Vascular Plant	*Chloropyron molle ssp. molle*	soft salty bird's-beak	17	17	17	100%	17	100%
Vascular Plant	*Layia carnosa*	beach layia	17	17	4	24%	5	29%
Vascular Plant	*Lupinus tidestromii*	Tidestrom's lupine	17	17	4	24%	6	35%
Vascular Plant	*Erysimum menziesii*	Menzies' wallflower	16	16	9	56%	13	81%
Vascular Plant	*Monardella viminea*	willowy monardella	15	2	0	0%	0	0%
Vascular Plant	*Dithyrea maritima*	beach spectaclepod	14	10	2	14%	3	21%
Vascular Plant	*Chorizanthe robusta var. robusta*	robust spineflower	14	14	1	7%	3	21%
Vascular Plant	*Dudleya cymosa ssp. marcescens*	marcescent dudleya	14	12	0	0%	0	0%
Vascular Plant	*Lilium occidentale*	western lily	13	13	1	8%	2	15%
Vascular Plant	*Plagiobothrys diffusus*	San Francisco popcornflower	13	13	0	0%	0	0%
Vascular Plant	*Suaeda californica*	California seablite	12	12	11	92%	12	100%
Vascular Plant	*Trifolium polyodon*	Pacific Grove clover	12	12	2	17%	2	17%
Vascular Plant	*Cirsium scariosum var. loncholepis*	La Graciosa thistle	12	10	0	0%	0	0%
Vascular Plant	*Clarkia speciosa ssp. immaculata*	Pismo clarkia	12	11	0	0%	0	0%
Vascular Plant	*Limnanthes douglasii ssp. sulphurea*	Point Reyes meadowfoam	12	12	0	0%	0	0%

Taxon	Scientific name	Common name	# Occurrences Statewide	# In Study Area	# In 2ft SLR Zone	% in 2ft SLR zone	# in 5ft SLR Zone	% in 5ft SLR Zone
Vascular Plant	*Mimulus fremontii var. vandenbergensis*	Vandenberg monkeyflower	12	9	0	0%	0	0%
Vascular Plant	*Blennosperma nanum var. robustum*	Blennosperma nanum var. robustum	11	11	1	9%	1	9%
Vascular Plant	*Pogogyne nudiuscula*	Otay Mesa mint	11	3	0	0%	0	0%
Vascular Plant	*Chloropyron maritimum ssp. maritimum*	salt marsh bird's-beak	10	10	8	80%	10	100%
Vascular Plant	*Sanicula maritima*	Sanicula maritima	10	10	2	20%	2	20%
Vascular Plant	*Cirsium rhothophilum*	surf thistle	9	9	7	78%	7	78%
Vascular Plant	*Eriogonum crocatum*	conejo buckwheat	9	3	0	0%	0	0%
Vascular Plant	*Pogogyne abramsii*	San Diego mesa mint	9	8	0	0%	0	0%
Vascular Plant	*Oenothera deltoides ssp. howellii*	Antioch Dunes evening-primrose	8	5	1	13%	1	13%
Vascular Plant	*Alopecurus aequalis var. sonomensis*	Sonoma alopecurus	8	7	0	0%	0	0%
Vascular Plant	*Arctostaphylos pallida*	pallid manzanita	8	8	0	0%	0	0%
Vascular Plant	*Castilleja affinis var. neglecta*	Tiburon paintbrush	8	6	0	0%	0	0%
Vascular Plant	*Dudleya verityi*	Verity's dudleya	7	7	0	0%	0	0%
Vascular Plant	*Chorizanthe orcuttiana*	Orcutt's spineflower	6	6	0	0%	1	17%
Vascular Plant	*Erysimum teretifolium*	Santa Cruz wallflower	6	6	0	0%	0	0%
Vascular Plant	*Trifolium trichocalyx*	Monterey clover	6	5	0	0%	0	0%
Vascular Plant	*Ceanothus masonii*	Mason's ceanothus	5	5	0	0%	0	0%
Vascular Plant	*Chorizanthe pungens var. hartwegiana*	Ben Lomond spineflower	5	4	0	0%	0	0%
Vascular Plant	*Dudleya brevifolia*	short-leaved dudleya	5	5	0	0%	0	0%
Vascular Plant	*Hazardia orcuttii*	Orcutt's hazardia	5	5	0	0%	0	0%
Vascular Plant	*Hesperocyparis abramsiana var. abramsiana*	Santa Cruz cypress	5	4	0	0%	0	0%
Vascular Plant	*Cirsium hydrophilum var. hydrophilum*	Suisun thistle	4	4	4	100%	4	100%
Vascular Plant	*Chorizanthe howellii*	Howell's spineflower	4	4	2	50%	2	50%
Vascular Plant	*Cirsium fontinale var. fontinale*	Crystal Springs fountain thistle	4	4	0	0%	0	0%

Taxon	Scientific name	Common name	# Occurrences Statewide	# In Study Area	# In 2ft SLR Zone	% in 2ft SLR zone	# in 5ft SLR Zone	% in 5ft SLR Zone
Vascular Plant	*Cordylanthus tenuis ssp. capillaris*	Pennell's bird's-beak	4	3	0	0%	0	0%
Vascular Plant	*Delphinium bakeri*	Delphinium bakeri	4	2	0	0%	0	0%
Vascular Plant	*Delphinium luteum*	golden larkspur	4	4	0	0%	1	25%
Vascular Plant	*Dudleya stolonifera*	Laguna Beach dudleya	4	4	0	0%	0	0%
Vascular Plant	*Eriodictyon altissimum*	Indian Knob mountainbalm	4	4	0	0%	0	0%
Vascular Plant	*Lupinus nipomensis*	Nipomo Mesa lupine	4	4	0	0%	0	0%
Vascular Plant	*Arctostaphylos morroensis*	Morro manzanita	3	3	1	33%	1	33%
Vascular Plant	*Arenaria paludicola*	marsh sandwort	3	3	1	33%	1	33%
Vascular Plant	*Fritillaria roderickii*	Roderick's fritillary	3	1	1	33%	1	33%
Vascular Plant	*Trifolium amoenum*	two-fork clover	3	3	1	33%	1	33%
Vascular Plant	*Acanthomintha duttonii*	San Mateo thorn-mint	3	3	0	0%	0	0%
Vascular Plant	*Amsinckia grandiflora*	large-flowered fiddleneck	3	1	0	0%	0	0%
Vascular Plant	*Chorizanthe robusta var. hartwegii*	Scotts Valley spineflower	3	3	0	0%	0	0%
Vascular Plant	*Chorizanthe valida*	Sonoma spineflower	3	3	0	0%	0	0%
Vascular Plant	*Clarkia franciscana*	Presidio clarkia	3	3	0	0%	0	0%
Vascular Plant	*Erysimum capitatum var. angustatum*	Contra Costa wallflower	3	3	0	0%	0	0%
Vascular Plant	*Lessingia germanorum*	San Francisco lessingia	3	3	0	0%	1	33%
Vascular Plant	*Pedicularis dudleyi*	Pedicularis dudleyi	3	2	0	0%	0	0%
Vascular Plant	*Tuctoria mucronata*	Crampton's tuctoria or Solano grass	3	1	0	0%	0	0%
Vascular Plant	*Ceanothus maritimus*	Ceanothus maritimus	2	2	1	50%	1	50%
Vascular Plant	*Dudleya cymosa ssp. ovatifolia*	Santa Monica dudleya	2	2	0	0%	0	0%
Vascular Plant	*Eriophyllum latilobum*	San Mateo woolly sunflower	2	2	0	0%	0	0%
Vascular Plant	*Hesperocyparis goveniana*	Gowen cypress	2	2	0	0%	0	0%
Vascular Plant	*Polygonum hickmanii*	Scotts Valley polygonum	2	2	0	0%	0	0%

Taxon	Scientific name	Common name	# Occurrences Statewide	# In Study Area	# In 2ft SLR Zone	% in 2ft SLR zone	# in 5ft SLR Zone	% in 5ft SLR Zone
Vascular Plant	*Potentilla hickmanii*	Hickman's cinquefoil	2	2	0	0%	0	0%
Vascular Plant	*Rosa minutifolia*	small-leaved rose	2	2	0	0%	0	0%
Vascular Plant	*Streptanthus glandulosus ssp. niger*	Tiburon jewelflower	2	2	0	0%	0	0%
Vascular Plant	*Verbesina dissita*	big-leaved crownbeard	2	2	0	0%	0	0%
Vascular Plant	*Astragalus tener var. titi*	coastal dunes milk-vetch	1	1	1	100%	1	100%
Vascular Plant	*Arctostaphylos bakeri ssp. bakeri*	Arctostaphylos bakeri ssp. bakeri	1	1	0	0%	0	0%
Vascular Plant	*Arctostaphylos franciscana*	Franciscan manzanita	1	1	0	0%	0	0%
Vascular Plant	*Arctostaphylos hookeri ssp. hearstiorum*	Hearsts' manzanita	1	1	0	0%	0	0%
Vascular Plant	*Arctostaphylos imbricata*	San Bruno Mountain manzanita	1	1	0	0%	0	0%
Vascular Plant	*Arctostaphylos montana ssp. ravenii*	Presidio manzanita	1	1	0	0%	0	0%
Vascular Plant	*Arctostaphylos pacifica*	Pacific manzanita	1	1	0	0%	0	0%
Vascular Plant	*Astragalus pycnostachyus var. lanosissimus*	Ventura Marsh milk-vetch	1	1	0	0%	0	0%
Vascular Plant	*Calochortus tiburonensis*	Tiburon mariposa-lily	1	1	0	0%	0	0%
Vascular Plant	*Nasturtium gambelii*	Gambel's water cress	1	1	0	0%	0	0%
Vascular Plant	*Ornithostaphylos oppositifolia*	Baja California birdbush	1	1	0	0%	0	0%
Vascular Plant	*Pentachaeta bellidiflora*	white-rayed pentachaeta	1	1	0	0%	0	0%
Vascular Plant	*Thermopsis macrophylla*	Santa Ynez false lupine	1	1	0	0%	0	0%

APPENDIX C.5: THE CALIFORNIA COASTAL COMMISSION'S JURISDICTIONAL COASTAL ZONE AND SEA LEVEL RISE INUNDATION. All area reported in units of km^2.

County	Area of dry Coastal Zone (current conditions)	Area of dry Coastal Zone after 5ft SLR	Change	Tidal area landward of current Coastal Zone boundary after 5ft SLR
Del Norte County	161.44	138.13	-23.31	0.31
Humboldt County	424.97	356.57	-68.40	2.29
Los Angeles County	366.51	356.45	-10.06	2.45
Marin County	327.91	318.52	-9.39	0.04
Mendocino County	377.90	373.25	-4.65	0.30
Monterey County	806.48	784.28	-22.20	6.93
Orange County	142.79	122.80	-19.99	16.58
San Diego County	292.68	273.13	-19.55	0.30
San Francisco County	7.64	7.40	-0.24	0.00
San Luis Obispo County	645.01	640.54	-4.48	0.03
San Mateo County	397.16	394.38	-2.78	0.00
Santa Barbara County	461.62	456.38	-5.24	0.14
Santa Cruz County	293.41	286.44	-6.97	0.07
Sonoma County	221.53	218.57	-2.96	0.16
Ventura County	134.25	119.14	-15.10	7.91
STATE TOTAL	***5061.30***	***4845.97***	***-215.33***	***37.51***

APPENDIX C.6: CONSERVATION MANAGEMENT STATUS AND SEA LEVEL RISE INUNDATION. All area reported in units of km^2.

Ecoregion/ County	Highly Conserved			Conserved			Public Non-Conserved			Private Non-Conserved		
	Total area	Area Inundated 2ft SLR	Area Inundated 5ft SLR	Total area	Area Inundated 2ft SLR	Area Inundated 5ft SLR	Total area	Area Inundated 2ft SLR	Area Inundated 5ft SLR	Total area	Area Inundated 2ft SLR	Area Inundated 5ft SLR
North Coast	**909.1**	**14.7**	**43.3**	**638.3**	**5.1**	**14.2**	**21.8**	**0.3**	**1.1**	**3931.7**	**35.8**	**92.6**
SF Bay/Delta	**750.0**	**209.3**	**303.3**	**365.1**	**30.9**	**59.1**	**129.3**	**15.6**	**25.1**	**3412.7**	**229.5**	**482.6**
Central Coast	**1260.3**	**8.9**	**21.2**	**1400.3**	**5.6**	**17.7**	**56.4**	**0.3**	**0.9**	**3130.9**	**14.9**	**54.0**
South Coast	**228.7**	**8.0**	**26.6**	**842.1**	**4.6**	**20.5**	**159.5**	**1.5**	**8.6**	**3159.8**	**14.3**	**66.6**
STATE TOTAL	**3148.1**	**240.9**	**394.4**	**3245.8**	**46.2**	**111.5**	**367.0**	**17.7**	**35.7**	**13635.1**	**294.5**	**695.9**
Alameda County	107.6	47.5	62.3	77.5	5.5	12.4	23.7	0.6	1.9	549.1	36.0	78.3
Contra Costa County	66.1	2.4	2.8	108.2	9.8	13.3	10.5	0.3	0.5	448.4	18.5	31.5
Del Norte County	57.3	0.1	15.6	223.1	0.1	1.4	0.4	0.0	0.0	509.2	1.6	9.2
Humboldt County	435.3	14.4	26.3	193.8	4.0	9.5	6.0	0.3	0.9	1562.8	32.2	78.0
Los Angeles County	25.2	0.5	1.2	163.7	0.1	0.5	38.5	0.3	1.5	875.0	3.4	13.8
Marin County	309.9	14.0	19.0	406.3	7.2	23.0	20.2	9.0	10.4	468.8	23.2	43.0
Mendocino County	325.1	0.2	1.3	178.3	0.8	2.4	1.9	0.0	0.1	1265.3	1.6	4.3
Monterey County	502.2	4.1	10.8	355.2	0.6	1.8	10.6	0.0	0.2	781.4	4.4	24.6
Napa County	58.5	19.2	29.2	2.4	0.5	1.9	7.9	1.3	3.2	258.1	6.5	13.0
Orange County	52.8	2.3	8.7	36.5	0.4	1.2	35.5	0.3	2.0	646.4	5.9	30.2
Sacramento County	27.3	0.0	0.0	6.0	0.0	0.0	--	--	--	18.8	--	--
San Benito County	--	--	--	--	--	--	--	--	--	12.3	--	--
San Diego County	110.1	4.5	13.9	334.9	1.6	5.8	65.3	0.7	3.5	748.0	3.3	9.0
San Francisco County	0.0	0.0	0.0	11.1	0.3	1.6	15.6	0.1	1.3	96.0	0.6	3.4
San Luis Obispo County	280.0	3.3	4.2	92.6	1.6	4.3	14.5	0.0	0.1	805.9	2.2	5.1
San Mateo County	239.7	16.5	22.2	93.0	0.8	1.6	26.4	1.0	3.2	567.1	20.7	67.2

Ecoregion/ County	Highly Conserved			Conserved			Public Non-Conserved			Private Non-Conserved		
	Total area	Area Inundated 2ft SLR	Area Inundated 5ft SLR	Total area	Area Inundated 2ft SLR	Area Inundated 5ft SLR	Total area	Area Inundated 2ft SLR	Area Inundated 5ft SLR	Total area	Area Inundated 2ft SLR	Area Inundated 5ft SLR
Santa Barbara County	57.4	0.7	2.1	566.5	0.5	1.3	8.5	0.1	0.3	810.9	2.2	5.9
Santa Clara County	47.8	24.9	30.1	9.0	3.0	3.9	16.5	0.5	1.8	338.6	27.5	39.0
Santa Cruz County	62.7	0.0	1.1	159.1	0.2	1.0	7.4	0.0	0.1	455.3	0.6	5.7
Solano County	151.6	36.0	85.0	58.6	6.1	10.0	28.0	2.8	3.1	767.6	55.2	162.5
Sonoma County	227.8	50.4	57.6	51.5	0.8	2.0	15.9	0.3	0.4	1127.5	48.0	61.8
Ventura County	4.0	0.0	1.0	118.5	2.3	12.5	13.7	0.0	1.3	520.9	0.6	10.4

APPENDIX C.7: LAND MANAGEMENT AND SEA LEVEL RISE INUNDATION

Ecoregion/County	California Department of Fish and Wildlife		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	40.01	7.17	15.87
SF Bay	171.34	67.76	128.21
Central Coast	45.51	3.52	8.01
South Coast	13.37	1.91	4.61
STATE TOTAL	**270.24**	**80.36**	**156.69**
Alameda County	23.83	19.14	20.09
Contra Costa County	--	--	--
Del Norte County	15.69	0.00	5.56
Humboldt County	18.29	7.16	10.30
Los Angeles County	2.23	0.48	1.09
Marin County	10.78	3.29	5.80
Mendocino County	5.91	0.00	0.00
Monterey County	31.84	2.82	6.01
Napa County	32.99	17.18	25.69
Orange County	2.57	0.60	1.30
Sacramento County	13.09	--	--
San Benito County	--	--	--
San Diego County	8.42	0.83	2.19
San Francisco County	--	--	--
San Luis Obispo County	6.04	--	--
San Mateo County	5.54	2.54	4.47
Santa Barbara County	0.18	--	0.02
Santa Clara County	0.11	0.11	0.11
Santa Cruz County	5.46	0.01	0.58
Solano County	72.56	15.38	59.56
Sonoma County	14.71	10.82	13.92
Ventura County	--	--	--

Ecoregion/County	California Department of Parks and Recreation		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	377.86	0.91	4.12
SF Bay	19.04	2.93	4.49
Central Coast	365.37	2.22	8.02
South Coast	177.13	1.56	4.97
STATE TOTAL	**939.39**	**7.62**	**21.60**
Alameda County	3.17	1.49	2.45
Contra Costa County	0.31	0.12	0.18
Del Norte County	135.56	0.11	1.29
Humboldt County	70.61	0.10	0.42
Los Angeles County	83.03	0.11	0.39
Marin County	54.65	1.01	1.51
Mendocino County	102.01	0.53	1.61
Monterey County	65.04	0.39	1.33
Napa County	--	--	--
Orange County	13.88	0.16	0.47
Sacramento County	--	--	--
San Benito County	--	--	--
San Diego County	11.50	1.13	3.42
San Francisco County	0.46	0.03	0.09
San Luis Obispo County	83.51	1.06	2.84
San Mateo County	50.42	0.26	2.18
Santa Barbara County	22.88	0.13	0.49
Santa Clara County	--	--	--
Santa Cruz County	110.39	0.13	0.78
Solano County	1.86	0.60	0.91
Sonoma County	74.44	0.18	0.91
Ventura County	55.66	0.07	0.32

Ecoregion/County	California State Lands Commission		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	15.90	0.15	9.83
SF Bay	51.31	31.31	46.69
Central Coast	17.62	3.66	5.19
South Coast	8.31	1.41	6.68
STATE TOTAL	**93.13**	**36.53**	**68.40**
Alameda County	1.32	0.54	0.97
Contra Costa County	6.88	4.46	5.22
Del Norte County	9.35	--	9.33
Humboldt County	5.78	0.02	0.13
Los Angeles County	--	--	--
Marin County	17.32	9.20	16.97
Mendocino County	0.60	0.10	0.27
Monterey County	0.14	0.03	0.07
Napa County	3.79	1.68	3.12
Orange County	3.95	0.72	3.73
Sacramento County	--	--	--
San Benito County	--	--	--
San Diego County	4.32	0.68	2.92
San Francisco County	0.22	0.01	0.04
San Luis Obispo County	5.46	3.61	5.07
San Mateo County	3.89	1.96	2.74
Santa Barbara County	11.94	0.02	0.04
Santa Clara County	--	--	--
Santa Cruz County	0.02	--	--
Solano County	17.83	13.41	17.58
Sonoma County	0.31	0.10	0.21
Ventura County	--	--	--

Ecoregion/County	Other State		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	99.42	0.13	0.19
SF Bay	31.38	4.85	5.85
Central Coast	49.38	0.04	0.17
South Coast	15.82	0.41	0.59
STATE TOTAL	**196.00**	**5.44**	**6.80**
Alameda County	1.52	--	--
Contra Costa County	--	--	--
Del Norte County	--	--	--
Humboldt County	1.05	0.12	0.15
Los Angeles County	6.38	0.01	0.03
Marin County	2.74	1.97	2.69
Mendocino County	98.37	0.01	0.04
Monterey County	22.21	0.01	0.03
Napa County	4.16	--	--
Orange County	0.33	--	--
Sacramento County	18.95		
San Benito County	--	--	--
San Diego County	2.91	0.00	0.00
San Francisco County	--	--	--
San Luis Obispo County	5.59	--	--
San Mateo County	0.18	0.01	0.03
Santa Barbara County	8.44	0.40	0.55
Santa Clara County	--	--	--
Santa Cruz County	17.58	0.03	0.12
Solano County	3.99	2.88	3.15
Sonoma County	1.07	0.00	0.00
Ventura County	0.52	--	--

Ecoregion/County	Department of Defense		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	0.14	0.00	0.01
SF Bay	103.33	12.93	25.00
Central Coast	453.55	0.31	0.77
South Coast	345.63	3.49	18.47
STATE TOTAL	**902.65**	**16.73**	**44.25**
Alameda County	10.25	0.25	4.38
Contra Costa County	39.92	5.21	7.05
Del Norte County	--	--	--
Humboldt County	0.14	0.00	0.01
Los Angeles County	0.37	--	--
Marin County	3.22	0.10	0.90
Mendocino County	--	--	--
Monterey County	99.55	0.00	0.01
Napa County	--	--	--
Orange County	6.94	0.00	0.00
Sacramento County	0.25	--	--
San Benito County	--	--	--
San Diego County	316.19	1.26	5.11
San Francisco County	4.29	0.06	1.80
San Luis Obispo County	0.36	--	--
San Mateo County	1.03	--	--
Santa Barbara County	352.72	0.30	0.76
Santa Clara County	6.81	2.62	3.25
Santa Cruz County	0.92	--	--
Solano County	37.55	4.68	7.61
Sonoma County	--	--	--
Ventura County	22.14	2.23	13.36

Ecoregion/County	Other Federal		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	1.75	0.33	0.65
SF Bay	3.39	0.19	0.25
Central Coast	0.70	0.01	0.05
South Coast	8.39	0.01	0.35
STATE TOTAL	**14.22**	**0.54**	**1.30**
Alameda County	0.06	0.01	0.06
Contra Costa County	3.11		
Del Norte County			
Humboldt County	1.75	0.33	0.65
Los Angeles County	1.59	0.00	0.00
Marin County	0.01		
Mendocino County			
Monterey County	0.33	0.01	0.03
Napa County			
Orange County	0.40	0.00	0.34
Sacramento County			
San Benito County			
San Diego County			
San Francisco County			
San Luis Obispo County	0.25	0.01	0.02
San Mateo County			
Santa Barbara County	0.62	0.00	0.00
Santa Clara County			
Santa Cruz County	0.00	0.00	0.00
Solano County			
Sonoma County	0.21	0.18	0.20
Ventura County	5.90		

Ecoregion/County	United States Bureau of Land Management		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	260.77	0.47	2.08
SF Bay	0.03	--	--
Central Coast	63.01	0.07	0.13
South Coast	0.23	0.00	0.00
STATE TOTAL	**324.05**	**0.54**	**2.22**
Alameda County	--	--	--
Contra Costa County	0.03	--	--
Del Norte County	0.02	0.01	0.01
Humboldt County	247.55	0.37	1.58
Los Angeles County	0.00	0.00	0.00
Marin County	0.00	0.00	0.00
Mendocino County	13.17	0.09	0.47
Monterey County	27.70	0.03	0.06
Napa County	--	--	--
Orange County	--	--	--
Sacramento County	--	--	--
San Benito County	--	--	--
San Diego County	0.00	0.00	0.00
San Francisco County	--	--	--
San Luis Obispo County	8.15	0.02	0.04
San Mateo County	0.15	--	--
Santa Barbara County	0.51	0.02	0.03
Santa Clara County	--	--	--
Santa Cruz County	26.50	--	--
Solano County	--	--	--
Sonoma County	0.03	0.01	0.02
Ventura County	0.23	--	--

Ecoregion/County	United States Fish and Wildlife Service		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	11.11	2.16	7.50
SF Bay	135.16	94.90	117.69
Central Coast	13.01	0.08	1.22
South Coast	9.61	2.29	7.47
STATE TOTAL	**168.89**	**99.44**	**133.88**
Alameda County	51.06	28.28	42.04
Contra Costa County	0.22	--	--
Del Norte County		--	--
Humboldt County	11.11	2.16	7.50
Los Angeles County	--	--	--
Marin County	--	--	--
Mendocino County	--	--	--
Monterey County	1.27	0.05	0.79
Napa County	0.13	0.10	0.12
Orange County	3.56	0.97	3.24
Sacramento County	--	--	--
San Benito County	--	--	--
San Diego County	6.05	1.32	4.23
San Francisco County	--	--	--
San Luis Obispo County	10.65	0.03	0.11
San Mateo County	13.32	10.70	11.63
Santa Barbara County	--	--	--
Santa Clara County	30.97	22.10	26.64
Santa Cruz County	1.08	--	0.31
Solano County	7.02	6.30	6.97
Sonoma County	32.44	27.42	30.29
Ventura County	--	--	--

Ecoregion/County	United States Forest Service		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	86.56	0.00	0.00
SF Bay	0.00	--	--
Central Coast	519.31	0.11	0.33
South Coast	169.88	--	--
STATE TOTAL	**775.75**	**0.11**	**0.33**
Alameda County	--	--	--
Contra Costa County	--	--	--
Del Norte County	86.41	0.00	0.00
Humboldt County	0.15	--	--
Los Angeles County	--	--	--
Marin County	--	--	--
Mendocino County	--	--	--
Monterey County	497.64	0.11	0.32
Napa County	--	--	--
Orange County	--	--	--
Sacramento County	--	--	--
San Benito County	--	--	--
San Diego County	--	--	--
San Francisco County	--	--	--
San Luis Obispo County	8.66	0.00	0.01
San Mateo County	--	--	--
Santa Barbara County	164.41	--	--
Santa Clara County	--	--	--
Santa Cruz County	--	--	--
Solano County	--	--	--
Sonoma County	--	--	--
Ventura County	18.49	--	--

Ecoregion/County	United States National Park Service		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	214.60	0.17	0.74
SF Bay	21.91	0.11	0.47
Central Coast	334.77	1.98	5.77
South Coast	61.85	0.01	0.02
STATE TOTAL	**633.13**	**2.27**	**6.98**
Alameda County	--	--	--
Contra Costa County	1.42	--	--
Del Norte County	27.34	0.12	0.42
Humboldt County	187.26	0.05	0.32
Los Angeles County	45.21	--	--
Marin County	321.83	1.88	5.47
Mendocino County	--	--	--
Monterey County	--	--	--
Napa County	--	--	--
Orange County	--	--	--
Sacramento County	--	--	--
San Benito County	--	--	--
San Diego County	0.63	0.01	0.02
San Francisco County	8.47	0.20	0.75
San Luis Obispo County	--	--	--
San Mateo County	24.96	0.00	0.01
Santa Barbara County	--	--	--
Santa Clara County	--	--	--
Santa Cruz County	--	--	--
Solano County	--	--	--
Sonoma County	--	--	--
Ventura County	16.02	--	--

Ecoregion/County	Other Public		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	39.31	4.89	10.23
SF Bay	532.08	25.40	41.25
Central Coast	261.52	1.07	4.44
South Coast	332.23	2.72	11.09
STATE TOTAL	**1165.14**	**34.08**	**67.02**
Alameda County	115.23	3.92	6.45
Contra Costa County	122.12	2.71	4.12
Del Norte County	1.37	0.02	0.06
Humboldt County	28.72	4.84	10.05
Los Angeles County	80.71	0.35	1.69
Marin County	170.96	10.53	15.52
Mendocino County	0.66	0.02	0.05
Monterey County	59.53	0.14	0.34
Napa County	14.16	1.95	5.37
Orange County	90.97	0.61	2.80
Sacramento County	--	--	--
San Benito County	--	--	--
San Diego County	114.57	1.45	4.88
San Francisco County	13.31	0.04	0.17
San Luis Obispo County	8.98	0.02	0.09
San Mateo County	175.53	2.34	5.13
Santa Barbara County	42.18	0.35	1.68
Santa Clara County	35.22	3.59	5.77
Santa Cruz County	15.81	0.04	0.28
Solano County	38.16	0.16	0.57
Sonoma County	23.57	0.99	1.80
Ventura County	13.38	0.02	0.19

Ecoregion/County	Total Public Lands		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	1147.43	16.39	51.23
SF Bay	1068.96	240.39	369.91
Central Coast	2123.74	13.07	34.09
South Coast	1142.45	13.81	54.25
STATE TOTAL	**5482.58**	**283.66**	**509.48**
Alameda County	206.43	53.62	76.43
Contra Costa County	174.01	12.50	16.58
Del Norte County	275.74	0.26	16.67
Humboldt County	572.41	15.16	31.12
Los Angeles County	219.51	0.95	3.21
Marin County	581.52	28.00	48.86
Mendocino County	220.72	0.75	2.44
Monterey County	805.24	3.59	8.99
Napa County	55.22	20.92	34.30
Orange County	122.60	3.06	11.88
Sacramento County	32.29	--	--
San Benito County	--	--	--
San Diego County	464.59	6.67	22.77
San Francisco County	26.75	0.35	2.86
San Luis Obispo County	137.66	4.75	8.18
San Mateo County	275.02	17.82	26.18
Santa Barbara County	603.90	1.22	3.58
Santa Clara County	73.11	28.42	35.77
Santa Cruz County	177.77	0.21	2.07
Solano County	178.97	43.40	96.36
Sonoma County	146.78	39.70	47.35
Ventura County	132.34	2.31	13.88

Ecoregion/County	Private		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	4353.53	39.56	99.90
SF Bay	3588.01	244.93	500.24
Central Coast	3724.08	16.62	59.70
South Coast	3246.08	14.54	68.10
STATE TOTAL	**14911.76**	**315.65**	**727.94**
Alameda County	551.53	36.11	78.46
Contra Costa County	459.15	18.46	31.49
Del Norte County	514.21	1.60	9.48
Humboldt County	1625.49	35.68	83.55
Los Angeles County	882.81	3.43	13.85
Marin County	623.65	25.42	46.48
Mendocino County	1549.85	1.83	5.56
Monterey County	844.12	5.48	28.37
Napa County	271.75	6.52	13.00
Orange County	648.54	5.95	30.22
Sacramento County	19.78	--	--
San Benito County	12.30	--	--
San Diego County	793.77	3.54	9.46
San Francisco County	96.05	0.59	3.37
San Luis Obispo County	1055.28	2.43	5.59
San Mateo County	651.14	21.11	68.03
Santa Barbara County	839.40	2.24	6.05
Santa Clara County	338.84	27.51	39.07
Santa Cruz County	506.71	0.65	5.84
Solano County	826.72	56.62	164.35
Sonoma County	1275.92	59.83	74.44
Ventura County	524.74	0.63	11.28

Ecoregion/County	Total Public & Private		
	Area (km²) of managed lands in study area	Area (km²) of managed lands inundated 2ft SLR	Area (km²) of managed lands inundated 5ft SLR
North Coast	5500.96	55.95	151.13
SF Bay	4656.97	485.31	870.15
Central Coast	5847.82	29.69	93.79
South Coast	4388.54	28.35	122.36
STATE TOTAL	**20394.34**	**599.31**	**1237.42**
Alameda County	757.96	89.74	154.89
Contra Costa County	633.16	30.96	48.06
Del Norte County	789.96	1.86	26.14
Humboldt County	2197.90	50.84	114.67
Los Angeles County	1102.32	4.38	17.06
Marin County	1205.16	53.42	95.34
Mendocino County	1770.57	2.58	8.00
Monterey County	1649.36	9.07	37.36
Napa County	326.96	27.44	47.30
Orange County	771.14	9.01	42.10
Sacramento County	52.07	--	--
San Benito County	12.30	--	--
San Diego County	1258.36	10.22	32.24
San Francisco County	122.80	0.94	6.23
San Luis Obispo County	1192.94	7.18	13.77
San Mateo County	926.16	38.93	94.22
Santa Barbara County	1443.29	3.46	9.62
Santa Clara County	411.94	55.93	74.84
Santa Cruz County	684.48	0.86	7.92
Solano County	1005.68	100.02	260.70
Sonoma County	1422.70	99.52	121.79
Ventura County	657.08	2.94	25.16

APPENDIX D: AREA OF BUILT ENVIRONMENT CATEGORIES WITHIN THE 5FT SLR ANALYTIC ZONE BY ECOREGION. Area reported in units of km^2.

Region/County	Developed-low intensity	Developed-medium intensity	Developed-high intensity	Transportation infrastructure	Other infrastructure	Undeveloped uplands	Grand Total
North Coast	**3.60**	**2.14**	**1.37**	**3.21**	**0.08**	**80.01**	**90.41**
SF Bay/Delta	**44.93**	**110.43**	**70.29**	**37.71**	**39.03**	**89.53**	**391.93**
Central Coast	**2.73**	**2.97**	**0.80**	**2.13**	**0.48**	**43.97**	**53.08**
South Coast	**27.52**	**67.74**	**33.11**	**21.79**	**3.49**	**29.70**	**183.34**
STATE TOTALS	**78.78**	**183.29**	**105.57**	**64.83**	**43.09**	**243.21**	**718.76**
Alameda	13.58	35.59	27.81	10.31	7.04	7.91	102.24
Contra Costa	4.91	8.6	6.76	3.27	2.41	2.16	28.1
Del Norte	0.44	0.14	0.35	0.39	--	7.02	8.35
Humboldt	3.00	1.91	1.01	2.64	0.08	71.76	80.39
Los Angeles	8.14	13.33	13.57	5.47	1.47	0.36	42.35
Marin	5.96	12.91	3.71	5.05	2.38	17.39	47.41
Mendocino	0.14	0.09	0	0.16	--	0.99	1.38
Monterey	0.67	0.91	0.25	0.71	0.2	32.38	35.12
Napa	1.75	1.62	0.48	0.53	3.09	2.97	10.44
Orange	7.98	26.97	5.81	7.95	0.99	8.3	58
San Diego	3.64	13.46	13.11	4.84	0.54	2.56	38.14
San Francisco	1.72	2.71	5.09	1.5	0.45	0.22	11.69
San Luis Obispo	0.91	0.47	0.12	0.3	0.06	0.62	2.48
San Mateo	7.14	27.82	16.95	8.76	3.43	2.29	66.39
Santa Barbara	2.00	2.82	0.07	0.87	--	1.03	6.79
Santa Clara	5.69	12.52	5.48	3.5	4.42	4.6	36.21
Santa Cruz	0.34	0.82	0.3	0.43	0.07	7.28	9.24
Solano	3.86	7.57	3.53	3.63	12.87	7.21	38.66
Sonoma	1.12	1.84	0.6	1.81	3.11	48.71	57.21
Ventura	5.8	11.16	0.56	2.71	0.49	17.45	38.16

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