U.S. Fish & Wildlife Service

Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California

California clapper rail (Rallus longirostris obsoletus)

Suaeda californica (California sea-blite)

Cirsium hydrophilum var. hydrophilum (Suisun thistle)

Chloropyron molle ssp. molle (soft bird's-beak)

Salt marsh harvest mouse (Reithrodontomys raviventris)

Volume I

Tidal marsh at China Camp State Park.

Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California

Region 8
U.S. Fish and Wildlife Service
Sacramento, California

Approved: ______________________________

Regional Director, Pacific Southwest Region, Region 8,
U.S. Fish and Wildlife Service

AUG 27 2013

Date: ______________________________

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An electronic copy of this recovery plan will be made available at http://www.pacific.fws.gov/ecoservices/endangered/recovery/plans.html and http://endangered.fws.gov/recovery/index.html#plans

A notice has been published in the Federal Register indicating the availability of this plan.

Cover Photos:

Tidal marsh at China Camp State Park: Valary Bloom, U.S. Fish & Wildlife Service
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Chloropyron molle ssp. *molle* (soft bird's-beak): Valary Bloom, U.S. Fish & Wildlife Service
Salt marsh harvest mouse (*Reithrodontomys raviventris*): Bob Dodge

Recovery Plan Preparation

The publication of the Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California is the culmination of a multiyear effort. While acknowledging the reality of changing scientific understanding, this document includes restoration maps which take into account anticipated sea level rise to the best of our knowledge. The maps are an illustration of one potential vision by which recovery may be achieved. The maps delineate our current understanding of the highest priority areas for protection or restoration of tidal marsh or associated habitats. Lands within the recovery unit boundaries have been defined by the range of historic tidal marsh. We recognize that not all lands within the boundaries will be necessary for species recovery and that alternative recovery strategies may become necessary as new scientific information becomes available. In addition, as with all recovery plans, implementation of this document is entirely voluntary, and relies upon the willing participation of our current and future public and private partners to achieve recovery.

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Dedication

This recovery plan is dedicated to Philip and Florence LaRiviere and Frank and the late Janice Delfino, who have spent countless hours protecting and restoring the habitats and species of the San Francisco Bay. The LaRivieres and Delfinos have spearheaded many efforts, dating back to the 1960s, passionately advocating for, and increasing public understanding and appreciation of, the ecosystems of the Bay. As cofounders of the Citizens' Committee to Complete the Refuge, they were instrumental in establishing the Don Edwards San Francisco Bay National Wildlife Refuge and have worked tirelessly since then to facilitate its development. The U.S. Fish and Wildlife Service extends its thanks to Philip, Florence, Frank, and Janice for their constant support and applauds their many years of selfless commitment toward the protection and recovery of the tidal marsh ecosystem of the San Francisco Bay.

Philip and Florence LaRiviere

Frank and Janice Delfino

Executive Summary

The *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* features five endangered species: two endangered animals, California clapper rail (*Rallus longirostris obsoletus*) and salt marsh harvest mouse (*Reithrodontomys raviventris*) and three endangered plants, *Cirsium hydrophilum* var. *hydrophilum* (Suisun thistle), *Chloropyron molle* ssp. *molle* (soft bird's-beak), and *Suaeda californica* (California sea-blite). The biology of these species is at the core of the recovery plan, but the goal of this effort is the comprehensive restoration and management of *tidal marsh*[1] ecosystems.

This recovery plan is an expansion and revision of *The California Clapper Rail and Salt Marsh Harvest Mouse Recovery Plan* (U.S. Fish and Wildlife Service 1984). The historic distribution of the California clapper rail encompasses major tidal marshes between Humboldt Bay and Morro Bay, defining the approximate geographic scope of this recovery plan. In addition to the California clapper rail and the salt marsh harvest mouse, the plan also covers three focal listed plant species that were listed as federally endangered in the 1990s and the northernmost *population* of an additional plant species. Two of the species, *Cirsium hydrophilum* var. *hydrophilum* and *Chloropyron molle* ssp. *molle* (this species' former name is *Cordylanthus mollis* ssp. *mollis* which is how it appears on the List of Threatened and Endangered Species, but we use the currently accepted name here), are restricted to the northern reaches of the San Francisco Bay *Estuary*. The other endangered tidal marsh plant, *Suaeda californica*, historically occurred in both San Francisco Bay and Morro Bay but, except for three *reintroductions* to San Francisco Bay, is now restricted to Morro Bay. Another federally listed plant, *Chloropyron maritimum* ssp. *maritimum* (salt marsh bird's-beak; formerly *Cordylanthus maritimus* ssp. *maritimus*), has its northern range limit in Morro Bay. Morro Bay was omitted from the *Salt Marsh Bird's-beak Recovery Plan* (U.S. Fish and Wildlife Service 1985*a*) because the *taxonomic* interpretation at the time classified this population in another subspecies that is not federally listed. Current taxonomic interpretation considers the Morro Bay population as *Chloropyron maritimum* ssp. *maritimum*. It is included in this recovery plan due to its co-location with *Suaeda californica* in Morro Bay. Though recovery strategies and actions are provided for the Morro Bay population of *C. maritimum* ssp. *maritimum*, recovery criteria are not, therefore, the species should not be considered covered by the recovery portion of the document.

In addition, this recovery plan addresses 11 species or subspecies of concern. These include the salt marsh wandering shrew (*Sorex vagrans halicoetes*), Suisun shrew (*Sorex ornatus sinuosus*), San Pablo vole (*Microtus californicus sanpabloensis*), California black rail (*Laterallus jamaicensis coturniculus*), three song sparrow subspecies of the San Francisco Bay Estuary (Alameda song sparrow [*Melospiza melodia* ssp. *pusillula*], Suisun song sparrow [*M.m. maxillaris*] and San Pablo song sparrow [*M.m. samuelis*]), saltmarsh common yellowthroat (*Geothlypis trichas sinuosa*), old man tiger beetle (*Cicindela senilis senilis*), *Lathryrus jepsonii* ssp. *jepsonii* (delta tule pea), and *Spartina foliosa* (Pacific cordgrass).

These species occur in a variety of tidal marsh habitats where they are limited by the requirements of moisture, *salinity*, topography, soil types, and climatic conditions. Adjacent

[1] With the exception of scientific names, words in italics are defined in the Glossary (Appendix G).

uplands and *ecotone* areas are also crucial habitats for many of these species. Primary threats to all the listed species include historical and current habitat loss and fragmentation due to urban development, agriculture, and diking related to duck hunting; altered *hydrology* and salinity; *non-native* invasive species; inadequate regulatory mechanisms; disturbance; contamination; risk of extinction due to small population size; and the most central threat, sea level rise due to climate change.

Current Species Status

Cirsium hydrophilum var. *hydrophilum—Cirsium hydrophilum* var. *hydrophilum* was designated as federally endangered over its entire range on November 20, 1997. It was once widespread in Suisun Marsh, but, due to habitat loss, in the last two decades has been found in only four localities: Grizzly Island, Peytonia Slough, Rush Ranch, and Hill Slough. These populations have been in decline in the 1990s and 2000s.

Chloropyron molle ssp. *molle—Chloropyron molle* ssp. *molle* was designated as federally endangered over its entire range on November 20, 1997. Though threatened by past habitat loss, persistent populations have been recorded in the tidal marshes of Napa-Sonoma, Point Pinole, Carquinez Straits, Suisun Marsh area, and northern Contra Costa County. These populations are composed of many shifting colonies or *subpopulation*s, with great variability in population size and distribution. Currently 11 populations are believed to be extant.

Suaeda californica—Suaeda californica was designated as federally endangered over its entire range on December 15, 1994. It occurred historically in high tidal marsh in portions of San Francisco Bay, where it became nearly extinct because of habitat loss. Due to several reintroductions between 1999 and 2008, it is currently known from three sites in the San Francisco Bay and scattered locations along the shoreline of Morro Bay, San Luis Obispo County.

California clapper rails—California clapper rails were designated as federally endangered on October 13, 1970. Historically, the range may have extended from tidal marshes of Humboldt Bay to Morro Bay. San Francisco Bay has been the center of its abundance. The California clapper rail now occurs only within the tidal and *brackish* marshes around San Francisco Bay where it is restricted to less than 10 percent of its former geographic range. Population numbers reached an all-time historical low of about 500 birds in 1991, then rebounded somewhat. Results of an estuary-wide survey estimated a minimum average population between 2005 and 2008 of 1,425 rails (Liu *et al*. 2009), however, population numbers declined during that period at a per-year rate of 20 percent as habitat was lost bay-wide and are currently lower.

Salt marsh harvest mouse—Both subspecies of the salt marsh harvest mouse were designated a federally endangered species on October 13, 1970. The two subspecies are restricted to the tidal and brackish marshes of San Francisco, San Pablo, and Suisun Bay areas. The southern subspecies inhabits central and south San Francisco Bay, and has suffered severe habitat loss and fragmentation. Less than 10 percent of its historic habitat acreage remains, and nearly all is deficient in its structural suitability. The northern subspecies, living in the marshes of San Pablo and Suisun bays, has also sustained extensive habitat loss and degradation, but less so than the southern subspecies.

Habitat Requirements and Limiting Factors

Cirsium hydrophilum var. *hydrophilum—Cirsium hydrophilum* var. *hydrophilum* grows in the upper middle marsh *plain* and high marsh, usually associated with small tidal creek banks that locally drain the marsh peat surface. Its extreme historical decline was due to diking and reclamation of nearly all the tidal marshes in Suisun Marsh for either agriculture or waterfowl production and sport hunting under nontidal, nearly *freshwater* management. Immediate threats include precariously low numbers, confined dispersal of its seeds in limited habitat, introduced non-native insect seed predators, and interference with its regeneration caused by non-native invasive marsh vegetation. Other threats include, disturbance, salinity changes, *genetic swamping* by non-native thistle species, and the long-term but severe threat of sea level rise in the face of limited opportunities for landward migration of habitat.

Chloropyron molle ssp. *molle—Chloropyron molle* ssp. *molle* occurs in high tidal and brackish marsh of northern San Pablo Bay and the Suisun Marsh area, and in some diked brackish marshes with limited tidal circulation. It has an affinity for the higher well-drained portions of the marsh and the edges of *salt pans*. It occurs primarily in portions of the middle to high marsh zones where the dominant vegetation includes gaps and areas of sparse vegetative canopy cover, often in association with *Sarcocornia pacifica* (pickleweed) and *Distichlis spicata* (saltgrass). It is negatively associated with dense, tall grass-like vegetation and dense or tall non-native brackish marsh vegetation. Isolation of populations by *levee*s and non-tidal marsh management limits its potential dispersal to suitable habitat. It is threatened by low population numbers, severely reduced habitat area, and reduced habitat quality. Invasion by non-native tidal marsh vegetation and hydrologic alterations to tidal *sloughs* are significant threats to remaining habitat, as is the long-term but severe threat of sea level rise in the face of limited opportunities for landward migration of habitat.

Suaeda californica—Suaeda californica occupies a narrow zone at the upper edge of tidal marsh, and prefers coarse marsh *sediments* or sheltered estuarine beaches. It requires well-drained marsh substrates, primarily sandy wave-built *berms* or ridges along marsh banks, and estuarine beaches. Because its habitat is naturally prone to destruction by wave erosion, it requires widespread populations in diverse environments over large areas to enable it to recolonize by seed after populations are destroyed by storms. It is threatened in Morro Bay by shoreline development, storm erosion, and interference with seedling regeneration caused by invasive non-native vegetation (mostly *Carpobrotus edulis* [iceplant]). Artificial stabilization of sandy shores, or other static modification of suitable estuarine shorelines, threatens the *resilience* of its population in Morro Bay, and could constrain its recovery in San Francisco Bay. In both locations, it is threatened with the long-term but severe threat of sea level rise in the face of limited opportunities for landward migration of habitat.

California clapper rails—California clapper rails occur almost exclusively in tidal and brackish marshes with unrestricted daily tidal flows, adequate invertebrate prey food supply, well developed tidal channel networks, and suitable nesting and escape cover providing *refugia* during extreme high *tides*. Non-native mammalian predators are a significant threat to the species. Lack of extensive blocks of tidal marsh with suitable structure is the ultimate limiting factor for the species' recovery; vulnerability to predation is exacerbated by reduction of clapper rail habitat to narrow and fragmented patches close to urban edge areas that diminish habitat quality. Levees provide artificial access for terrestrial predators, and displace optimal cover of high marsh vegetation. Although bay-wide invasion of exotic *Spartina alterniflora* and its hybrids with the native *S. foliosa* may threaten California clapper rails in future decades, hybrid *Spartina* currently provides habitat for the rail and eradication of exotic hybrid *Spartina* is a current threat. Contaminants, particularly methylmercury, are a significant factor affecting viability of California clapper rail eggs. Anticipated sea level rise presents a severe threat in the long-term, especially in the central and south San Francisco Bay where opportunities for landward migration of habitat are absent.

Salt marsh harvest mouse—The salt marsh harvest mouse is generally restricted to saline or *subsaline* marsh habitats around the San Francisco Bay Estuary and, with some exception, mixed saline/brackish areas in the Suisun Bay area. The distribution in tidal and diked marshes closely corresponds with the abundance of *Sarcocornia*, a dominant plant species of tidal marshes and a common component of brackish marsh vegetation. *Viable* populations of salt marsh harvest mice also appear to be limited by the distribution of high tide cover and *escape habitat*. Recurrent but shallow flooding by saline water is probably needed to maintain habitat that favors the salt marsh harvest mouse over its potential competitors. Anticipated sea level rise presents a severe threat in the long-term, especially in the central and south San Francisco Bay where opportunities for landward migration of habitat are absent.

Recovery Strategy

Recovery units have been designated for most species covered in this recovery plan (see **Table III-1**). Recovery of each listed species discussed in this recovery plan depends upon satisfying the recovery criteria within each recovery unit for the given species. Although recovery units are not designated for non-listed species, the establishment of recovery units for the listed species will assist in meeting conservation objectives for the non-listed species as well.

Maintaining well-distributed populations throughout the geographic range of each species is necessary for the long-term recovery of the listed species covered in this recovery plan. To ensure that each *taxon* can persist despite weather variations, climate change, or *catastrophic* events, the suite of microhabitats in recovery areas should represent the full range of environmental conditions in which the taxon occurred historically. The range of genetic variation must also be maintained to minimize the risk of *inbreeding depression* and allow for future evolution and resilience to environmental change. While the *Salt Marsh Harvest Mouse and California Clapper Rail Recovery Plan* (U.S. Fish and Wildlife Service 1984) focused on acquisition of lands restorable to tidal marsh, great strides have been made in that regard in the last 25 years. Therefore, this document places a greater emphasis on the restoration and management of those and other acquired lands.

Recovery Priority Numbers
Recovery priority numbers are determined per criteria published in the Federal Register (U.S. Fish and Wildlife Service 1983), as described in **Appendix B**. Recovery priority numbers for the focal listed species are:
• *Cirsium hydrophilum* var *hydrophilum* = 3C
• *Chloropyron molle* ssp. *molle* = 9C
• *Suaeda californica* = 8
• California clapper rail = 3C
• Salt marsh harvest mouse = 2C

Recovery Goals
The ultimate goal of this recovery plan is to recover all focal listed species so they can be delisted. The interim goal is to recover all endangered species to the point that they can be downlisted from endangered to threatened status. For *Chloropyron maritimum* ssp. *maritimum*, the goal is to support recovery as described in the Salt Marsh Bird's-beak (then *Cordylanthus maritimus* ssp. *maritimus*) Recovery Plan (U.S. Fish and Wildlife Service 1985*a*). For species covered by this recovery plan that are not federally listed as threatened or endangered, the goal is to conserve them so as to preclude the need for protection provided by listing.

Recovery Objectives
Within a 50-year planning period (based on estimated time to achieve sufficiently mature restored tidal marsh habitats), the Service expects that the following species recovery objectives will be met:

1. Secure self-sustaining wild populations of each covered species throughout their full ecological, geographical, and genetic ranges.

2. Ameliorate or eliminate the threats, to the extent possible, that caused the species to be listed or of concern and any future threats.

3. Restore and conserve a healthy ecosystem function supportive of tidal marsh species.

Recovery objectives for the regional tidal marsh ecosystems are implicit in the recovery of their species, and are identified explicitly in recovery strategies, actions, and restoration maps.

Recovery Criteria:
We have identified 5 recovery units: Suisun Bay Area, San Pablo Bay, Central/South San Francisco Bay, Central Coast, and Morro Bay. Recovery criteria comprise a combination of numerical *demographic* targets and measures that must be taken to directly ameliorate or eliminate threats to species in the appropriate subset of the above recovery units. They are too varied to summarize concisely here, but see section III.A.3 of this document for detailed information.

Actions Needed:

1.0 Acquire existing, historic, and restorable tidal marsh habitat to promote the recovery of listed species and the long-term conservation of species of concern and other tidal marsh species.

2.0 Manage, restore, and monitor tidal marsh habitat to promote the recovery of listed species and the long-term conservation of species of concern and other tidal marsh species.

3.0 Conduct range-wide species status surveys/monitoring and status reviews for listed species and species of concern.

4.0 Conduct research necessary for the recovery of listed species and the long-term conservation of species of concern.

5.0 Improve coordination, participation, and outreach activities to achieve recovery of listed species and long-term conservation of species of concern.

Estimated Cost of Recovery:
Priority 1 actions: $841,400,710
Priority 2 actions: $393,486,550
Priority 3 actions: $7,614,380
Grand Total: $1,242,501,640, plus costs that are unable to be determined at this time.

Date of Recovery:
If recovery criteria are met, we estimate that most listed species covered in this recovery plan could be recovered by 2063 (50 years). If the rates of global climate change and consequent sea level rise increase, more time may be required to achieve recovery.

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I. INTRODUCTION

A. Introduction to the California tidal marsh ecosystem

Balanced between sea and shore, tidal marshes form an interesting, scenic, and compelling part of the coastal landscape. Not quite land and not quite water, buffeted by tides, waves, sun, and salt, their tenacity fascinates the casual and scientific observer alike.

Technically, tidal marshes are vegetated, intertidal, sedimentary wetlands that develop in coastal environments sheltered from high wave energy, with variable ecological influence from marine or estuarine salinity (Adam 1990, Ranwell 1972). Fluctuating salinity and moisture from daily tides support vegetation and fauna adapted to the unique conditions. Tidal marsh ecosystems range from tidal marshes with salinity from about 18 parts per thousand (ppt) salt to near marine concentrations (34 ppt), to tidal brackish marshes typically diluted to salinity ranges from 3-15 ppt, less than half the concentration of seawater (National Wetlands Research Center 2007), to tidal freshwater marshes. Tidal *mudflats* continue beyond tidal marsh ecosystems, extending into the lower elevations of the tidal gradient (Pethick 1992). For purposes of this recovery plan, the term "deep" refers to the linear distance from shore to bay, as opposed to a measurement of water depth. The distribution of listed species covered in this recovery plan along the tidal gradient is shown in **Figure I-1**. A glossary of relevant terms can be found in **Appendix G**. These terms are italicized at first use in the text.

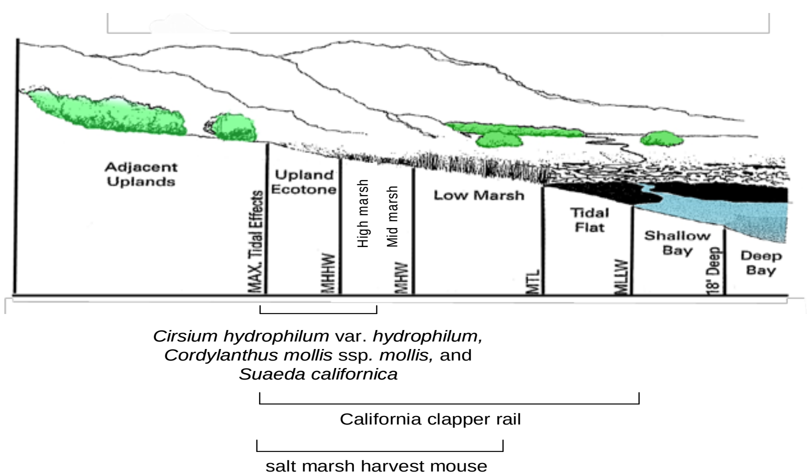


FIGURE I-1. Intertidal distribution of the focal species covered in this recovery plan (adapted from Goals Project 1999; MHHW: mean higher high water; MHW: mean high water; MTL: mean tide line; MLLW: mean lower low water).

a. Scope of the Recovery Plan

This recovery plan addresses endangered and threatened species of tidal marshes in California from Humboldt Bay to Morro Bay. Its geographic scope is based principally on the biogeographic unity of this region, common land-use threats to federally listed species, and the shared recovery and conservation requirements of many listed species and species in decline. This area corresponds with the historical distribution of the California clapper rail (*Rallus longirostris obsoletus*); all of the other species considered fall within this range. Southern California tidal marshes are ecologically distinct from those further north, and occur in a very different landscape. Morro Bay tidal marshes, therefore, set the southern boundary for the geographic scope of this recovery plan. **Figure I-2** illustrates the geographic scope of the recovery plan.

Ecosystem restoration is the principal means of recovering the listed species *endemic* to tidal marshes. The large geographic and ecological scope of ecosystem restoration for tidal marsh recovery will necessarily affect other parts and species of the estuaries. Wetland habitats around and within tidal marshes must be included in an ecosystem-based approach. Even where habitat boundaries are well-defined, strong links are established by sediment transport, nutrient exchanges, and major controlling physical variables of hydrology.

This recovery plan is an expansion and revision of the *California Clapper Rail and Salt Marsh Harvest Mouse Recovery Plan* (U. S. Fish and Wildlife Service 1984). It also covers three endangered plant species, *Cirsium hydrophilum* var. *hydrophilum* (Suisun thistle), *Chloropyron molle* ssp. *molle* (soft bird's-beak), and *Suaeda californica* (California sea-blite), and provides conservation strategies for the northernmost population of *Chloropyron maritimum* ssp. *maritimum* (salt marsh bird's-beak).

In addition to the six listed species, other species are covered that may be protected from a need for listing as threatened or endangered by appropriate tidal marsh recovery actions. Numerous plant and animal species from tidal marsh ecosystems within the geographic range of this recovery plan have become rare or are in significant decline. These species are influenced by most of the same major threats that caused the federally endangered species to be listed. These associated tidal marsh species of concern (including some populations of more wide-ranging species) include the tidal marsh shrew species (*Sorex vagrans halicoetes* and *S. ornatus sinuosus*), San Pablo vole (*Microtus californicus sanpabloensis*), California black rail (*Laterallus jamaicensis coturniculus*), three local tidal marsh races of song sparrows (*Melospiza melodia* spp.), salt marsh common yellowthroat (*Geothlypis trichas sinusus*), old man tiger beetle (*Cicindela senilis senilis*), *Lathyrus jepsonii* var. *jepsonii* (delta tule pea), and *Spartina foliosa* (Pacific cordgrass; see Appendix C).

Figure I-2. Overview of tidal marsh recovery plan area

Consideration of the larger ecosystem is also necessary to avoid potential conflicts between recovery needs of endangered tidal marsh species and those of federally listed native birds, mammals, and estuarine fish and other species of concern that lack protected legal status. Six federally listed species considered in this recovery plan that may be affected by tidal marsh ecosystem recovery include the western snowy plover (Pacific coast *population*; *Charadrius alexandrinus nivosus*), California least tern (*Sterna antillarum browni*), tidewater goby (*Eucyclogobius newberryi*), delta smelt (*Hypomesus transpacificus*), Chinook salmon (*Onchorhynchus tschawytscha*), and steelhead (*Oncorhynchus mykiss irideus*). By incorporating the recovery needs of these species in the ecosystem-wide and regional recovery strategies of this recovery plan, they are expected to benefit from tidal marsh recovery implementation rather than suffer indirect adverse impacts.

Recovery actions directed at tidal marsh ecosystems may also affect other species that are established in habitats in the modern San Francisco Bay Estuary that are related to, but distinct from, tidal marshes, such as shallow *lagoons*, salt pans, many types of diked baylands, tidal *riparian* habitat, and intertidal flats. These associated wetlands provide ecologically important habitat for migratory shorebirds and waterfowl, and federally listed western snowy plovers and California least terns. Many species that depend on wetland types other than tidal marsh in California estuaries would be affected by restoration of tidal marsh to recover endangered species. These include rare endemic insects, waterfowl, resident and migratory shorebirds, wading birds, perching birds, and raptors. A major objective of the recovery plan is to remedy the historical and ongoing causes of degradation or loss of both tidal marsh ecosystems and associated estuarine wetland habitats. Our intent is to facilitate use of recovery strategies that prevent avoidable conflicts of estuarine resource management, and that generate sustainable conditions for recovery of endangered tidal marsh species and their ecosystems. Since the publication of the *California Clapper Rail and Salt Marsh Harvest Mouse Recovery Plan* in 1984 (U. S. Fish and Wildlife Service 1984), many strides have been made in habitat acquisition for tidal marsh species. Whereas the former recovery plan focused relatively equally on habitat acquisition, restoration and management, this document places the majority of emphasis on restoration and management.

A list of common and scientific names of species covered in this recovery plan is provided in **Appendix A**. **Appendix B** illustrates the process for determining recovery priority for endangered and threatened species. **Appendix C** contains background information on associated species, such as those above, and is entitled Species of Concern or Regional Conservation Significance in Tidal Marsh Ecosystems of Northern and Central California.

In addition, as with all recovery plans, implementation of this document is entirely voluntary and relies on the willing participation of our current and future public and private partners to achieve recovery.

b. Tidal Marsh Ecosystems of Northern and Central California

Three groups of tidal marsh communities are recognized in California: southern, central, and northern (MacDonald and Barbour 1974, MacDonald 1977, Peinado *et al*. 1994). The southern

California tidal marshes are ecologically similar to tidal marshes of Baja California (MacDonald and Barbour 1974). Point Conception (Santa Barbara County) is a major geographic boundary for many tidal marsh species with subtropical affinities, such as the endangered light-footed clapper rail (*Rallus longirostris levipes*), *Monanthochloë littoralis* (shoregrass), and *Batis maritima* (saltwort). The vegetation dynamics of many southern California tidal marshes appear to be distinct from those north of Point Conception, marked by strong influences from hypersalinity, pulses of coarse river sediment deposition, and episodic constriction of tidal *inlets* and flows (MacDonald and Barbour 1974, Zedler *et al*. 1986, Callaway *et al*. 1990). Characteristic species of southern Californian tidal marshes have their northern limits at either Morro Bay—such as *Chloropyron maritimum* ssp. *maritimum* and *Atriplex watsonii* (Watson's saltbush)—or south of Point Conception, such as *Astragalus pycnostachyus* var. *lanossisimus* (Ventura Marsh milkvetch) and *Suaeda esteroa* and *S. taxifolia* (estuary and wooly sea-blites).

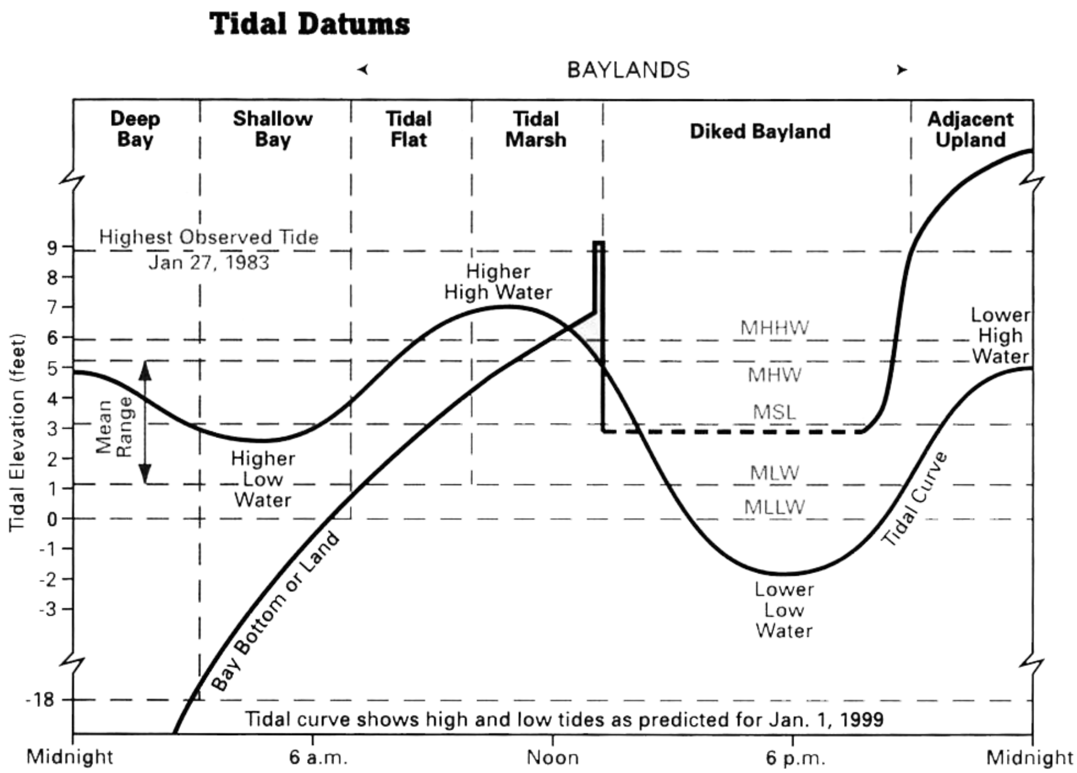
Central and northern California estuaries are linked by numerous rare species that require tidal, and brackish marsh habitats, such as the endangered California clapper rail. Other rare state or federally listed tidal marsh species include *Suaeda californica* and *Chloropyron maritimum* ssp. *palustre* (Point Reyes bird's-beak, previously known as *Cordylanthus maritimus* ssp. *palustris*). Tidal marsh endemic species include *Castilleja ambigua* ssp. *humboldtiensi* (Humboldt Bay owl's clover) and *Astragalus pyncnostachyus* var. *pycnostachyus* (coast milk-vetch).

The ecological boundaries of tidal marsh ecosystems are elastic; they change depending on the specific component species and the physical processes of the environment. Important physical factors influencing tidal marsh ecosystems include the tides and elevation relative to the tides (tidal datums; see **Figure I-3**), salinity versus freshwater inputs, sedimentation, waves and erosional energy, and soil factors, such as soil salinity, aeration, and chemical reduction-oxidation potential. Tides follow a well-marked lunar cycle and also are shaped by local geography. Many other physical factors are closely interrelated with tides and each other. For example, soil salinity is influenced by water salinity, frequency of tidal inundation, evaporation, drainage, and other factors. Even elevation, which would seem primarily derived from geology, is affected by erosional and depositional forces as well as the role of vegetation in trapping sediment and building elevation.

Tidal marsh ecosystems can be affected by landscapes and processes distant from the marsh. For example, the San Francisco Bay Estuary is the downstream end of the entire Sacramento-San Joaquin watershed, which has profound control over the estuary's hydrology and salinity.

The steep California outer coastline provides relatively few settings where tidal marshes can develop. Tidal marsh systems in California are principally found in sheltered shallow *embayments* (lagoons, *esteros*, harbors, bays), *barrier beach* systems, and drowned river valleys with relatively stable or persistent tidal inlets. Modern California tidal marshes formed near their current locations in response to sea level rise following deglaciation (Atwater 1979). The San Francisco Bay Estuary contains by far the largest tidal marsh ecosystem in California today, but the distribution and viability of many endemic salt marsh species depends on smaller marshes along the coast.

The seven major tidal marsh systems of the central and northern California coast covered in this recovery plan are Humboldt Bay, Bodega Bay, Tomales Bay, Bolinas Lagoon, the San Francisco Bay Estuary, Elkhorn Slough, and Morro Bay. These and related smaller, but ecologically important, tidal marsh systems are briefly described below.



This schematic diagram shows tidal datums for a mixed tide for the major baylands and adjacent habitats. The tidal curve and datums represent the Golden Gate. Bay bottom and land elevations are much more variable than shown. The mean range of the tide also varies around the Estuary.

FIGURE I-3. Tidal datums (reprinted with permission from Goals Project 1999; *MHHW*: mean higher high water; *MHW*: mean high water; *MSL*: mean sea level; *MLW*: mean low water; *MLLW*: mean lower low water)

B. San Francisco Bay Estuary tidal marshes

The San Francisco Bay Estuary here refers to the saline tidal waters and wetlands between the Golden Gate Bridge and the mouths of the Sacramento and San Joaquin rivers near Antioch. It is also known as the San Francisco Estuary (Goals Project 1999) and the Sacramento-San Joaquin River Estuary. It includes San Francisco Bay, Richardson Bay, San Pablo Bay (including Petaluma Marsh, Napa-Sonoma Marshes), Carquinez and Mare Island straits, Suisun Bay, Honker Bay, Grizzly Bay, Suisun Marsh, and the lower Sacramento/San Joaquin River to Browns Island. For convenience, the bays, straits, and marshlands on the Contra Costa and Solano County shores around Suisun Bay are collectively treated as the Suisun Bay area.

The San Francisco Bay Estuary contains the largest expanses of tidal marshes in California. The size and ecological characteristics of the tidal marsh of the estuary varied in post-*glacial* times (Atwater 1979, Byrne *et al*. 2001). The early 19th century tidal marsh, before substantial human impact, is estimated to have been approximately 190,000 acres (Goals Project 1999). Today, only about 40,000 acres of tidal marsh remain, much of which occurs along the bayward fringes of levees along the former edges of large tidal channels or mudflats. Mudflats are an extensive component of the intertidal zone of the San Francisco Bay Estuary today.

a. Pre-historical and early historical tidal marsh

Extensive ecosystem changes from the pre-historical and early historical ecological conditions of the San Francisco Bay Estuary have caused the decline of many tidal marsh species. Conditions of the pre-historical estuary also provide important information on habitat features and processes that need to be restored or replaced to recover endangered species.

The predecessors of modern tidal marshes probably were distributed along the now-submerged coastal shelf during periods of lower sea level during the late *Pleistocene* and early *Holocene* epochs. Much as today, these marshes probably were associated with river deltas, estuaries, and tidal inlets along former coastal plains many miles west of the modern coastline.

The San Francisco Bay Estuary, like all others in California, formed in relatively recent geologic times (10,000 to 6,000 years ago) as a result of rising sea level following the melting of continental glaciers. The Golden Gate, a stream-cut valley during glacial low sea level, became the mouth of the estuary. Tidal marshes formed along shallow margins of the estuary where sediments from major stream systems and the Sacramento-San Joaquin Rivers accumulated (Atwater 1979, Atwater *et al*. 1979).

Tidal marshes of the San Francisco and San Pablo bays in early historical times consisted of systems of highly sinuous hierarchical *dendritic* tidal creek networks and complexes of salt pans in a matrix of extensive continuous marsh plain. The structure of many of these early historical tidal marshes is recorded in detailed topographic maps produced by the U.S. Coast Survey (Grossinger 1995).

In the 19th century, Suisun Marsh consisted of extensive brackish marsh plains and tidal creeks affected by the salinity fluctuations of the mixing zone of the Sacramento/San Joaquin delta (Conomos 1979, Peterson *et al*. 1989, Grewell *et al*. 1999). The extensive marsh plains were dominated by *Distichlis spicata* (saltgrass) assemblages, consisting of *Distichlis spicata, Sarcocornia pacifica* (pickleweed), *Juncus* spp. (rush), *Schoenoplectus* spp. (bulrush) or sedge vegetation (*Schoenoplectus* spp.) in more brackish conditions (George *et al*. 1965, Wells 1995, Byrne *et al.* 2001).

Habitat diversity of early historical tidal marshes was much higher than today, as indicated by the richness and diversity of vascular plant species (Brewer *et al*. 1880, Greene 1891, 1894; Brandegee 1892, Jepson 1911, Howell 1949, Thomas 1961). Many historical tidal marsh species were indicators of ecotones. Important ecotones in and around tidal marsh include brackish marshes and marsh edges (indicators of local freshwater drainage and subsurface flows), sandy or shell-hash marsh beaches and *spits*, winter-ponded subsaline or alkaline tidal marsh borders of lowland grasslands, and *alluvial fans* and small deltas grading into tidal marsh. Early historical records and accounts also indicate that wildlife species abundance in tidal marshes was far greater only a century ago (Zucca 1954; Meiorin *et al*. 1991; Goals Project 1999, 2000).*Soils.* The marsh substrate in the western part of the estuary is mostly bay mud ("Reyes" soil series), *silty* clays, and clayey silts, with peaty organic matter accumulation in the upper marsh soil profile. Deep organic muck and peaty soils ("Joice" and other typical soil series) occur in the brackish tidal marshes of the Suisun Marsh area (U.S. Department of Agriculture 1977). Sands are relatively localized in San Francisco Bay tidal marsh soils today, unlike maritime California tidal marshes.

Remaining marshes. While most original pre-historical marshes have been destroyed or altered, one large expanse of pre-historical tidal brackish marsh has been preserved (Petaluma Marsh), and numerous smaller marsh remnants persist. These remnant pre-historical marshes are not only critically important refuges for populations of rare species, but they contain invaluable and irreplaceable information, preserving clues of the origin, development, structure, and composition of natural tidal marsh systems over several thousand years. Other important examples of remnant pre-historical tidal marshes in the San Francisco Bay Estuary include portions of Newark Slough, Bird Island, and Greco Island (South Bay); China Camp, Fagan Marsh, and Whittell Marsh (North Bay); and the Hill Slough-Rush Ranch area (Suisun Marsh).

Tidal marsh pans. Tidal marsh pans (or pannes) are shallow pools or seasonally drying flats in poorly drained areas of marsh plains. They were formerly much more common and extensive, occurring between tidal creeks, often toward the landward edge of the marsh. Large pans also occurred where wave-built berms or natural creek levees obstructed tidal drainage (Atwater *et al*. 1979), and in areas with relatively pronounced influence of stream discharges (Grossinger 1995). In general, these pans would have tidal exchange at least during extreme high tides.

Upland habitat. The interspersion of uplands and tidal marsh habitats in pre-historical estuarine conditions was significantly different from the modern estuary. Although some parts of the estuary had relatively steep upland slopes and sharply demarcated tidal marsh edges, much of the estuary edge occurred along floodplain valleys and alluvial fans, with very gradual slopes and ecotones. Beyond these ecotones were vast, deep (from shore to bay), extensively contiguous tidal marshes separated by large distances from uplands. Although natural levees along large sloughs provided emergent habitats above normal tides, these did not provide refugia for predator nests or dens, because they were submerged in spring tides and *storm surges*. Tidal marsh "islands" were common, separated from each other and the mainland by a network of tidal creeks. Native terrestrial predators, such as foxes (*Urocyon cinereoargenteus*), coyotes (*Canis latrans*), skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*), were restricted to contacts along upland and alluvial margins. Terrestrial predator access to deep, extensive tidal marshes and *marsh islands* was limited by long distances from secure, unflooded terrestrial nest and denning sites. Large tidal creeks, wide salt pans, and distance from uplands probably provided substantial barriers to dispersal of terrestrial predators in tidal marsh ecosystems.

Unlike terrestrial tidal marsh ecotones along the marsh edge, creek bank levees were extensively distributed throughout the marsh, providing well-dispersed emergent marsh and tall vegetation during extreme high tides (Johnston 1957), providing important protection from predators. The diking of major sloughs destroyed natural levee habitats on both sides of the levees via flooding. Adjacent undiked sloughs filled with sediment and sloping young marsh, eliminating natural levee-forming processes.

Barrier beaches and sand spits. Important exceptions to the lack of true terrestrial habitats within early historical tidal marshes were barrier beach and sand spit habitats, which were formerly widespread around tidal marshes of the central portions of San Francisco Bay. A barrier beach is a *beach ridge* that encloses and shelters a lagoon, tidal flat, or *backbarrier* marsh. Barrier beaches attached at one end, usually near the sand source, are called spits. Barrier beaches, beach ridges, and sand spits formed ecotones between tidal marsh and sand dunes. Beaches and spits along tidal marshes (*e.g*., Alameda, Bay Farm Island) were probably important high tide/ flood refugia for many wildlife species, provided unvegetated high tide shorebird roosts on unstable beach ridges, and created well-drained high marsh habitat for tidal marsh plants that have become rare or extinct regionally (*e.g., Suaeda californica, Atriplex californica*).

Sandy estuarine barrier beaches were concentrated around the central Bay. They were common in Richardson Bay, the northern San Francisco peninsula, and were particularly well-developed in the East Bay from Richmond to Alameda. Beaches tended to cluster around erodible sand sources, such as the Pleistocene Merritt (East Bay) and Colma/Merced (San Francisco peninsula) geologic formations (Louderback 1951). Barrier beaches often enclosed lagoons or sheltered tidal marshes. The San Francisco Estuary Institute (1998) estimated that over 37 kilometers (23 miles) of sand beach shoreline, both fringing and barrier beaches 12 to 18 meters (40 to 60 feet) wide, existed in San Francisco Bay alone before 1850 (Goals Project 1999, R. Grossinger pers. comm. 2000).

There are few barrier beaches or sand spits left in the San Francisco Bay Estuary. The extensive sand spits of the Berkeley-Oakland shoreline were largely destroyed by urbanization by 1880. One significant sand spit has re-formed at the bayward edge of tidal marshes near the mouth of San Lorenzo Creek (Alameda County) where it grew large enough to develop low dunes and *washover* fans (P. Baye pers. observ. 1991-2002). Another narrow spit has retreated along with the edge of Whittell Marsh, Point Pinole. Relatively small and short-lived shell spits and beach ridges are scattered around Brisbane, Foster City, Bird Island, Bair Island, and Ravenswood in San Francisco Bay.

Lagoons. Natural *impoundment* of local freshwater drainages, for example by barrier beaches, created lagoons, which were probably intermittently tidal and brackish depending on tides and flood events. Natural lagoon habitats have been almost entirely eliminated from the San Francisco Bay Estuary, although examples remain along the outer coast. Morro Bay is an example of a large barrier beach with a persistently open channel to the ocean, thus its title of “bay” rather than “lagoon.” One small example of a backbarrier lagoon occurs in a natural tidal marsh and narrow sand beach near Point Pinole today.

Salt ponds. Vegetated sandy marsh berms (e.g., beach ridges), or similar features made of sediments other than sand (e.g. *shell hash*), were probably important to the natural impoundment of Crystal Salt Pond, an area of drowned marsh near present-day Hayward (Alameda County) that functioned as a natural salt crystallizing pan (Atwater *et al*. 1979). A cluster of similar salt ponds extended from what is now southern Oakland to the San Lorenzo Creek area. Little is known of the original condition of these natural salt ponds because they were modified as early as 1853 to become the forerunners of the industrial solar salt industry (Ver Planck 1958). They supported thick beds of halite (up to 20 centimeters [8 inches] of crystalline salt) (Ver Planck 1958), unlike typical tidal marsh pans, and were exploited by local Native Americans. The ecological attributes of these salt ponds are inferred by comparison with industrial salt ponds (Baye et al. 1999), but were not documented by early naturalists or scientists before they were converted to highly managed artificial systems. They have been entirely eliminated in their natural state.

Berms. Natural bay/marsh edge berms along northern and eastern San Pablo Bay became the foundations for Highway 37 and the original levee alignments for the Novato (Marin County) Hamilton/Ignacio levees. Natural bay/marsh edge levees have partially reformed in the prograded marsh plain south of Highway 37.

Vernal pool/grasslands. One of the most significant types of tidal marsh ecotone, of which only vestiges remain today, was extensive lowland *alkaline*/subsaline grassland with complexes of *vernal pools*, vernal swales, and marshes. Tidal marsh edges along alluvial grasslands with clayey soils apparently developed wetland types intermediate between vernal pools and brackish salt pans. The vegetation that occurs in this ecotone includes a number of species that occur in both tidal marsh edges and subsaline/alkaline vernal pools of valley grasslands, such as *Downingia pulchella* (flatface downingia), *Astragalus tener* var. *tener* (alkali milk-vetch), *Eryngium armatum* and *E. aristulatum* (coyote-thistles), *Castilleja ambigua* (johnny-nip or salt marsh owl's-clover), *Lepidium latipes* (peppergrass), and others. Vernal pool/tidal marsh indicator species were reported from localities where vernal pools and tidal marshes apparently formed ecotones (Jepson 1911). The derelict pasturelands in the Warm Springs area near Fremont (Alameda County) are surviving representatives of this former ecotone.

Other vernal pool-bearing grasslands formerly graded into brackish tidal marshes in the Petaluma, Sonoma, and Napa valleys, and the Suisun-Fairfield-Denverton area, with remnant grasslands persisting today near Denverton, Potrero Hills, and lower Sonoma Valley (Goals Project 1999). Tidal marsh/vernal pool ecotones in valley lowlands fringing the bay from Hayward to Redwood City were formerly prevalent (from herbarium collection data, habitat and distribution descriptions from older regional floras, and historical descriptive accounts, including by J.B. Davy; R. Grossinger pers. comm. 2000), including many vernal pool/tidal marsh "dualist" species, which have adapted to both habitats. The federally endangered *Lasthenia conjugens* (Contra Costa goldfields) is one example. Today, no intact examples of intermediates between brackish tidal marsh edge pans and vernal pools exist because tides are generally excluded from low-lying areas adjacent to San Francisco Bay.

b. Historical tidal marsh loss and degradation around the San Francisco Bay Estuary

Major alteration of the San Francisco Bay Estuary tidal marshes occurred during and after the California Gold Rush. The principal causes of tidal marsh loss were diking for agricultural conversion of tidelands in the North Bay and solar salt production (and some failed agriculture) in the South Bay (Nichols *et al*. 1986). Conversion of tidelands was accomplished by construction of mud levees along the edges of marsh plains, and damming of smaller tidal creeks (Ver Planck 1958). In addition, roughly 50,000 acres of tidal marsh were filled to allow urban or commercial development (Goals Project 1999). (See section *E. Tidal marsh, conservation, restoration, and management* for details on conservation efforts).

By the early 20th century, most of San Pablo Bay and Suisun Bay tidal marshes had been diked for agriculture (Meiorin *et al*. 1991). Partial failure of levees or drainage systems caused some agricultural baylands to revert to wetland conditions. This facilitated the conversion of many parcels to managed waterfowl marshes in Suisun Marsh and solar salt ponds in eastern San Pablo Bay.

By 1989, the total area of tidal marsh in the estuary was estimated to have declined to between 12,140 hectares (30,000 acres; Dedrick 1989) and 16,187 hectares (40,000 acres; Goals Project 1999). At a minimum, estimates indicate a loss of 79 percent of tidal marsh habitat area since the 1800s, and only 8 percent of the original pre-historical tidal marshes remain (Goals Project 1999). The habitat structure and quality of modern marshes differ from their pre-historical antecedents. Thus, the ecological impact of tidal marsh loss exceeds the minimum 79 percent loss.

Agricultural alteration of former tidal areas continues around the estuary. Around San Pablo Bay, for example, replacement of low-intensity agriculture (pasture and oat hayfields) with intensive agriculture (vineyards) is occurring, and threatens to preclude tidal marsh restoration over significant areas where restoration is otherwise highly feasible.

Managed salt ponds. Managed salt ponds are shallow open water habitats with no tidal flow. These wetlands contain water all year long and can have various salinities, from low salinity (similar to seawater) to high salinity (3 times seawater salinity or more). The ponds can vary in depth from very shallow (less than 12 inches) to more than 3 feet. The solar salt industry began building managed salt ponds in the San Lorenzo area in San Francisco Bay in the mid-1850s. The 1920s and 1930s witnessed the end of extensive tidal marshes in the South Bay due to their replacement by the rapidly expanding salt industry (Ver Planck 1958). Managed salt ponds occupied more than 11,000 hectares (27,000 acres) in former tidal marsh in south San Francisco Bay. The last extensive tidal marshes of the South Bay, between Sunnyvale and Milpitas, were diked in the early 1950s (U.S. Army Corps of Engineers, San Francisco District, permit file information). Some salt pond levee failures in the early 20th century resulted in reversion to tidal marsh, which are relatively mature habitats today (*e.g.,* Whale’s Tail Marsh, Ideal Marsh, near Hayward).

The modern industrial salt pond system has been in place since the 1950s. Internal changes within the system occurred when the caustic magnesia industry left the region, causing *bittern*, a by-product of salt production, to accumulate as a waste product. When bay discharges of bittern became prohibited by law, toxic bittern was stored in former salt evaporation ponds for decades, covering hundreds of acres adjacent to tidal marsh.

Diked wetlands. Diked wetlands, such as swales in farmed baylands or managed non-tidal waterfowl marshes in Suisun Marsh, provide surrogate habitat for species that historically used habitats within tidal marshes, particularly shorebirds, wading birds, waterfowl, and salt marsh harvest mice. These are, however, artificial and sometimes unstable wetlands. In addition to long-term constraints on sustainability and costs of levee maintenance, these baylands are subject to progressive *subsidence* and related problems, such as decreasing drainage efficiency, salt accumulation, and potential for catastrophic flooding. Subsidence problems (depression of ground surface elevation below sea level) in diked baylands are due primarily to (1) aerobic microbial decomposition of organic matter in former marsh soils, (2) cessation of tidal sedimentation, and (3) rising sea level. The longer marsh soils are kept drained, the more soil organic matter may be lost, and the further they may subside. The more organic matter in the soil, the greater the potential for subsidence. For these reasons, the diked baylands in Suisun Marsh, with thick organic soils, are subject to particularly severe subsidence. As diked baylands subside below sea level, they become increasingly difficult to drain through flapgates at low tide. Adverse soil conditions, such as local accumulation of soluble iron salts, sulfides, and sodium salts, develop in undrained depressions. As diked baylands subside further and sea level continues to rise, the risk of levee failure and prolonged flooding increases. In Suisun Marsh, wetland conservation practices by current owners have kept diked wetlands wet most of the year, minimizing subsidence, however these habitats remain reliant on continual maintenance.

Extensive diking of tidal marshes and smaller tidal creeks results in reduced *tidal prism* of tidal flows, which increases sedimentation in slough beds and mudflats. The combined effects of tidal prism loss and massive discharges of sediments from hydraulic gold mining in the Sierra Nevada caused large-scale deposition of intertidal mudflats and rapid growth of fringing tidal marshes in San Pablo Bay (Atwater *et al.* 1979). This growth partially offset some of the initial losses of tidal marsh area caused by conversion, but new marshes were structurally unlike the original tidal marshes. New marshes formed on sloping mudflats drained by relatively straight, narrow channels and lacked the sinuous dendritic creeks and complex topography of pre-historical marshes. Unlike the gentle or variable gradients from marsh to upland of the pre-historical tidal marsh ecotones, recently formed marshes often have abrupt, steep contacts with levees. This artificially narrow high marsh zone resulted in a profound decline in the availability and distribution of ecotonal habitat as well as high tide cover for wildlife (Shellhammer pers. comm. 2005).

Diking of tidal marshes resulted in fragmentation of wetland habitats around the estuary. Levees and habitat destruction or alteration in areas surrounded by them created barriers between remaining tidal marsh habitats and populations. Normal channels of water and sediment movement were cut off. Levees themselves occupy considerable area, and destroyed or drastically altered the habitat around them.

Predation. The pervasive system of levees in the modern San Francisco Bay Estuary has changed the way terrestrial predators move in tidal marshes. Marshes today are linked by a network of upland dispersal *corridors* provided by levees. Most remnant or recent tidal marsh area now lies within a few hundred meters (less than 0.25 mile) from upland levees. Levees also provide nesting and denning sites for both native and non-native predators, allowing them to expand their foraging into otherwise inaccessible tidal marshes. This structural change of modern tidal marshes is the core of modern predation problems for native marsh wildlife today, as discussed later in this document.

Fill. Extensive fill of tidal marsh and mudflat for urbanization beginning in the 19th century was another major cause of tidal marsh losses in the San Francisco Bay, notably in the urban corridor from Richmond to Alameda and on the San Francisco peninsula. Expansion of airports, shipping ports, industry, commercial and suburban residential development, and landfills spread into many square miles of diked baylands, tidal marshes, and mudflats through the 1960s (Nichols *et al*. 1986, Meiorin *et al*. 1991). Unlike diked baylands in agricultural or solar salt production, this urban and suburban sprawl caused essentially irreversible habitat destruction. Fill of tidal wetlands decreased significantly between the 1980s and today with increased enforcement of new Federal and State environmental regulations (*e.g.*, Clean Water Act). Still, extensive fill of restorable diked baylands has continued (*e.g.*, Redwood City, Black Point, Fremont Airport projects), and further extensive fills are still pending (Bahia, St. Vincent's/Silvera [Marin County]).

Other changes. Other major changes in California tidal marsh conditions in the last two centuries have included rising sea level, alteration of freshwater flows due to dams and diversions, the introduction of many non-native species, and exposure of tidal marshes to a variety of chemical contaminants. These changes are discussed in greater detail in the Threats to California Tidal Marsh Ecosystems section, below.

c. Tidal marsh habitats of the San Francisco Bay Estuary

Healthy intact tidal marsh ecosystems include a variety of habitats, generally stratified in zones depending on their elevation in relation to the reach of the tides (Hinde 1954; Atwater and Hedel 1976, Peinado *et al*. 1994). Some of these habitats, or particular variations within them, have been mentioned above, such as tidal marsh pans, barrier beaches, and natural berms. A diversity of habitat types is often beneficial to wildlife, especially where it provides a range of habitats useful in feeding, breeding, or sheltering. Even for plants, which live most of their life cycle fixed in place, habitat diversity can be important in providing habitats for pollinators or controlling environmental factors such as erosion or drainage.

Low marsh. Low marshes, those below Mean High Water (MHW; see **Figure I-1**), usually occur in narrow bands along tidal channel banks and mudflat edges, providing habitat for inundation-tolerant grasses or grasslike vegetation: *Spartina foliosa* (California cordgrass) and *Sarcocornia europaea* (annual pickleweed) in tidal marshes, *Schoenoplectus* species (bulrushes and tules) and *Typha* species (cattails) in brackish marshes. Salinity is one factor in preventing other plants from growing here, and lack of drainage and associated soil conditions preclude other *halophytic* plants. At the lowest elevations, low marsh vegetation is inhibited by frequent, prolonged, often severe inundation and disturbance by waves or currents. Significant areas of marsh establishment and *accretion* (build up) over mudflats still occur in parts of the South Bay (Mowry and Dumbarton Marshes, Calaveras Point to Coyote Creek) and portions of San Pablo Bay (Doane 1999). Once vegetation is established, it often can trap and accrete sediments and plant litter, gradually building marsh elevation in opposition to forces of erosion, and may eventually build high enough to put the habitat into a higher marsh zone.

Middle marsh. Broad, nearly flat tidal marsh plains typically represent the middle marsh zone, dominated mostly by low herbaceous and weakly woody species, often with creeping growth habits. Middle marsh usually is found between MHW and Mean Higher High Water (MHHW). This zone is typically dominated by *Sarcocornia pacifica* (pickleweed) and sometimes also *Cuscuta* spp. (dodder; Howell 1949) in young/developing marshes, but consists of variable mosaics of *Sarcocornia pacifica*, *Cuscuta salina* (salt marsh dodder), *Jaumea carnosa*, *Distichlis spicata* (saltgrass) and *Frankenia salina* (alkali-heath) in established tidal marshes. While *Sarcocornia* and other plants here provide food for wildlife, there is relatively little cover and no refuge from higher tides, which completely flood the typical vegetation of the middle marsh. Besides elevation relative to the tides, marsh vegetation also is affected by drainage so that higher areas with poor drainage may have vegetation more characteristic of lower elevations.

High marsh. High tidal marsh zones (also known as upper marsh) generally occur above MHW to the limit of influence of spring tides or storm surges. In the San Francisco Bay Estuary high marsh now is often confined to natural levees along tidal creek banks and edges of artificial levees. High marsh typically occurs along elevated or better-drained sediment deposits associated with major creek banks, alluvial fans, stream mouths, and gradients to terrestrial soils. This zone may be dominated by a variety of plant species with higher plant species richness and intraspecies variability than the lower zones. It is also subject to invasion by many non-native plant species in the Bay area. High marsh often includes a *driftline* zone or *wrack* line of tidal litter, debris that can smother marsh vegetation locally and open vegetation gaps. The moist undersides of driftlines provide important microhabitats for invertebrates and are preferred salt marsh wandering shrew habitat (Albertson *in litt*. 2009*a*).

High tidal marsh often is dominated by a variable association of *Grindelia stricta var. angustifolia* (marsh gumplant), *Distichlis spicata*, *Sarcocornia pacifica*, *Frankenia salina*, but includes many other species that have declined or are regionally rare in tidal marshes. In the eastern part of the estuary, *Cressa truxillensis* (alkali-weed) is common in the high marsh zone. High tidal marsh with lower soil salinity also includes *Baccharis douglasii* (marsh baccharis) and *B. pilularis* (coyote brush), *Scrophularia californica* (California figwort), *Leymus triticoides* (creeping wildrye), *Rosa californica* (California rose), and *annual* salt-tolerant herbs. High marsh at the landward edge can also *intergrade* with freshwater marsh (cattail/bulrush/sedge marsh) or riparian thickets (willow/blackberry vegetation).

Improved drainage often facilitates the dense growth of taller forms of high tidal marsh vegetation, such as *Grindelia stricta* var. *angustifolia* and tall erect forms of *Sarcocornia pacifica*. This effectively raises the height of marsh plant stems well above the locally elevated marsh surface, adding a canopy 0.30 to 1.0 meter (0.31 to 1.09 yds) above the high marsh. This high marsh canopy may remain emergent above even the highest storm tides, providing well-distributed high tide cover (tidal refugia) for marsh wildlife. In fact, *Frankenia salina*, *Jaumea carnosa* (fleshy jaumea) and *Distichlis spicata* in this zone have been observed to be teeming with rodents during high tide events (Albertson *in litt.* 2009*a*). High marsh vegetation along tidal creek networks can trap debris in the marsh during extreme tides, providing additional important cover for wildlife (Johnston 1957).

Brackish tidal marsh. Regionally, brackish marsh refers to vegetation that develops under fluctuating mixed tidal and freshwater influence. It is not precisely defined by salinity range, but has been defined as marsh with a salinity range of approximately 3 to 15 parts per thousand (National Wetlands Research Center 2007). Brackish marsh vegetation prevails in the vicinity of river and creek discharges, for example, in the Petaluma Marsh, Napa-Sonoma Marshes, and Suisun Marsh and Bay (Baye *et al*. 2000).

Brackish marsh vegetation in the San Francisco Bay Estuary is distinguished from tidal marsh by several factors, particularly the structure and composition of low marsh and middle marsh vegetation. Low brackish marsh is dominated by *Bolboschoenus maritimus* (alkali-bulrush), *Schoenoplectus acutus* (hardstem tule), *Schoenoplectus californicus* (California tule), and *Typha* spp. (cattails). *Spartina* is a significant component of low brackish tidal marsh only west of Grizzly Bay. Middle marsh plains in brackish marshes vary in composition more than in tidal marshes, and in years of high runoff include significant abundance of bulrushes (*Schoenoplectus americanus* in Suisun area, *S. maritimus* in south San Francisco Bay and north San Pablo Bay), rushes (*Juncus arcticus* ssp. *balticus*, *J. lesueurii* and intermediates), *Triglochin maritima* (sea-arrow grass), and many herbaceous tidal marsh plants with relatively low salt tolerance. Species composition and relative abundance of plants in brackish marsh plains fluctuate significantly over precipitation cycles, and vary across *salinity gradients* along tidal reaches of rivers and creeks (Grossinger 1995, Baye *et al*. 2000, Byrne *et al*. 2001).

The highest plant species diversity is usually found in the high marsh zone in both tidal and brackish marshes (the upper marsh edge and higher creek berms or natural levees). The distinction between brackish and tidal marsh is weakest in the high marsh zone because salt influence can be locally elevated by evaporation or depressed by surface drainage or groundwater discharge. As a result, there is considerable variability and overlap in plant species of high brackish and high tidal marsh.

The Pacific Flyway

Tidal marsh and pond habitat along the coast of California is vital to migratory birds as they travel between their nesting grounds in the north and their wintering grounds in the south. The Pacific Flyway, one of four major routes in North America, is a bird migration pathway that generally runs from Alaska and the Aleutian Islands south to Mexico and South America, paralleling the coast of Washington, Oregon, and California. Other routes of the Pacific Flyway pass further inland. A network of wetlands along the flyway serves as critical resting and refueling stops for large populations of shorebirds and waterfowl. Important habitats for the migrating and wintering waterbirds include tidal flats, managed wetlands, large persistent seasonal ponds, and active and inactive salt evaporation ponds (Goals Project 1999). Migrating land birds benefit from higher marsh habitats and riparian and upland transition habitats.

The San Francisco Bay Estuary is the largest estuary on the west coast of the U.S. and one of the most important staging and wintering areas for migratory waterfowl in the Pacific Flyway. It has been designated a Western Hemisphere Shorebird Reserve Network site of hemispheric importance. During the height of migration, up to 1,000,000 shorebirds can be counted in the spring, and up to 375,000 in the fall (Page *et al.* 1989). At least 34 species occur regularly in the estuary. San Francisco Bay is the winter home for more than 50 percent of the diving ducks in the Pacific Flyway with one of the largest wintering populations of canvasbacks (*Aytha valisineria*) in North America (Goals Project 1999). Seventy percent of the birds that migrate along the Pacific Flyway spend some time each year at the San Francisco Bay.

Migration strategies are complex, with great variation both between and within species (Warnock *et al.* 2002; Greenberg and Marra 2005). Birds travel varying distances and follow different routes. They may stay for varying lengths of time to rest, feed, or overwinter in an area. The primary need of both migrating and wintering birds is food. However, different habitats serve different functions. Mudflats at low tide provide the primary foraging areas for most waterbirds; seasonal and farmed wetlands may be a secondary foraging area for several species (Harvey *et al.* 1992). Salt ponds provide important roost sites for many shorebirds. In salt ponds during high tides, Point Reyes Bird Observatory studies (http://www.prbo.org) indicate that black-bellied plovers and marbled godwits spend almost the entire time roosting, whereas semipalmated plovers, American avocets, willets, dunlins, western sandpipers, least sandpipers, and dowitchers may spend time foraging.

In addition to the San Francisco Bay Estuary, other tidal marsh areas along the Northern California coast have been identified as Important Bird Areas (Cooper 2004) including Elkhorn Slough, Bolinas Lagoon, Point Reyes, Tomales Bay, Bodega Harbor, and Humboldt Bay.

Integration of this recovery plan with conservation efforts for other species and ecosystems, including recovery plans for other species, such as western snowy plover (U.S. Fish and Wildlife Service 2007*b*) and California least tern (U.S. Fish and Wildlife Service 1985*b*), is discussed in the Recovery Strategies section below, under Ecosystem-level Strategies.

C. Other major tidal marsh ecosystems of the northern and central California coast

a. Humboldt Bay Area

Humboldt Bay is the second largest estuary on the California coast. The bay was historically over 11,000 hectares (27,000 acres) in area, and supported approximately 2800 hectares (7,000 acres) of tidal marsh. Today, fewer than 400 hectares (1000 acres) of tidal marsh remain (Shapiro and Associates 1980, Barnhart *et al*. 1992). Humboldt Bay is structurally similar to Drake's Estero (Marin County), with drowned river valleys enclosed by asymmetric double barrier spits that lack major stream discharges. Jacoby, Freshwater, and Salmon creeks discharge into the bay, creating local brackish marsh ecotones. Most of the sediment inputs to Humboldt Bay are derived from offshore, and fed by the diffuse sediment plume of the Eel River, which discharges very large volumes of fine sediment into the ocean about 15 kilometers (9 miles) south of the Humboldt Bay inlet (Barnhart *et al.* 1992). Humboldt Bay also supports extensive intertidal mudflats (65 to 70 percent of the bay), and *Zostera* (eelgrass) beds (nearly 1200 hectares [3,000 acres; Barnhart *et al.* 1992]). These mudflats are higher in silt and sand, and lower in very fine sediments, than mudflats in San Francisco Bay.

The Humboldt Bay tidal inlet was stabilized by construction of jetties at the beginning of the 20th century. The artificially open and deep inlet has enabled ocean swells to pass through with greater energy than would propagate through a shallower natural inlet, resulting in salt marsh erosion (Barnhart *et al*. 1992).

Most of the historical tidal marshes of Humboldt Bay were diked for agriculture (primarily cattle pasture) in the 1880s and early 20th century. These low-lying diked baylands support seasonally ponded or saturated wetlands and much non-native vegetation, as in San Francisco Bay. They also provide important habitat for migratory water birds. Many of the diked baylands have subsided below current sea level. There is extensive urban development along portions of the eastern historical baylands.

Early historic tidal marsh persists only in remnants, but numerous well-preserved areas occur on Indian Island near Eureka and the Mad River Slough of Arcata Bay (North Bay). Rare marsh-to-upland ecotones with coastal dunes and brackish *dune slacks* also occur along the lagoon shoreline of the North Spit and South Spit, and along the more recently formed Elk River Spit at the mouth of the Elk River, within Humboldt Bay. North of Humboldt Bay, the Mad River mouth has migrated north in recent decades, creating an enlarged linear stream-mouth lagoon, which ranges from fully tidal to *microtidal*, with associated vegetation ranging from tidal marsh to brackish and freshwater marsh. Extensive tidal wetlands also are associated with the Eel River mouth immediately south of south Humboldt Bay.

Humboldt Bay was the site of an early exotic marsh plant invasion when *Spartina densiflora* (dense-flowered cordgrass) became naturalized there in the 19th century. It was mistaken for decades as an *ecotype* of *Spartina foliosa* (Spicher 1984). *Spartina densiflora* is now one of the dominant tidal marsh species in Humboldt Bay, along with the typical dominant tidal marsh species of the central coast tidal marshes (*Sarcocornia pacifica* and *Distichlis spicata*). It concentrates in the high marsh and upper middle marsh zones. *Spartina foliosa* is not known from Humboldt Bay.

There are several historical reports of California clapper rail from Humboldt Bay (Harris 1996, Gill 1979). The species does not occur there now, and records appear inadequate to determine whether the species formerly bred there in small numbers, or whether those reports that were valid referred to vagrant birds.

Humboldt Bay supports three rare tidal marsh plants. The largest populations of *Castilleja ambigua* ssp. *humboldtiensis* (Humboldt Bay owl's-clover) still occur in Humboldt Bay tidal marshes, the *type locality*. Importantly, large populations of *Chloropyron maritimum* ssp. *palustre* (Point Reyes bird's-beak; previously known as *Cordylanthus maritimus* ssp. *palustris*) also persist there. The rare *Astragalus pycnostachyus* var. *pycnostachyus* (marsh locoweed) formerly occurred in the barrier beach/tidal marsh complex near Samoa at its northern range limit, but has not been reported there in recent years (Pickart *in litt.* 2009). *Castilleja ambigua* ssp. *humboldtiensis* also occurs at the mouth of the Mad River, and in some agricultural wetlands that are hydrologically influenced by leaking tidegates or levee overtopping. *Grindelia stricta* ssp. *blakei* (Humboldt gumplant), now considered taxonomically indistinct from the more widespread *G. stricta* var. *stricta* (Hickman 1993), occurs in local abundance in Humboldt Bay shores and tidal marshes.

Humboldt Bay presents a number of challenges to tidal marsh recovery. The bay is relatively sediment-starved compared with San Francisco Bay, especially for fine sediment. Rapid tidal sedimentation may not occur naturally following tidal flooding of subsided diked baylands in Humboldt Bay. Relatively few tidal marsh restoration projects have been implemented there (Barnhart *et al*. 1992), most by breaching of levees. Some tidal marsh restorations, such as the Bracut Marsh near Arcata, have been extensively invaded by the non-native *Spartina densiflora*, and have suffered difficulties in establishing appropriate marsh elevations.

Eel River Estuary

Information provided below is summarized from the Lower Eel River Watershed Assessment Report (Downie and Gleason 2007).

The Eel River Estuary, located 15 kilometers (9 miles) south of Humboldt Bay, is the fourth largest estuary in California. It is composed of three main areas: the Eel River mainstem, North Bay, and the Salt River. The Eel River Delta encompasses about 130 square kilometers (50 square miles), of which 10 square kilometers (4 square miles) are open sloughs, side channels, and mudflats. The tidal area of the estuary has been reduced by an estimated 1,584 hectares (3,913 acres; 60 percent) due to sedimentation and reclamation for agriculture, leaving approximately 560 acres today. Tidal marsh originally present in the estuary has been lost due to diking, filling, and other human activities. Invasive *Spartina densiflora* has been noted to be widespread in the marshes of the Eel River estuary.

The Eel River was designated as a Critical Coastal Area in 1995 and in 2002, the U.S. Environmental Protection Agency listed the lower portion of the Eel River as an impaired water body due to excessive sediment and increased temperatures that enter the estuary. The high rates of sedimentation and deposition in the lower Eel River are a result of historic and current land use practices, highly erodible soils, and a great deal of seismic activity and have resulted in:

- An overall decrease in tidal prism and shallowing of the estuary and riverbed;
- Loss of estuarine habitat area and diversity;
- Loss of spawning area for salmonids due to excess siltation of gravel beds;
- Intermittent and periodically dry reaches in tributaries and lower mainstem Van Duzen River during low summer and autumn flows;
- Highly channelized streams; and
- Reduction of riparian vegetation on stream banks.

The Eel River Estuary is home to several species of fish and wildlife, including rare plant and fish species. Currently, there is insufficient information about sensitive plants there, and a complete inventory is recommended.

Tidal marsh restoration is planned for nearly 162 hectares (400 acres) of previously reclaimed lands in the Salt River area. This is part of a larger Salt River Ecosystem Restoration Project that is utilizing upslope erosion control and riparian and tidal restoration techniques to achieve a dynamic and self-sustaining river system, incorporating low and high marsh, mud flat, and slough channel habitat. The North Humboldt Bay is managed primarily by the California Department of Fish and Wildlife (CDFW) as part of their Eel River Wildlife Area. Units within this area are managed for mixed uses including waterfowl hunting, agricultural management for Aleutian goose habitat, and fish and wildlife habitat. Local researchers have been collecting hydrological data on the tidal regimes in North Bay to use as a reference for tidal restoration projects in Humboldt Bay and the Eel River Estuary.

b. North coast stream mouth estuaries and lagoons

Between the Eel River Estuary and Bodega Harbor (Mendocino and Humboldt counties), coastal rivers and creeks form mouths that are intermediate between estuaries, with persistent tidal inlets, and non-tidal brackish lagoons, where beach ridges allow only storm *overwash* or intermittent tidal circulation following storm breaches. These mouths vary in how often tidal inlets form, depending on stream discharge, sediment supply, storms and waves. Examples of small northern California coast stream-mouth estuary/lagoons include the Mattole River, Big River, Navarro River, Garcia River, and Gualala River. Of these, only the Big River mouth typically has a tidal inlet, due to the shelter from wave energy of Mendocino Bay. The rest tend to fluctuate between non-tidal lagoon conditions in summer and fall, and tidal or *fluvial* conditions in the rainy winter-spring months. Accordingly, their wetlands include elements of freshwater riparian vegetation, lagoon beds (submerged *Ruppia*, emergent annual herbaceous vegetation), brackish tidal marsh, and tidal marsh. The Big River mouth estuary vegetation is unique among these. It supports a small true tidal and brackish marsh system with distinctive fluvial topography and channels, and includes narrow *Zostera* beds along channels and tidal marsh vegetation. The Noyo River mouth is structurally similar, but its floodplains and wetlands have been extensively urbanized. Big Lagoon and Stone Lagoon in Humboldt County are predominantly non-tidal brackish lagoons, which breach on an annual basis. Coarse gravel barrier beaches are relatively permeable and permit some subsurface exchange of freshwater and seawater, as well as infrequent overwash. Some lagoons intergrade with brackish dune wetlands (dune slacks) and with intermediate ecotonal vegetation, such as at Manchester State Park, Mendocino County.

These local estuaries, though small, provide significant bridge, or stepping-stone, populations for some rare species, and may facilitate range re-expansion of rare species. For example, the Big River Estuary supports an isolated population of the rare *Castilleja ambigua* ssp. *humboldtiensis*. These estuaries may have served as staging areas for clapper rails dispersing between San Francisco Bay and Humboldt Bay.

c. Marin-Sonoma coast

The Marin-Sonoma coastline includes many sheltered embayments (lagoons or esteros) along larger open bays. These embayments contain shallow subtidal habitats, extensive sand and mud tideflats, and significant pockets of diverse tidal marsh systems. Most tidal marshes of the Marin-Sonoma coast are relatively young (Niemi and Hall 1996) compared to the original San Francisco Bay estuarine marsh systems (Atwater *et al*. 1979). They consist mostly of pocket tidal marshes in partially submerged drainage or fault zones associated with extensive tideflats. The major tidal marsh areas of the Marin-Sonoma coast occur at Bolinas Lagoon, Drake's and Limantour esteros (Point Reyes, south shore), portions of Tomales Bay (mostly creek mouths of the south end and northeast shore), and near Doran Beach and the inlet in Bodega Harbor. Small tidal and brackish marshes also occur at small lagoons and stream mouths with intermittent inlets (*e.g.*, Rodeo Lagoon, Estero Americano, Estero San Antonio, Russian River mouth) or without inlets (Abbotts Lagoon), usually with limited tidal range.

The Marin-Sonoma coast tidal marshes have strong maritime influence, with near-marine salinity during rainless summers and relatively low suspended sediment concentrations compared with San Francisco Bay. Tidal flats dominate the intertidal zone of the Marin-Sonoma coast embayments. Brackish marshes, indicated by *Bolboshoenus maritimus* stands, occur locally, associated with fresh groundwater emergence and creeks. Tidal marshes in these systems are associated with deltas and alluvial fans of local drainages, flood tidal delta shoals, and barrier beaches. Sandy marsh sediments are relatively abundant, as are local wave-influenced marsh features and patterns. Deposition of fine sediment occurs primarily at the sheltered upstream portions of deltaic-patterned tidal marshes. These tidal marshes typically have relatively smaller, simpler tidal creek networks than those of San Francisco Bay tidal marshes. Some recently accreting marshes lack tidal drainage patterns altogether. Tidal marshes in these systems tend to occur in small patches rather than in extensive marsh complexes.

Bolinas Lagoon is a tidal embayment sheltered by the Stinson Beach spit. Its waters are primarily marine, but 10 small seasonal drainages and the *perennial* Pine Gulch Creek empty into it and establish local brackish salinity gradients. The lagoon, like Tomales Bay and Bodega Harbor, is associated with crustal movements of the underlying San Andreas Fault. It consists of approximately 405 hectares (1,000 acres) of open shallow water, an emergent flood tidal delta island with a thin cap of beach and dune sands (Kent Island), extensive mud and sand tidal flats (approximately two-thirds of the lagoon), small alluvial fans and deltas, and fringing tidal marsh. The tidal flats, channels, and marsh fringe of the backbarrier shoreline were dredged and filled in the 1960s for a large residential development and marina. Portions of the Pine Gulch delta wetlands were diked and converted to agriculture, some of which is still in cultivation. Sedimentation of Bolinas Lagoon during the 19th century has been attributed to past logging and agricultural disturbances in the lagoon's watershed (Giguere 1970), but the relative contribution of sediments from marine and local headland origin has not been fully resolved (Rowntree 1973). Although options to reduce sedimentation of the lagoon, including dredging, appeared near funding in the mid and late 1990s (Coastal Post Online 2005), a 2006 report by Marin County Open Space District stated sediment sources are of 75 percent marine and 25 percent alluvial origin, obviating the need for dredging (Marin County Open Space District 2006). In fact, a recent study by Gulf of the Farallones National Marine Sanctuary (2008) indicates that the lagoon's transition—its loss of depth and the growth of mudflats—is natural and progressing toward an equilibrium that won't lead to the loss of the lagoon or the need for dredging.

Bolinas tidal marshes consist of broad plains dominated by short turf-like vegetation in upper zones, grading to broad *Sarcocornia* zones, *Sarcocornia-Spartina* zones, and pure *Spartina foliosa* stands. Tidal flats and channels are important habitat for seals, shorebirds, and wading birds. Bolinas marshes contain populations of rare annual plants, and formerly supported vagrant California clapper rails. Bolinas was the type locality for the rare *Astragalus pycnostachyus* var. *pycnostachyus* (coastal marsh milkvetch), a species now thought to be *extirpated* there.

Drake's and Limantour esteros, located along Drake's Bay at Point Reyes, consist of extensive sandy shoals, flats, *Zostera marina* (eelgrass) beds, and a few major tidal channels with tidal marsh along the margins. Their waters are primarily marine, but numerous small streams, mostly seasonal, empty into them. *Zostera marina* beds thrive in the clear estero waters, which have low discharge of fine sediments from upland drainages and little resuspension of fine sediment from tideflats. Tidal marsh is confined primarily to the heads and fringes of the smaller bays, alluvial areas of local streams, and shoal areas fringing Limantour spit. Most tidal marshes here appear to be young, based on historical maps. Most smaller tidal marshes have relatively small and simple tidal creeks, and bayward edges that show evidence of growing shoals and bars stabilized by vegetation. Some tidelands were diked in the 19th century for impoundments, but some of these barriers have been breached and culverted (tidal flows partially restored by large pipes under roads) to restore tidal action.

Drake's and Limantour estero marshes have relatively infrequent, but abundant, stands of *Spartina foliosa*, which have expanded significantly in the 1990s (Baye pers. comm. 2004). *Spartina foliosa* was present in Drake's Estero prior to 1950 (Howell 1949), but was reported to be absent in Tomales Bay as recently as the 1970s (MacDonald and Barbour 1974). *Schoenoplectus pungens* (common threesquare bulrush) occurs along sandy marsh shorelines of Drake's Estero where fresh groundwater influence is significant. Marsh plains in the esteros are similar to those of Bolinas Lagoon, with turfy low vegetation that supports significant populations of *halophytes*, some of which are regionally uncommon or globally rare. Important populations of *Astragalus pycnostachyus* occur in Drake's and Limantour Esteros, as does most of the total population of *Polygonum marinense* (Marin knotweed). The esteros support large populations of *Chloropyron maritimum* ssp. *palustre* (Point Reyes bird's-beak), regionally rare tidal marsh ecotypes of *Castilleja ambigua* ssp. *ambigua* (johnny-nip, salt marsh owl's-clover), and the rare *Castilleja ambigua* ssp. *humboldtiensis*.

Tomales Bay is a feature of the San Andreas fault, like Bolinas Lagoon and Bodega Harbor, with a wide mouth and an incomplete sand barrier (Dillon Beach). Two relatively large streams, Walker Creek and Lagunitas Creek, establish local estuarine gradients within Tomales Bay. The largest tidal marshes are associated with the alluvial deltas of these creeks. The Lagunitas Creek delta expanded in the 19th century due to sediment deposition from watershed erosion, and most of it was diked for agriculture and railroad alignments. Similarly, the Walker Creek delta has expanded rapidly in recent decades (U.S. Geological Survey, Tomales quadrangle 1998) due to watershed erosion. Pastures in diked baylands at the south end of Tomales Bay are still maintained today, but railroad berms have been breached and habitat restored to tidal flats and tidal marsh. Tomales Bay also supports extensive tidal flats and subtidal *Zostera marina* beds, with strong influence of marine sands and seawater near the mouth. Silts dominate near-surface sediments at the head of the bay, although local headland sources of coarse sediments are common. These are eroded and re-deposited in high marsh zones. The bay margins are indented with coves and numerous gulches (intermittent and perennial stream valleys) associated with small deltas, beaches, and discrete pocket tidal marshes, riparian vegetation, or lagoons.

The importance to the health of Tomales Bay and the outer Marin coastline of restoring hydrological connectivity between Giacomini Ranch, Olema Marsh, and Tomales Bay is underscored by the relative scarcity of coastal wetlands present along the central California coastline (State Coastal Conservancy *in litt.* 2007). The California Coastal Conservancy, in September 2007, recommended funds be spent to implement the Giacomini Wetland Restoration Project on a 225-hectare (550-acre) site at the southern end of Tomales Bay, purchased in 2000 by the National Park Service (NPS) and managed by Point Reyes National Seashore. Construction efforts aimed at restoring Giacomini Ranch to wetland were largely complete as of December 2008; however, additional construction may occur in future years in the Giacomini Ranch and Olema Marsh, should the NPS and Point Reyes National Seashore Association be able to secure additional funding. These restoration activities include continued restoration of hydraulic connectivity in Olema Marsh and further lowering of high elevation areas in Giacomini Ranch, as well as continued treatment and retreatment of non-native invasive plant species. In addition, the Park Service continues to seek funding to implement the public access portion of the project.

The vegetation of Tomales marsh plains is similar to that of Bolinas Lagoon and Drake's/Limantour Estero. *Spartina foliosa* occurs primarily at the head of the estuary in the Lagunitas Creek delta marshes, but also occurs at some smaller deltas. The tidal marshes of Tomales Bay also support some of the largest populations (collectively and individually) of rare tidal marsh plants, such as *Chloropyron maritimum* ssp. *palustre* and *Castilleja ambigua* ssp. *humboldtiensis*. The tidal flats are important economically for oyster culture, and the tidal flats are important for migratory shorebirds and waterfowl.

Bodega Harbor is an embayment sheltered by Doran Beach, a low sand spit. It is structurally similar to Bolinas Lagoon, and shares a geologic association with the San Andreas fault. The harbor inlet is maintained in an open state. The lagoon supports extensive sand and mud intertidal flats, abundant subtidal *Zostera* beds, dredged subtidal areas (channel, turning basin, marinas), and local tidal marshes. Tidal marshes are associated with deltas of small seasonal streams, dredge spoil fans, and wave-built shoals and bars. Intertidal and subtidal habitats total approximately 356 hectares (880 acres; Standing *et al.* 1975). Tidal marsh area is less than 40 hectares (100 acres), most of which is recent in origin. Tidal marsh probably expanded on the Cheney Gulch delta after increased erosion due to grazing and cropping within the watershed in the 19th century. Tidal drainage systems are not well-developed, but some well-developed tidal marsh pans occur within the marsh plain of Cheney Gulch delta. Much of this marsh was destroyed by filling; the filled area is now a dredge disposal site and sewage treatment plant. In the mid-1980s, a large spill of dredge spoil was deposited over marsh and mudflats. It has since re-vegetated. Wildlife enhancement ponds with damped tidal circulation for waterbirds were excavated at this marsh in the 1990s.

The vegetation of the tidal marshes at Bodega Harbor is similar to that of Tomales Bay, but has very little *Spartina foliosa*. Local freshwater and brackish non-tidal marsh areas are adjacent to tidal marsh at the east end of Doran Beach spit, and seasonal freshwater wetlands occur in dune slacks within the Salmon Creek Beach dunes.

d. San Mateo coast

In San Mateo County and northern Santa Cruz County, small tidal marshes, often brackish in character, occur at coastal stream mouths that are open to tidal flows for much of the year. These compressed estuaries often develop small tidal marshes on alluvial flood deposits (point or channel bars, flood tidal deltas) or along gently sloping creek shorelines. The largest of these is the Pescadero Creek Estuary. Despite their relatively small size, these tidal marshes are often as rich in species as larger marshes in San Francisco Bay. They probably provide stepping stone connections for long-term dispersal and *gene* flow among tidal marsh populations along the coast. They also provide important habitat for some rare species, such as *Astragalus pycnostachyus* var. *pycnostachyus,* which has over half its current range supported by these small marshes. The federally endangered tidewater goby intermittently inhabits these stream mouth lagoons and estuaries. Examples occur at San Gregorio Creek, Pomponio Creek, Pescadero Creek, and Gazos Creek. Smaller stream mouths with similar habitat occur at Scott Creek and Waddell Creek.

e. Monterey Bay (Elkhorn Slough, Salinas River mouth)

Elkhorn Slough is the largest tidal marsh system between San Francisco Bay and Morro Bay, and was the first estuarine sanctuary in the nation. It is similar in size to Morro Bay, including approximately 600 hectares (1,440 acres) of tidal marsh within an estuary of nearly 1,000 hectares (2,400 acres; Browning 1972). Elkhorn Slough became a sheltered estuary with tidal marshes approximately 3,000 years ago. By historical times, it was associated with the mouth of the Salinas River, with a tidal inlet that constricted tidal flows and formed an intermittent beach-dammed lagoon/brackish tidal marsh (Browning 1972). Freshwater discharges from fluvial and spring sources, in conjunction with restricted tidal flows caused by the barrier beach and inlet, probably maintained a dynamic brackish-tidal marsh ecotone over much of the estuary. Thick freshwater peat deposits occur at the head of the slough, particularly McClosky Slough, now a non-tidal freshwater pond and marsh (Schwartz *et al.* 1986).

Large areas of the Elkhorn Slough tidal marshes were diked and drained for agricultural use in the 19th century. Approximately 50 percent or 405 hectares (1,000 acres) of tidal marsh habitat was lost between 1870-2003 due to human impacts (Van Dyke and Wasson 2005). Approximately 325 hectares (800 acres) were converted to solar salt ponds in the 20th century; about 62 hectares (153 acres) remain today as salt pan habitat and are managed for shorebirds and western snowy plovers (*Charadrius alexandrinus nivosus*) by CDFW (Elkhorn Slough Tidal Wetland Project Team 2007). The Salinas River mouth was diverted to the location of a flood breach, and the former channel managed as a low flow channel bypass. In the 1940s, the system was altered by the construction of a marina and a permanent large tidal inlet stabilized by jetties. The inlet increased the tidal prism of the slough, causing chronic erosion of tidal channel banks and tidal marshes, and greatly diminishing brackish to freshwater influences on the tidal marsh. Salinity in the western part of the estuary is now very close to marine salinity (Broenkow 1977). A railroad levee and tidegate at the southeastern corner of the estuary have established a local brackish microtidal marsh and shallow lagoon habitat.

Tidal marsh vegetation of Elkhorn Slough is similar to that of Morro Bay. Tidal channels lack *Spartina foliosa*, and marsh plains consist primarily of relatively prostrate *Sarcocornia pacifica*-dominated vegetation (Macdonald and Barbour 1974, Baye pers. comm. 2004). Despite the lack of *Spartina*, Elkhorn Slough supported California clapper rails from before the diversion of the Salinas River and permanent stabilization of the tidal inlet (Silliman 1915) through at least the 1960s (Browning 1972). No records of clapper rails have been confirmed there since the 1980s, and rails are presumed to have only vagrant status today (C. Wilcox pers. comm. 2005). Terrestrial habitats adjacent to Elkhorn Slough tidal marshes are dominated by heavily grazed dairy pasture. Transitional ecotones and high tidal marsh are poorly developed, disturbed, or lacking along most of the estuary margin. No rare estuarine plant populations are reported from Elkhorn Slough.

f. Morro Bay

Morro Bay is relatively small, but its estuary supports the only sizeable maritime tidal marshes (brackish and tidal marsh) on the southern central coast of California. It consists primarily of extensive tidal mudflats and sandflats with significant areas of *Zostera marina* and large tidal channels. Extensive tidal marsh plains occur primarily along the eastern shore, patterned over the convergent deltas and distributary channels of Chorro Creek and Los Osos Creek drainages. Much of the tidal marsh area developed on these deltas in historical times. Smaller fringing tidal marshes occur along the bay margin of the large barrier spit and dune system. Brackish tidal marsh ecotones occur near the deltaic mouths of Chorro and Los Osos creeks. The tidal marsh acreage of Morro Bay increased from approximately 113 hectares (280 acres) in 1895 to approximately 170 hectares (420 acres) in 1951. Sedimentation and marsh growth declined by the 1960s, and there is an ongoing local effort to reduce sedimentation of the bay. Morro Bay has an inlet stabilized by a jetty for navigation. Historically, it naturally supported a permanently open tidal inlet that permitted strong tidal flushing (Gerdes *et al.* 1974). Periodic dredging of the navigation channel at the tidal inlet is located away from tidal marsh areas (Gerdes *et al*. 1974).

Morro Bay tidal wetlands have experienced relatively minor alteration by historical diking and filling compared with other estuaries in central and northern California. They retain excellent examples of brackish riparian ecotones, high marsh/upland ecotones (especially diverse marsh-dune ecotones), and many types of salt pans. Relatively large salt pans, composed of sandy/silty flood deposits and *hypersaline* depressions, occur near the banks of Los Osos Creek. Many smaller ponded depressional pans, ranging from brackish to slightly hypersaline conditions, are widely distributed within and along the edges of the marshes of the Chorro Creek and Los Osos Creek deltas. These smaller pans provide high tide foraging roost habitat for waterfowl and shorebirds, and flats of the larger pans provide nesting habitat for killdeer (*Charadrius vociferus*; Baye pers. comm. 2004). Unique features occur at the south end of Morro Bay where the large, steep mobile dunes cause marginal bulge and rapid uplift of extensive fractured marsh peat blocks as the dunes advance (Baye pers. comm. 2004). These peat blocks become colonized by high marsh and upland (dune ecotone) vegetation. Numerous freshwater seeps from the dunes also establish steep brackish marsh ecotones in the coves between dunes.

The community of Los Osos gets its water entirely from the underlying groundwater, predominately the lower aquifer. The lower aquifer is presently experiencing seawater intrusion at approximately 460 acre-feet per year. The portions of the aquifer that have already been intruded are likely permanently lost from the freshwater supply (San Luis Obispo County 2008*a*).

Like other central and northern California tidal marshes with sandy substrates and influenced by marine tidal waters, most of the tidal marsh vegetation at Morro Bay is low and turf-like, dominated by short *Sarcocornia pacifica* and *Triglochin concinna* (creeping arrow-grass) in the middle marsh plain; and *Distichlis spicata*, *Frankenia salina*, and other species near creek levees. *Spartina foliosa* is notably absent (MacDonald and Barbour 1974); pioneer tidal marsh vegetation is often *Sarcocornia pacifica*. Morro Bay supports the only remaining natural population of *Suaeda californica*, and a *disjunct* population of *Chloropyron maritimum* ssp. *maritimum* that exhibits some intermediate traits of the northern subspecies *palustris* (Chuang and Heckard 1986). Morro Bay tidal marshes support other rare or unique botanical features. The northernmost tidal marsh population of *Lasthenia glabrata* ssp. *coulteri* (Coulter's goldfields), a subspecies of smooth goldfields, occurs near Sweet Springs Marsh. The northernmost population of *Atriplex watsonii* (Watson's saltbush) and the only tidal marsh populations of *Solidago confinis* (southern goldenrod) extant in California occur there.

Morro Bay tidal marshes have no major intertidal non-native plant invasions. *Lepidium pubescens* (white-top), a European weed similar to *Lepidium latifolium* (perennial pepperweed), is a problem in brackish upper reaches of the tidal marsh where seed washes down from higher in the watershed (M. Walgren pers. comm. 2005). *Carpobrotus edulis* (iceplant), *Eucalyptus* trees, and various other non-native trees and shrubs (*Myoporum* spp. and *Cupressus macrocarpa*) cause locally intensive invasions near the marsh edge.

The extensive tideflats and salt pans of the Morro Bay wetlands support abundant waterfowl and shorebirds of the Pacific flyway, including the largest tidal flat and shallow lagoon areas between Elkhorn Slough (Monterey County) and Mugu Lagoon in southern California. Morro Bay has been designated an Important Bird Area (IBA; National Audubon Society 2009), with up to 20,000 shorebirds estimated to use the tidal habitat there (Page and Shuford 2000). From 59 to 89 bird species have been observed. Shorebirds (particularly willets [*Catoptrophorus semipalmatus*], marbled godwits [*Limosa fedoa*], western sandpipers [*Tringa solitaria*], curlews [*Numenius* ssp.], dunlins [*Caladris alpina*], dowitchers [*Limnodromus* ssp.], and sanderlings [*Caladris alba]*) are the most abundant, followed by waterfowl (dominated by black brant (*Branta bernicla*), but commonly including pintails (*Anas acuta*), green-wing teal (*Anas crecca*), lesser scaups (*Aythya affinis*), widgeons (*Anas americana*), ruddy ducks (*Oxyura jamaicensis*), and buffleheads (*Bucephala albeola*). An important heron rookery occurs at Fairbank Point toward the north end of the bay, supporting up to 74 great blue heron (*Ardea herodias*) nests and 100 black-crowned night heron (*Nycticorax nycticorax*) nests (Gerdes *et al*. 1974). Morro Bay also supported a small historical population of clapper rails, which has been interpreted as either California clapper rails or light-footed clapper rails (*Rallus longirostris levipes*) (Brooks 1940), but is now extirpated. California black rails (*Laterallus jamaicensis coturniculus*) occur in Morro Bay tidal and brackish marshes (Gerdes *et al*. 1974).

Tidewater goby have not recently been found in Morro Bay itself, but occur regionally in nearby creek mouths (U.S. Fish and Wildlife Service 2005), and have the potential to colonize in Morro Bay. The waters and eelgrass beds of Morro Bay are important habitat for a variety of fish species, including Pacific herring (*Clupea harengus*), pipefish (*Syngnathus* sp.), and rays (Order Myliobatiformes).

Terrestrial habitats that support endangered species occur adjacent to, and contiguous with, Morro Bay tidal marshes. These include Holocene dunes (sand deposits of the barrier spit), important habitat for the threatened western snowy plover (*Charadrius alexandrines nivosus*), and ancient Pleistocene dunes of the eastern bay (sandy brownish soils with coastal chapparal and scrub). The Pleistocene dunes provide habitat for the endangered Morro Bay kangaroo rat (*Dipodomys heermanii morroensis*; U.S. Fish and Wildlife Service 1999) and the endangered Morro shoulderband snail (*Helminthoglypta walkeriana*; U.S. Fish and Wildlife Service 1998), which can occur in non-native *Carpobrotus edulis* (iceplant) vegetation of dunes adjacent to tidal marsh.

D. Existing threats to California tidal marsh ecosystems

Conditions and factors that threaten most or all of the species covered in this recovery plan are described below. These are often threats to the tidal marsh ecosystem as a whole. Threats to individual tidal marsh species may exist as well, and are described under Reasons for Decline and Threats to Survival in the respective species accounts in Chapter II.

Section 4(a)(1) of the Endangered Species Act identifies five major categories of threats, which are considered when a species is listed. These are (a) the present or threatened destruction, modification, or curtailment of its habitat or range, (b) overutilization for commercial, recreational, scientific, or educational purposes, (c) disease or predation, (d) the inadequacy of existing regulatory mechanisms, and (e) other natural or manmade factors affecting its continued existence. Threats currently facing the ecosystem in general are categorized below according to these five factors. Major categories within these general threats include: habitat loss and fragmentation, habitat degradation and disturbance, invasive non-native species, climate change, and risk associated with small population size.

Factor A: The Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range. (See section *E. Tidal marsh, conservation, restoration, and management* for details on conservation efforts).

<u>Habitat loss and fragmentation</u>

Habitat loss. The greatest historical and present threat to tidal marsh ecosystems and the species they support is the destruction and alteration of habitat. Loss of coastal wetland habitat to urban and industrial development has been extensive in California, with 90 percent of these wetlands being lost since settlement of the San Francisco Bay region (Goals Project 1999). Roughly 90 percent of original tidal marsh habitat has been altered or destroyed in Humboldt Bay (A. Pickart pers. comm.). Only eight percent of the original pre-historical tidal marshes remain in the San Francisco Estuary (Goals Project 1999). By 1930, one-half of the historical tidal marsh in the South Bay had been converted to salt ponds by Leslie Salt Company (later purchased by Cargill Incorporated). Leslie Salt expanded its operations to the North Bay in 1952, where it ultimately converted 14,500 hectares (36,000 acres) of diked agricultural baylands into salt ponds (Goals Project 1999). Many of the last remaining large tracts (hundreds of contiguous acres) of undiked tidal marsh in the South Bay were converted to salt ponds in the early to mid-1950s (U.S. Army Corps of Engineers, San Francisco District, aerial photograph and map archives). Effectively irreversible conversion of former tidal marsh to residential and industrial areas around Oakland, Alameda, Foster City, and Redwood City was complete by the 1960s, although some residential extension within diked baylands of Redwood City continued through the 1990s. Presently, applications for private development around the Bay occasionally occur, which threaten to result in further tidal marsh habitat loss.

Habitat fragmentation and edge effects. Habitat fragmentation occurs when tidal marsh habitat, once extensive and contiguous, is divided into relatively small discontiguous fragments. Fragmentation complicates the impact of habitat loss by reducing tidal marsh populations, not to one contiguous population a tenth of its former size, for example, but to many isolated tiny populations on habitat fragments of varying size, shape, and condition. In addition to the difficulty of supporting a viable population on a habitat fragment of limited area, marsh fragments may lack the full range of habitat features needed by a species throughout its life cycle. For example, a fragment might contain feeding and nesting habitat for the salt marsh harvest mouse, but completely lack refuge from high tides or storm surges.

As remaining marsh areas are reduced in size, *edge effects* become increasingly severe. Smaller populations and smaller (or narrower) habitats have less ability to absorb or buffer adverse impacts from outside influences, such as predation, human disturbance, or pollution.

Local extinction rates in habitat fragments generally increase as habitat area decreases and distance from neighboring populations increases (Hanski 1999). Correspondingly, breeding populations of species with limited population densities and dispersal, such as the California clapper rail, have generally been lost from smaller and more isolated tidal marsh fragments, and are at risk in many fragments where they still persist.

Habitat degradation and disturbance

The quality of remaining tidal marsh habitat for tidal marsh species in central and northern California has been altered and degraded by human actions, including diking, habitat conversion in buffering lands, flow and salinity alteration, contamination by pollutants, and actions causing disturbance. Habitat fragmentation may be considered a form of habitat degradation. Also, invasion by non-native species often results in habitat degradation or disturbance. Many factors cause habitat degradation or disturbance in California tidal marshes; some of the most common are summarized below.

Diking. As discussed earlier in this chapter, many hundreds of miles of levees disect former tidal areas of the San Francisco Bay Estuary and Humboldt Bay. Most were first constructed years ago to create salt ponds, allow agriculture, or for purposes related to flood control. Levees require periodic maintenance, typically by clamshell dredges that deposit bay spoil material on the tops and sides of the levees.

Maintenance of levee systems continues to isolate tidal marshes into areas too small to develop complex tidal drainage networks. Levees ordinarily hinder normal circulation of tidal flows and drainage, with the result that diked areas have less tidal amplitude and flushing, and are either drier or wetter (or both, seasonally) than undisturbed marsh. Vegetation and soils are altered, for example, by persistent inundation or evaporative concentration of salts. Drying of marsh sediments has resulted in increased decomposition of organic matter in the soil or peat, causing subsidence of the ground surface. Groundwater pumping may also contribute to subsidence. Many diked areas are today substantially below sea level as a result, in some areas by more than 6 meters (20 feet).

Diking is often associated with artificial channelization, where drainage or flood flows constricted by levees are directed in straightened, shortened, deepened, and otherwise altered channels to the bay. Channelization, along with diking and fragmentation of marsh into small areas, has led to a reduction in the amount and complexity of natural creek channels in remaining tidal marsh, which normally provides important habitat for many tidal marsh species. Natural tidal channels require normal tidal flows and adequate space and drainage to develop.

Levees are now the only upland edges of many tidal marsh remnants. Levees generally are too steep, narrow, and weedy to be high quality high-tidal refugia for tidal marsh animals. Levees also greatly facilitate site access for both people and predators. Mammalian predators, especially non-native red foxes (*Vulpes vulpes*), Norway rats (*Rattus norvegicus*), and domestic cats use levees as movement corridors and denning/nesting sites (American Bird Conservancy 2006). In many small remnants of tidal marsh in the San Francisco Estuary, levees allow predator access across the entire remaining habitat. Levees allow predators to travel distances out into baylands that would otherwise be naturally isolated from frequent contact with terrestrial predators. Access by people and pets also creates disturbance that may affect sensitive species.

Loss of ecotones. Prior to settlement of the bay area by Europeans, tidal baylands graded landward into transitional zones (or ecotones) of low-lying moist grassland or willow thickets, including some vernal pool grasslands, and then into upland areas (Goals Project 1999). Appropriately sized and structured ecotones are a critical component of California clapper rail and salt marsh harvest mouse habitats, especially in urbanized settings. These areas provide two primary benefits to adjoining wetlands by (1) absorbing and deflecting disturbances originating in upland areas, and (2) providing upland refugia during high tide and flood events, both of which ultimately influence habitat quality and carrying capacity of tidal marshes for clapper rails and other marsh birds.

In particular, the presence of a broad marsh/upland ecotone, which may be the only escape refugia during high tide situations, is crucial to the viability of small mammals, such as salt marsh harvest mice. In flood years, these areas may be responsible for harboring most of the surviving mice, which then repopulate the adjacent marsh in future years. Without adequate ecotone, viability of salt marsh harvest mouse populations will likely be low in tidal marshes, particularly in light of projected climate change (Albertson *in litt.* 2009*a*).

Much of the historical development around the bay has not allowed for these buffering transitional zones between urban or industrial areas and tidal marshes. Refuse dumped or blown in from adjacent urban areas also affects habitat quality by attracting predators or damaging habitat. Even in rural areas, transitional and upland vegetation has been replaced with non-native annual grasses, and livestock graze up to and sometimes into the marsh. Consequently, there has been extensive loss of high marsh-to-upland transition area and ecotones, and urban influences and disturbances frequently border directly on remaining tidal marsh. Shellhammer (unpubl. research) found that the adjacent upland edge (*i.e.,* the ecotone between marsh and upland) exists today in only 2.5 percent of the South Bay's edge.

Disturbance. Numerous routine human activities that can cause disturbance to sensitive species, include: for example, maintenance activities for levees, flood control, dredge locks, pipelines, and utility rights-of-way; vegetation control activities; recreational uses including hiking, biking, dog-walking, bird watching, horseback riding, and water sports such as boating and kiteboarding; human and domestic and feral animal incursion from adjoining developments; ditching or spraying for mosquito control; and use of all-terrain/off-road vehicles in baylands (Goals Project 1999). Trampling by livestock and other animal populations sometimes causes physical disturbance to tidal marsh and ecotonal habitats.

Though the U.S. Fish and Wildlife Service recognizes the value of allowing recreational trails as an effective means to foster appreciation for tidal marsh species, quite often these trails attract predators, disturb breeding of sensitive species or fragment or otherwise degrade habitat, especially in the absence of proper management.

***Salinity changes*. ** Both fresher and more saline conditions alter tidal marsh habitats, often with adverse consequences to the species that live there. Diking can alter salinity conditions, both in water and soils. In fact, concentrating salt was a primary reason for some levee construction. Diking reduces salinity when it blocks entry of the tides and impounds rainfall or freshwater drainage. Salinity can be controlled in some diked habitats with flow control structures (tide gates).

Wastewater discharges, which are usually lower in salinity due to pollutant discharge requirements pursuant to Federal and State water quality laws, can alter natural salinity levels in tidal waters. For example, freshwater discharges from the San Jose/Santa Clara Water Pollution Control Plant have led to the conversion of approximately 120 hectares (300 acres) of tidal marsh to fresh and brackish marsh near the southern end of San Francisco Bay since about 1970 (H.T. Harvey and Associates 1997), which has been detrimental to the clapper rail and other species. The habitat conversion trend reversed between 2006 and 2008, resulting in a net increase of 31 hectares (77 acres) of tidal marsh. No more recent data on habitat conversion since 2008 are available. Additional acreage where the marsh vegetation has not been fully converted may also have been degraded by these discharges. Wastewater discharges and other urban runoff alter freshwater input to varying degrees around the San Francisco Bay and other estuaries.

Another form of salinity alteration is occurring in Suisun Marsh. Under natural conditions, Suisun Marsh salinity would be closely linked with Delta outflows and freshwater inflows from other creeks in the Suisun Marsh watershed, with considerable seasonal variation, from nearly fresh in the spring, to brackish in the fall. During high rainfall years, lowered summer soil salinity would favor conversion of middle tidal marsh zones to *Schoenoplectus*-dominated vegetation, causing decline of *Sarcocornia-Distichlis* vegetation. During dry years, *Sarcocornia-Distichlis* vegetation would re-establish dominance and *Schoenoplectus* vegetation would retreat (Suisun Ecological Workgroup 2001). In 1988, the California Department of Water Resources and the U.S. Bureau of Reclamation constructed and began operating the Suisun Marsh salinity control gates (SMSCG) in Montezuma Slough to mitigate for increased Suisun Marsh salinities caused by the operation of the State Water Project and Central Valley Project and other upstream diversions (www.water.ca.gov/suisun/facilities.cfm). Though use of the gates has been minimal since its initial set-up, when used, operation of the salinity control gates has widespread effects on water and soil salinity, raises water levels in the marsh, and reduces tidal range and circulation. Artificially stabilizing salinities at low levels during the summer and fall subdues the climate-driven pattern of vegetation fluctuations. These low salinity levels are harmful to species that favor plant communities of higher or more variable salinity, especially plants that require bare areas in salty soils for colonization. In 1999, water quality standards that relate to the operation of the Suisun Marsh salinity control gates were modified by the State Water Resources Control Board in light of broader estuarine ecological considerations (State Water Resources Control Board 1999). Water quality standards for salinity were modified in western Suisun Marsh to allow greater climate-driven fluctuation. However, the artificially narrow low salinity range is still enforced in eastern Suisun Marsh.

Gradual changes in salinity in California estuaries are projected to result from sea level rise pushing saline ocean water further inland (Knowles 2002, Knowles and Cayan 2002, Wilkinson 2002). Sea level rise is an ongoing process precipitated by climate change. See the paragraph below on climate change and sea level rise.

<u>Invasive species</u>

One of the most pressing threats to the tidal marshes of California is invasion and modification of the ecosystem by non-native species. Non-native plant species capable of living in tidal marshes have invaded and profoundly altered vegetation, or threaten to do so, over extensive areas. Non-native plant species of greatest concern are those that (1) become so abundant that native plant species are diminished significantly in population size or displaced altogether, (2) become extensively dominant or develop nearly monotypic (single-species) stands, (3) colonize habitats naturally lacking in vascular plants, such as tidal flats, or (4) are annuals that thereby provide no escape cover during winter high tides because they are simply a plant skeleton that predators can see through. Invasive species cause major impacts to the structure of vegetation, species competition, and composition within communities, and even influence the soil-building properties of the tidal marsh ecosystem. Plant invasions harm tidal marsh animal populations by altering food availability or habitat structure. Invasions by non-native animals also affect tidal marsh species. To date, most animal impacts of concern have been those of non-native predators, such as red fox and Norway rats, on native prey species.

Invasive Spartina. Of several invasive non-native *Spartina* species (**Figure I-4**) found in San Francisco Bay, the most abundant is a hybrid formed between *Spartina alterniflora* (smooth cordgrass) and the native *Spartina foliosa*. Hybrids of *Spartina alterniflora*, native to tidal marshes of the Atlantic coast and Gulf of Mexico, have invaded native tidal marshes in the San Francisco Bay Estuary. Outlying infestations in Bolinas Lagoon and Tomales Bay have been found. A separate and earlier invasion at Willapa Bay, Washington State, resulted in extensive conversion of tidal mudflats to dense, continuous, monotypic *S. alterniflora* marsh (Mumford *et al*. 1990). Unless controlled, invasive hybrid *Spartina* has the potential to continue to spread throughout the San Francisco Estuary, and to transform its tidal ecosystems (Ayres *et al.* 2003, 2004*a*, 2004*b*; Zaremba 2004). It also had the potential to spread and invade Pacific tidal marshes and mudflats south and north of the Golden Gate. However, with control efforts nearly complete, it is possible that the invasion will be controlled (see Conservation Efforts section).

Spartina alterniflora is a coarse perennial grass that re-sprouts annually from thick *rhizomes* (underground stems), and spreads rapidly to form extensive colonies on mudflats, marshes, tidal creeks, and even rip-rap. It reproduces from seed and also by re-growth from rhizome fragments. In the bay region, it is much taller and faster-growing, grows more densely, and occupies a wider tidal range than the native *S. foliosa* (Callaway 1990, Daehler and Strong 1996). More information on native *Spartina* is found in the *S. foliosa* species account in Volume II of this recovery plan.

Spartina alterniflora was reportedly introduced to San Francisco Bay around 1976 from seed collected in Quinby, Virginia, and cultivated at Lafayette, California, for bank stabilization. The non-native *Spartina* hybridized with native *S. foliosa*, forming proliferations of hybrid plants (*hybrid swarms*) that spread extensively and rapidly during the 1990s (Grossinger *et al*. 1998). Hybrid plants may exhibit the large size and high growth rate more typical of *S. alterniflora*. These hybrids swamp native *S. foliosa* stigmas with hybrid pollen and crowd out *S. foliosa* plants, with the potential to threaten this recently common species with genetic assimilation (Daehler and Strong 1997, Ayres *et al.* 1999). Sloop *et al.* (2008) found that populations of later generation hybrids and their seedling progeny were almost two-fold more homozygous than early generation hybrids. They posit that evolved self-fertility contributed substantially to the rapid spread of hybrid *Spartina* in San Francisco Bay. As most remaining *Spartina* in the San Francisco Bay is not *S. alterniflora*, but the hybrid, from this point forward in the document, "invasive Spartina" shall be synonamous with the *S. alterniflora* x *S. foliosa* hybrid. Change in the distribution of the infestation is now so rapid that it is not useful to detail it here; moreover, control efforts are nearly complete. Instead, interested parties should consult recent monitoring reports (*e.g.,* reports of the interagency's Invasive Spartina Project http://www.spartina.org/).

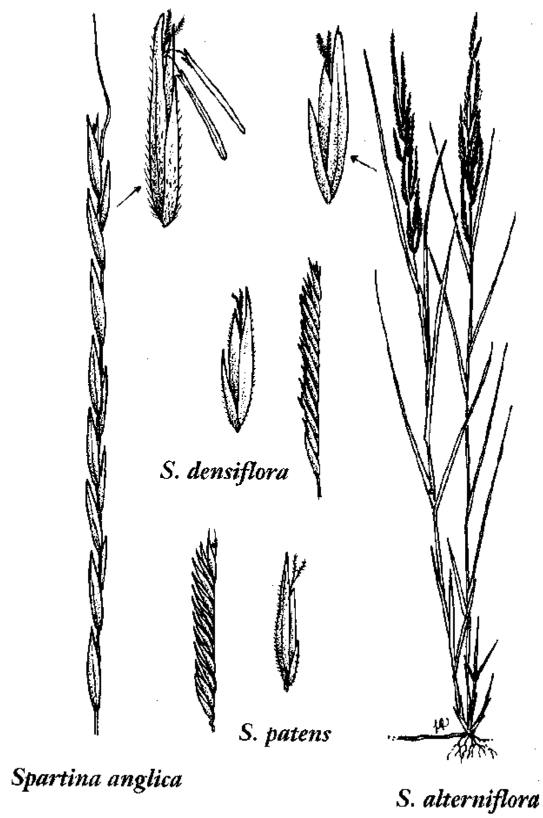


FIGURE I-4. **Invasive *Spartina*** (from Invasive Plants of California's Wildlands, edited by C.C. Bossard, J.M. Randall, and M.C. Hoshovsky, with permission from University of California Press © 2000

Some hybrids are cryptic, appearing morphologically similar to native *S. foliosa* and behaving similarly. However, many *Spartina* hybrids markedly alter tidal marsh habitat. With high biomass production and sediment trapping, *S. alterniflora* and hybrids are capable of accretion at unusual rates. The sediment-trapping efficiency of *Spartina* stands is proportional to density and height (Gleason *et al.* 1979, Knutson *et al*. 1982); and the density and biomass of invasive *Spartina* stands in San Francisco Bay exceeds that of the native *S. foliosa* by six to seven times (Callaway 1990). Invasive *Spartina* resists erosion and promotes sediment-trapping and marsh spread much more effectively than native *Spartina* in the South Bay (Josselyn *et al.* 1993, Newcombe *et al*. 1979). The invasion has resulted in the evolution of novel hybrid forms that invade tidal mudflats and tidal creeks well below the ordinary tidal elevation limits of native *Spartina* (as low as 0.3 meter [1 foot] above mean low water) and higher elevation marsh plain habitats above the elevation range of native *Spartina* (Daehler *et al*. 1999, Baye 2004). Invasive *Spartina* is capable of producing much more biomass than native tidal marsh vegetation, and can form extensive, thick wracks of tidal litter that can smother vegetation on marsh plains and the high tide line, as well as trapping sediment. The density, height, productivity, and intertidal elevational range of invasive *Spartina* enable it to convert areas of mudflat and small tidal creeks to areas of nearly solid marsh, with relatively few small tidal creeks. Invasive *Spartina* is filling in both higher and lower elevations once free of *Spartina* at Elsie Roemer Marsh (Alameda Island; Nordby *et al.* 2004). One long-term result of habitat alteration by invasive *Spartina* is concurrent decline of mudflats. Another possible long-term result is that the hybrids could compensate for sea level rise by accelerating marsh accretion (see Daehler and Strong 1996); however, there might be other unanticipated adverse ecosystem-level impacts, in addition to those noted above, if invasive Spartina were intentionally introduced at a large-scale. A third possible long-term result is that cryptic hybrids could form a new equilibrium in the Bay. However, too many uncertainties exist to accurately determine what will occur.

Expansion of invasive *Spartina* over mudflats and marsh plains would be likely to destroy or degrade habitat for numerous tidal marsh plants and animals, including estuarine fish, migratory shorebirds, and waterfowl. However, invasive *Spartina* benefits the rail by providing habitat for breeding and high tide refugia. (See more on this below, under the rail species account.) The long-term impacts of invasive *Spartina* are unknown but may include negative impacts to other tidal marsh species depending on the potential future outcomes of the invasion. In particular, species that rely on open mud or salt *pan* areas likely to be invaded, such as the old man tiger beetle (*Cicindela senilis senilis*) and other tiger beetles, could be adversely affected by invasive *Spartina*. Species that rely, directly or indirectly, on mudflats would likely be reduced in numbers or distribution by development of extensive monotypic hybrid *Spartina* stands.

Invasive *Spartina* is likely to compromise tidal restoration projects wherever abundant seed or pollen sources occur near receptive habitats, such as new tidally restored sheltered mudflats and young marsh. In order to achieve effective restoration, eradication and revegetation need to be planned in a way that restores native ecosystems while protecting listed species, such as the clapper rail, that currently depend on invasive *Spartina*.

In 2004, it was acknowledged that while invasive *Spartina* held short-term value to the rail, those benefits were outweighed by the long-term ecosystem altering effects of invasive *Spartina* invasion. Following agreement of the resource agencies, a treatment program began in 2004 to eradicate all sources of invasive *Spartina*. At that time it was believed that eradication of invasive Spartina could be accomplished with minimal impact to the clapper rail. Subsequently, an interagency cooperative program called the Invasive Spartina Project (ISP) embarked upon a major effort to eradicate invasive *Spartina* in the San Francisco Bay Estuary. The ISP has reduced the coverage of invasive *Spartina* baywide by more than 90 percent since its peak coverage in 2005-2006 (Olofson *in litt.* 2011). However, a substantial decrease in rail numbers has been observed since the physical breakdown of treated invasive *Spartina*, due to loss of its use as refugial habitat (Takekawa *et al*. 2011). Though invasive *Spartina* is an ecosystem threat, current data indicate that eradication in occupied habitat is a threat to the clapper rail. However, efforts are underway to assess if this threat to the clapper rail can be ameliorated with immediate replacement of refugial habitat following eradication. While eradication efforts were aggressive and widespread from 2005- 2009 with concurrent declines in clapper rail numbers, treatments have subsequently been modified for a more phased, focused approach to reduce threats to clapper rails. Additional monitoring and restoration efforts have been integrated into the eradication program to ameliorate the adverse effects of treatment.

Other non-native species of *Spartina* have become established in California tidal marshes, although most are as yet at a lower level of invasion than *Spartina alterniflora*, and none seems likely to hybridize so readily with native *Spartina*. The Invasive Spartina Project has already targeted some of these other non-native *Spartina* infestations for control. Other *Spartina* species present are:

- *Spartina patens* is native to tidal marshes of the northern Gulf of Mexico and Atlantic coast. It is a fine-stemmed, creeping, matted grass, which forms dense turfs with tussocky (clumping) peaks in middle marsh plains and high marsh zones of tidal or brackish marshes (Blum 1968). It spreads by creeping rhizomes and by seed (Mobberly 1956). *Spartina patens* increased exponentially after introduction to the Siuslaw Estuary in Oregon (Frenkel and Boss 1988). It has been present at Benicia State Recreation Area (BSRA; also called Southhampton Marsh, Carquinez Straits) since at least the 1960s (Munz 1968). There it occurs as an extensive, diffuse, and relatively continuous *colony* on the marsh plain adjacent to the south bank of a tidal creek, and as numerous, dense, discrete, essentially monotypic colonies on the marsh plain (P. Baye with D. Smith, S. Klohr pers. observ. 2000). The distribution and abundance of *S. patens* colonies at BSRA suggests that it has been reproducing both by seed and clonal growth for many years, and is continuing to spread. Two other populations of *S. patens* have been reported in the estuary; one from San Bruno has not been confirmed (D. Smith pers. comm. 2000). The other is lower Tubbs Island and Tolay Creek in the San Pablo Bay National Wildlife Refuge (Baye pers. comm. 2004). The extent of the population at Lower Tubbs Island appears to be small compared with BSRA, but further surveys are needed. If *S. patens* spreads in San Francisco Bay it has the potential to dominate middle and high marsh habitat, displacing *Sarcocornia pacifica,* and converting habitat used by many listed tidal marsh species in the region to unsuitable conditions.

- *Spartina densiflora* (dense-flowered cordgrass) is a tussock-forming grass of the middle and high marsh zones. The species is widespread and locally dominant in Humboldt Bay and portions of Richardson Bay and Corte Madera Creek (Marin County). It was probably introduced to Humboldt Bay before 1900 by ballast from lumber ships, and now covers 330 hectares (814 acres), or 94 percent of the tidal marsh (Tatum *et al.* 2005). Whereas it had been thought to be restricted to mid-elevation tidal marsh in Humboldt Bay, it has been found spreading into the high-elevation tidal marsh (Pickart 2001). The species also was introduced by plantings in Creekside Park in Richardson Bay (San Francisco Bay) in 1977 (Spicher and Josselyn 1985, P. Faber pers. comm. 1998). It spread spontaneously around Richardson Bay and to a disjunct population at Point Pinole (San Pablo Bay) by the 1990s.

Because of its ecological and geographic distribution, *Spartina densiflora* may be a threat to habitat suitability of tidal marsh for salt marsh harvest mice, California clapper rails, and *Chloropyron molle* ssp. *molle*, as well as many species of concern, such as *Chloropyron maritimum ssp. palustre* (Point Reyes bird's-beak) and *Castilleja ambigua* spp. *humboldtiensis*. Consequences of a *S. densiflora* invasion to the clapper rail may be similar to the hybrid *Spartina* invasion in terms of domination of the middle and high marsh plain. Control of *S. densiflora* by herbicide application and manual removal at Point Pinole has been initially successful (D. Smith pers. comm. 1998), although some re-emergence has occurred (P. Baye unpubl. data 1999). In Humboldt Bay, studies on removal of *S. densiflora* by mowing and digging are underway and show promise (Tatum *et al.* 2005). In fact, a recent study at the Lanphere Dunes Unit of Humboldt Bay National Wildlife Refuge found that *C. ambigua* ssp. *humboldtiensis* responded in a dramatic and positive manner to *S. densiflora* removal conducted in 2006-2007 (U.S. Fish and Wildlife Service 2009*a*).

o *Spartina anglica* (English cordgrass) is a fertile polyploid hybrid that originated when *S. alterniflora* of North America and *Spartina maritima* (small cordgrass) of Europe came into contact in England (Raybould *et al*. 1991). It is ecologically similar to *S. alterniflora*. *Spartina anglica* was introduced to Creekside Park, Richardson Bay, in 1977 from Puget Sound where it is also exotic (Spicher and Josselyn 1985), and it persisted at this location through 1998 (Grossinger *et al*. 1998). A long latency phase of significant invasions elsewhere suggests that a history of slow spread is not an indicator of low risk of invasion (Gray *et al*. 1991). Because of its invasiveness in other places it has been introduced, *S. anglica* should be regarded as a threat.

Lepidium latifolium (broadleaf or perennial pepperweed, also known as peppergrass [although it is not a grass and does not resemble one], white-top, and slough mustard). *Lepidium latifolium* is native to tidal marshes of the Mediterranean, where it is not reported as a dominant or aggressive species (Chapman 1964). This perennial herb in the Brassicaceae (mustard family) grows from rhizomes or adventitious root-buds that produce tall, leafy stems topped with heads of abundant small white-petalled flowers in late spring and pale tan seeds in summer (**Figure I-5**). Heads release clouds of pollen when disturbed, suggesting that pollination may occur independently of insects. Seed production is extremely high; each shoot can produce thousands of seeds, and the marsh surface beneath canopies of this species can become covered with ripe seed. Above-ground stems and leaves tend to die back by early summer after the plant produces seed, but in favorable conditions a second crop of flowering stems can replace them. In tidal marshes of San Francisco Bay, *L. latifolium* is found along the high marsh edge, especially in disturbed areas, deposits of sand or tidal litter, or levee slopes. In brackish tidal marshes with lower salinity it invades the middle marsh plain and channel edges, often forming large *swards*. It may even dominate the vegetation in entire marshes. *Lepidium latifolium* colonies expand more rapidly and establish with increased frequency in years of high rainfall (Baye pers. comm. 2004).

May (1995) noted that *Lepidium latifolium* invasion is generally restricted to areas with freshwater input in the southern estuary, and is most abundant in the northern estuary, where salinity levels are lower. A survey (Grossinger *et al*. 1998) found *L. latifolium* in the following areas within the estuary:

<u>North Bay</u>: Potrero Hills area (especially Rush Ranch), along tidal channels and the upland margin of tidal marshes; Contra Costa shoreline marshes along natural channels and mosquito control ditches; Suisun Marsh (especially Grizzly Island Wildlife Area), in high tidal marsh areas and diked *seasonal wetlands*; BSRA (though a treatment program is currently ongoing); Montezuma Slough; Mare Island; San Pablo Bay, in marshes of the northeastern shore; Tolay Creek, lower reach; Petaluma River, lower reach marshes; Petaluma Marsh, along berms, levees and creek banks; Hamilton Air Field, marsh bordering air field; Miller Creek.

<u>Central Bay:</u> Strawberry Creek (Berkeley), on the beaches at the creek mouth; Pt. Pinole; China Camp; Arrowhead Marsh (San Leandro Bay), in the higher intertidal marshes; Hayward area, marshes with restricted tidal influence; Old Alameda Creek, surrounding areas.

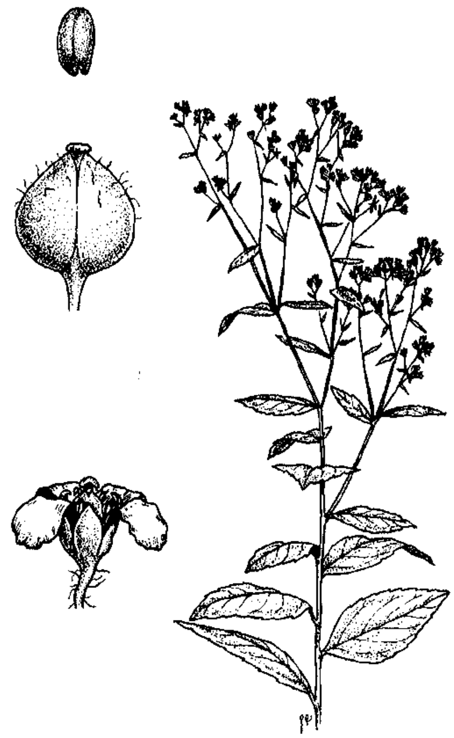


FIGURE I-5. *Lepidium latifolium* (reprinted from Invasive Plants of California's Wildlands, edited by C.C. Bossard, J.M. Randall, and M.C. Hoshovsky, with permission from University of California Press © 2000)

South Bay: Present in almost all marshes, but most substantial infestations are in: Coyote Creek, adjacent marshes; Warm Springs Marsh, on levees and in *Sarcocornia* marsh; Alviso Slough; Guadalupe Slough; Charleston Slough.

Lepidium latifolium is also a widespread weed of the Sacramento-San Joaquin delta, and alkaline or subsaline grazing land and cropland in interior California (M. Renz pers. comm. 1999). It has not yet been recorded in abundance in tidal marshes outside of the Golden Gate, but, in the mid 1990's, a few individuals were detected along tidal marsh edges of southern Tomales Bay, Marin County (P. Baye pers. observ. 1998). The status of *L. latifolium* since that time is unknown.

Lepidium latifolium appears to be a major threat to rare plant species of the estuary (Howald 2000, Spautz and Nur 2004, Baye pers. comm. 2004; Grewell pers. comm. 1997-2000). In California tidal marshes, *L. latifolium* is actively displacing several endangered plant populations, including *Chloropyron molle* ssp. *molle* and *Cirsium hydrophilum* var. *hydrophilum*, and reducing biomass and stature of perennial pickleweed habitat that supports other native wetland dependant species (Grewell *et al.* 2007). Researchers are concerned that as the invasion progresses, growing populations of *L. latifolium* will exclude grasses and native vegetation which may reduce food resources for wildlife (Howald 2000, Spautz and Nur 2004). Without control, *L. latifolium* can be expected to spread and increase in abundance.

It should be noted that in a study by Spautz and Nur (2004), the size of song sparrow territories were reduced in *Lepidium*-invaded areas, suggesting that higher levels of *Lepidium* may actually increase habitat value. It is unclear whether *Lepidium* has a positive or negative impact on reproductive success of song sparrows.

Manual removal, mowing, discing, and burning of *Lepidium latifolium* have failed to suppress populations, and may even stimulate them (M. Renz pers. comm. 1999, Grossinger *et al*. 1998). *Lepidium latifolium* mortality is high in response to applications of glyphosate in the pre-flowering stage (M. Renz pers. comm 1999), particularly in the early stages of shoot elongation (P. Baye pers. observ. 1999-2000). Glyphosate was used in the 1990s in San Francisco Bay to control the species (Grossinger *et al*. 1998). Imazapyr is also registered for use in wetlands and has resulted in higher control levels. However, it has soil residual activity. California Department of Fish and Game (Estrella *in litt*. 2008) had success using chlorsulfuron to control *L. latifolium* in stands away from water. In 2007 and 2008, San Pablo Bay National Wildlife Refuge preliminarily had most success by using a mixture of imazapyr and glyphosate (U.S. Fish and Wildlife Service 2007*a*, Downard *in litt*. 2009*a*).

Salsola soda (Mediterranean saltwort) is a succulent annual salt-tolerant herb in the Chenopodiaceae (goosefoot family), closely related to *Salsola tragus* (Russian-thistle or tumbleweed), as well as *Sarcocornia pacifica* and *Suaeda californica*. It has only relatively recently been recognized in the California flora (Thomas 1975; not cited in Munz 1968, Howell 1970), and was probably introduced to San Francisco Bay in ship ballast years before its discovery. By the mid-1980s, it became widespread in the South Bay (P. Baye pers. observ. 1985). The largest population appears to be in high tidal marsh and within disced dredge disposal ponds at Mare Island, San Pablo Bay, where it unevenly occupies hundreds of acres that serve as a significant seed source for the region. San Francisco Bay is apparently exporting seed of *S. soda*; in the mid 1990's, small colonies were detected in Drake's Estero and Bolinas Lagoon (P. Baye pers. observ. 1998). The status of *S. soda* since that time is unknown. *Salsola soda* tends to be confined to driftlines and disturbed high marsh, but is widespread in low density in the marsh plain at Dumbarton Marsh near Newark (P. Baye unpubl. data 1999). It is a potential threat to endangered, rare, or declining plant species of high tidal marsh.

Other exotic plant species. There are a number of other exotic plant species that are more restricted in distribution and abundance in central and northern California tidal marshes. These can have significant local impacts where they occur, especially in high marsh zones. Some of the notable exotics include the following:

- *Carpobrotus edulis* (iceplant, hottentot-fig, sea-marigold) and its hybrids with *C. chilense* are locally important weeds in tidal marsh edges, such as at Morro Bay (P. Baye unpubl. data 1997-2000) and Napa marshes, as well as a severe problem in coastal strand vegetation in California.
- *Lotus corniculatus* (birdsfoot-trefoil) can become locally dominant in high marsh zones of brackish tidal marshes in the San Francisco Bay Estuary, as well as maritime tidal marsh edges north of the Bay area.
- *Lythrum salicaria* (purple loosestrife) is an extremely invasive forb of freshwater marshes of the central and eastern United States. It escaped from cultivation in

ornamental horticulture, and has marginally established in the Bay area. The species is beginning to invade fresh-brackish tidal marshes here.

- *Polypogon monspeliensis* (annual beard grass) is associated with seasonally ponded depressions, and is extremely dense locally in high tidal marsh zones, particularly in cattle-trampled areas or in depressions. It can become locally abundant to dominant in brackish marshes, especially in depressions and salt pans in high rainfall years.
- *Atriplex semibaccata* (Australian saltbush) is a naturalized saltbush species from Australia. It can become locally common to abundant near the high tide line of disturbed tidal marsh areas, mostly on levees or berms in San Francisco Bay.

The list above is not exhaustive. Some additional invasive species are discussed under threats to particular tidal marsh regions or species in section II. Also, new introductions may result in establishment of additional exotic invasives of concern.

Some native tidal marsh plant species can become unusually abundant or dominant over large areas because of environmental changes, such as rapid sedimentation or climate-driven shifts in salinity. Some are perceived by marsh managers to be problematic because of conflicts with specific management objectives, although this is primarily a concern for diked waterfowl marshes, not tidal marshes. *Phragmites australis* (common reed), *Typha latifolia, T. dominguensis, T. angustifolia,* and intermediates (cattail ssp.), and even *Distichlis spicata* or *Sarcocornia pacifica* are the objects of local suppressive management actions. These management conflicts should not be confused with invasion problems of non-native species. Conversely, some managers of Suisun Marsh wetlands deliberately promote the growth and spread of non-native vegetation *(Echinochloa* spp. [millet], *Cotula coronopifolia* [brass-buttons], *Chenopodium chenopodioides* [small red goosefoot], and reportedly *Chenopodium album* [white goosefoot], which they presume are favored by waterfowl more than natural habitats such as submersed aquatic vegetation (*Ruppia* or *Potamogeton* ponds) and associated invertebrate communities.

Invertebrates. The role of non-native tidal invertebrates in California tidal marsh ecosystems is just beginning to be studied (*e.g.,* Grosholz *et al.* 2004). Feeding, tunneling, and other invertebrate activities have the potential to significantly impact the ecosystem and species. Many non-native invertebrates, such as the mitten crab (*Eriocheir sinensis)*, were likely introduced through discharged ship ballast water, as described further under Reasons for Decline and Threats to Survival.

Factor B: Overutilization for Commercial, Scientific or Educational purposes.

Though the commercial hunting of California clapper rail at the turn of the 20th century had a significant negative effect on rail population numbers, by the time of listing this threat had been eliminated. Currently, overutilization of this or any of the other listed species covered in this plan is not known to be occurring for any purpose.

Factor C: Disease or Predation

Disease
Ecosystem-wide disease issues are not currently known to exist.

Predation
***Vertebrates*.** Predatory species of mammals, birds, and reptiles are known to take individuals and eggs of tidal marsh native species. Some predators, such as the Norway rat, domestic cats (*Felis catus*), and the red fox present in South San Francisco Bay (discussed further under Reasons for Decline and Threats to Survival in California clapper rail and California black rail species accounts), are not native to California. Others, such as raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), ravens (*Corvus corax*), gulls *(Larus* spp.), and red-tailed hawks (*Buteo jamaicensis*), may be native to the general area, yet their abundance or impact in tidal marshes is aggravated by human modifications of the environment, such as levees providing dryland access, landfills providing an attractive nuisance, or poles or towers providing perches. Extensive discussion of predation threats is presented in Chapter II, under California clapper rail.

Factor D: Inadequacy of Existing Regulatory Mechanisms

Inadequate regulatory oversight
Wetland regulation policies and practices can have a great impact on tidal marsh habitat and species. They usually help notify the public of wetlands values and divert inappropriate development. However, these policies and practices often do not adequately consider indirect and cumulative impacts on habitat quality and population viability over large spatial scales and long time frames.

Many activities that are either unregulated or weakly regulated (*e.g.,* mowing, grazing, ditching) may degrade tidal marsh habitats on both public and private lands. Wetlands owned by CDFW are managed for waterfowl hunting in the Suisun Marsh, and some remnant tidal marshes were considered for conversion to non-tidal waterfowl managed marshes as recently as the early 1990s. Wetland management practices in Suisun Marsh were in partial non-compliance with Endangered Species Act requirements in the 1990s (U.S. Fish and Wildlife Service, file information). However, they are now on a healthier recovery trajectory for the ecosystem. The Suisun Marsh Principals Group was developed in 2001 to guide management and restoration programs, as well as recovery actions for listed species in Suisun Marsh, in a manner responsive to the concerns of stakeholders and based upon voluntary participation by private land owners. As part of this effort, they have developed a program to fulfill and exceed monitoring and *mitigation* requirements.

In addition, the success of wetlands created as mitigation for development or other projects have not been adequately monitored. This presents an additional threat to the tidal marsh ecosystem in that impacts to the ecosystem may be unjustly presumed to be offset.

Although *Cirsium hydrophilum* var. *hydrophilum*, *Chloropyron molle* ssp. *molle* and *Suaeda californica* are included in the California Native Plant Society's (CNPS) inventory of rare and endangered vascular plants of California, there are no significant statewide efforts to protect them and they are not state-listed as endangered or threatened. However, they are all included by CNPS as List 1B species which necessitates their consideration during assessments in accordance with the California Environment Quality Act.

Factor E: Other Natural or Manmade Factors Affecting its Continued Existence

Global climate change

Sea level rise associated with global climate change is the most central threat to the long-term survival of California's tidal marshes because it results in loss of habitat by submergence. It is also the most difficult threat to ameliorate at a local level. California tidal marshes are expected to be subject to the effects of climate change and resulting global sea level rise (Knowles and Cayan 2002). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007*a*), global sea level rose by about 120 m (400 ft) during the several millennia that followed the end of the last ice age (approximately 21,000 years ago), and stabilized between 3,000 and 2,000 years ago. Sea level indicators suggest that global sea level did not change significantly from then until the late 19th century. The instrumental record of modern sea level change shows evidence for onset of sea level rise again during the 19th century. Estimates show that during the 20th century global average sea level rose at a rate of about 1.7 mm (.07 in) per year.

Satellite observations available since the early 1990s provide more accurate sea level data with nearly global coverage. This satellite altimetry data set shows that since 1993, sea level has been rising at a rate of approximately 3 mm (.12 in) per year, significantly higher than the average during the previous half century (IPCC 2007*a*). It has been suggested that the climate system, particularly sea levels, may be responding to climate changes more quickly than the models predict (Heberger *et al.* 2009). Additionally, most climate models fail to include ice-melt contributions from the Greenland and Antarctic ice sheets and may underestimate the change in volume of the world's oceans.

Sixteen California state agencies worked collaboratively with the Ocean Protection Council's Science Advisory Team and the Ocean Science Trust to develop recommendations based on the best available science for incorporating sea level rise projections into decision-making in the face of future uncertainty (California Ocean Protection Council 2010). That document, dated October 2010, was required under California Governor's Executive Order S-13-08 to serve as interim guidance prior to the release of the final report from the National Academy of Sciences, expected in 2012. The guidance recommends the use of ranges of sea level rise presented in the December 2009 Proceedings of National Academy of Sciences publication by Vermeer and Rahmstorf (2009) as a starting place and selection of sea level rise values based on agency and context-specific considerations of risk tolerance and adaptive capacity. On a global scale, the guidance document projects sea level rise to be in the range of 0.75 m (2.5 ft) to 1.9 m (6.2 ft) for the period 1990- 2100, depending on greenhouse gas emissions scenarios. Due to strong agreement among the various climate models, the range of values for sea level rise prior to 2050 tightens to 0.26 to 0.43 m. This recovery plan uses a 50 year timeframe for recovery (2063) so, depending on the emissions scenario, sea level is expected to rise slightly more than 0.26 to 0.43 m (0.85 ft to 1.4 ft) during that time.

According to a 2009 study conducted by Pacific Institute, under medium to medium-high emissions scenarios, mean sea level along the California coast will rise from 1.0 to 1.4 meters (1.09 to 1.53 yds) by the year 2100 (**Figure I-6**). Other key findings of the study report that a 1.4 meter (1.53 yds) sea level rise would flood approximately 150 square miles of land immediately adjacent to current wetlands and would result in accelerated erosion resulting in a loss of an additional 41 square miles of California's coast by 2100 (Heberger *et al.* 2009). The U.S. Fish and Wildlife Service has chosen to adopt this medium to medium-high emissions scenario for planning purposes, as have most other government regulatory and land and resource management entities. Therefore, the sea-level rise data shown on the restoration maps herein are reflective of this study. However, other studies using other climate modeling assumptions have indicated more drastic estimates—that sea level rise could increase by up to 2.0 m (2.19 yds) by 2100 (Vermeer and Rahmstorf 2009, Pfeffer *et al*. 2008, Grinsted *et al*. 2009, Jevrejeca *et al*. 2010).

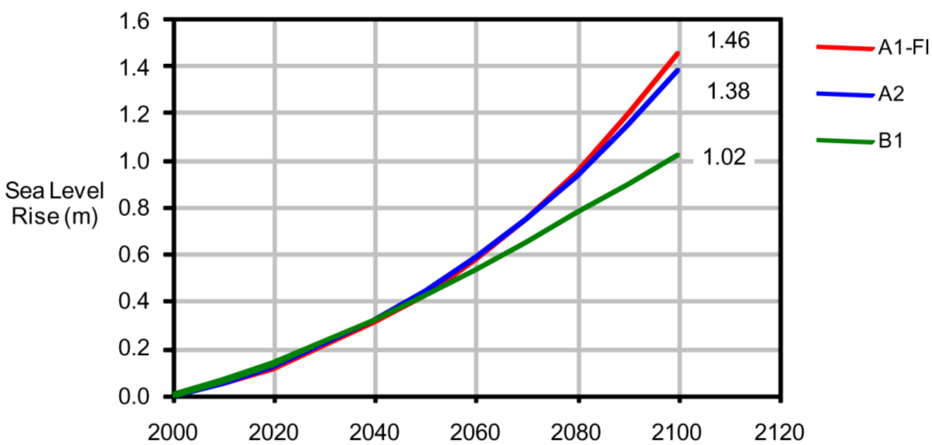


FIGURE I-6. **Scenarios of sea-level rise to 2100** (Cayan *et al.* 2009). Estimated overall projected rise in mean sea level along the California coast for the B1 and A2 scenarios of 1.0 meter and 1.4 meters (1.09 and 1.53 yds) rise in sea level, respectively, by 2100. The A1FI scenario assumes a continued high level use of fossil fuels. (Source: Dan Cayan, Scripps Institution of Oceanography, NCAR CCSM3 simulations, Rahmstorf method.)

Other effects associated with warmer climate and higher sea level include more extreme storm events and greater extremes of wave height and energy (Wilkinson 2002, Bromirski *et al.* 2004) and lower amounts and altered timing of freshwater inflow (Knowles and Cayan 2002). Storm surges will be riding on a higher sea surface which will push water further inland and upland (Scavia *et al*. 2002). When storm surges coincide with high tides, the chances for coastal damage are greatly heightened (Cayan *et al*. 2008). In fact, in most cases, more extreme storm events present a far greater near-term threat to local populations than sea level rise (Downard *in litt*. 2009*b*). The effects of past subsidence of diked marsh areas (Atwater *et al.* 1979) are likely to be amplified by rising sea level, making it harder to restore some subsided areas to tidal marsh.

Effects of climate change are time-delayed, long-lasting and largely irreversible. There is a time lag between the emission of greenhouse gases and the full physical climate response to those emissions (IPCC 2007*a*, *b*). Sea level rise will continue for centuries due to continuing thermal expansion of the oceans and melting of the Greenland ice sheets (Meehl *et al*. 2007). Also, climate changes that result from increases in carbon dioxide ($CO_{2)}$ concentrations are largely irreversible for 1,000 years after emissions cease (Archer and Brovkin 2009, Solomon *et al*. 2009).

The effects of rising sea levels on tidal marshes are dependent upon the relative rate of sea level rise versus rates of sedimentation and accretion of the marsh surface. Unless a balance between sedimentation/accretion and erosion/subsidence is met that equals or exceeds the rate of sea level rise, there will be a net loss of tidal marsh habitat. According to Orr *et al*. (2003), it remains uncertain whether accretion will keep pace with accelerated sea level rise and other climate-related effects; California's tidal marshes may either rise with rising sea level, or erode or drown. Callaway *et al*. (2007) goes one step further in concluding that sea level rise rates on the order of 10-15 mm per year will likely lead to marsh loss for well-established marshes, while lower rates will cause shifts from marsh-plain to low-marsh vegetation. Heberger *et al*.'s (2009) conservative end estimate of 1.0 meter (1.09 yds) sea level rise by 2100 would equate to an average 11 mm per year, making marsh loss the more likely scenario. Finally, as stated by Kirwan *et al*. 2010, much depends on the contribution of melting sea ice. Kirwan *et al*. models indicate that if global temperature increases follow conservative IPCC projections and ice sheets contribute little water to the oceans, many marshes will accrete vertically and maintain their position within the intertidal zone.

The maintenance of tidal marsh habitat area during sea level rise requires (1) space for tidal marshes to expand upward into adjacent habitats as sea and tide levels increase; (2) available sediment adequate to support marsh accretion rates equal to or greater than the rate of sea level rise; and (3) stable erosion rates, or at least rates that do not defeat marsh accretion. The first of these requirements—room for marshes to "move up" in elevation—is especially problematic in the many areas of the San Francisco Bay Estuary where tidal marsh abuts a levee, seawall, or other human barrier at its landward edge. The requirement for stable erosion rates is also of concern, given that climate change and sea level rise in California are expected to be accompanied by increased storm severity and maximum wave heights; trends that are already suggested by available data (Wilkinson 2002, Bromirski *et al.* 2004). Sediment supply for marsh accretion is not yet well understood.

As reviewed in Callaway *et al*. (2007), the salinity of California tidal marshes will be altered by climate change-related shifts in regional precipitation, changes in the timing of precipitation and snowmelt runoff, and increases in sea level. Rising temperatures have already been linked to lower snowfall, more rain, and earlier snowmelt throughout California, which is leading to significantly earlier runoff within California watersheds. Higher pulses of freshwater in winter will result in lower marsh salinities while lower freshwater delivery in summer and fall will result in higher marsh salinities. Also, sea level rise will cause salinity levels overall to increase up the estuary as tides push further up bays, rivers, and sloughs. For example, Suisun Bay and the Delta may become more saline.

Callaway *et al*. (2007) noted that the intial impacts of climate change are likely to stem from these salinity changes, and that even relatively small salinity changes can cause shifts in dominant vegetation. Higher salinities in the summer and fall are expected to produce increased stress on tidal marsh plants, potentially leading to reduced productivity and mortality (Callaway *et al*. 2007). Furthermore, as overall salinity in the San Francisco Estuary increases and more salts accumulate in tidal marsh soils, larger pulses of freshwater of greater duration will be required to reduce soil salinities in the marsh and promote germination and recruitment (Callaway *et al*. 2007). Ultimately, species that prefer brackish conditions over tidal marshes would presumably suffer reduction in habitat, while tidal marsh species might expand into Suisun Bay and even the Delta. Closer study is needed of the potential amount and extent of salinity and habitat change, and the species-level effects of these changes.

Overall, threats from global climate change to tidal marsh habitats and species in California include: (1) habitat loss where landward migration of tidal marsh plant communities is prevented by artificial or geographic barriers, or where sea level rise or erosion exceeds sedimentation; (2) salinity gradients migrating up-estuary as tidal inundation increases; (3) greater extremes of heat and desiccation stress on wetland plants; (4) the loss and/or decreased *fecundity* of rare populations and species (Reid and Trexler 1991, Boorman 1992, Keldsen 1997); and (5) high mortality rates associated with extreme weather events (Downard *in litt.* 2009*b*).

<u>Contaminants</u>

Environmental contaminants may adversely affect the survival, growth, reproduction, health, or behavior of species. Some contaminants may affect a narrow range of organisms while others, like petroleum products, can impact a broader range of organisms. Known contaminants of concern in the San Francisco Bay Estuary include mercury, selenium, polychlorinated biphenyls (PCBs), organochlorine and organophosphate pesticides, dioxins/furans, polycyclic aromatic hydrocarbons (PAHs), and tributyltin from anti-fouling boat paints (see SWRCB 303d list, Region 2; Oros and Hunt 2005; Schwarzbach *et al*. 2006; Adelsbach and Maurer 2007). Ammonia and pyrethroid insecticides have become a recent concern. In addition, newly emerging contaminants which may act to disrupt endocrine systems, such as polybrominated diphenyl ethers (PBDEs) and phthalates, are being detected in the estuary's water, sediments, and biota (Oros *et al*. 2005, Oros and Hunt 2005) and are poorly understood. Unmonitored contaminants in San Francisco Bay include such chemicals as pharmaceuticals, plasticizers, flame retardants, and detergent additives (San Francisco Estuary Institute 2000). Toxic effects of many of these chemicals to rails and other estuary biota are not known. In other species, some of these chemicals have caused endocrine disruption and altered gender development through *in ovo* exposures (Colburn and Clement 1992). While the full impact of these emerging contaminants on species in the estuary remains to be determined, the increasing frequency at which they are being detected is cause for concern. All of the contaminants mentioned above have the potential to adversely impact biota in the estuary, depending on the extent and degree of contamination (Phillips 1987). Three of the primary known threats are described in further detail below.

Mercury: The estuary's aquatic and aquatic-dependent wildlife species are the most at risk from contamination by bioaccumulative pollutants such as mercury and selenium. Historically, the major source of mercury contamination in the San Francisco Bay-Delta was mine waste and drainage from Coast Range mercury mines and Sierra Nevada Range gold mines (San Francisco Estuary Regional Monitoring Program 1996). Substantial reservoirs of this toxic metal left over from mining activities remain in estuary *sediments*, as well as in *sediments* and soils associated with upstream tributary water bodies. Even today, mercury from these upstream sources continues to wash downstream into the estuary (California Regional Water Quality Control Board 2004). However, other significant sources of mercury have been identified as being of concern. Mercury released into the atmosphere through oil and coal combustion and through waste incineration can be re-deposited into aquatic ecosystems through precipitation, contaminating water bodies with no other known mercury inputs (Wiener *et al*. 2002). Once in the aquatic realm, certain conditions (*e.g.*, anoxia and sulfate-reducing bacteria) may allow for the transformation of inorganic mercury into methylmercury, an organic form that is highly toxic and much more bioavailable than the inorganic precursor. Under continuous exposure in a contaminated ecosystem, methylmercury is introduced into the body at a much faster rate than the body can eliminate it, and aquatic and aquatic-dependent organisms bioaccumulate it into various tissues. Methylmercury concentrations in aquatic ecosystems biomagnify in each successive trophic level, from primary producers to the top predators (Wiener *et al*. 2002). Tidal marshes often exhibit the conditions that promote methylation of mercury, and high mercury concentrations have been found in a variety of fish from the San Francisco Estuary (Greenfield *et al*. 2003).

Selenium: Selenium, another bioaccumulative element, can contaminate aquatic ecosystems through a variety of human activities, including fossil fuel combustion, mining and manufacturing processes, and irrigation of seleniferous soils (Maier and Knight 1994). All of these sources may be contributing to the selenium contamination observed in the estuary, with agricultural drainage of lands from the west side of the San Joaquin Valley and discharges from local oil refineries the two primary sources (Presser and Luoma 2007). A non-native clam (*Potamocorbula amurensis*) that is abundant in the estuary has been shown to bioaccumulate selenium at a higher rate than crustacean zooplankton, and several predators of these bivalves have tissue selenium concentrations above thresholds thought to be associated with *teratogenesis* and reproductive failure (Stewart *et al*. 2004). The selenium contamination of the estuary's bivalve food web may pose a threat to bottom-feeding animals, such as the white sturgeon (*Acipenser transmontanus*), surf scoter (*Melanitta perspicillata*), and Sacramento splittail (*Pogonichthys macrolepidotus*) (Presser and Luoma 2007, Linville *et al*. 2002, Stewart *et al*. 2004, Teh *et al*. 2004). In fact, deformities typical of selenium-induced teratogenesis have been observed in Sacramento splittail (Stewart *et al*. 2004).

Petroleum: The San Francisco Bay Estuary has many potential sources of petroleum and petroleum-byproduct (*e.g.*, PAHs) releases, due to a high degree of urbanization, with six oil refinery complexes, substantial ship and oil tanker traffic, and a large number of gasoline, diesel, or fuel oil-powered vehicles. PAHs are commonly detected in bay waters and sediments where tidal marsh species may be exposed to them (Ross and Oros 2004). Exposure of tidal marsh species to free petroleum products generally occurs as a result of vessel- or pipeline-related oil spills. As is known from numerous spill events, even relatively small exposures to oil can harm or kill birds and other wildlife (Gilardi and Mazet 1999).

Oil spills in San Francisco Bay have potential to cause serious consequences to sensitive tidal marsh species. As a consequence of the catastrophic oil spills of 1989, the Oil Pollution Act of 1990 required contingency plans be completed by both State and Federal Governments. The U.S. Coast Guard and CDFW – Office of Spill Prevention and Response agreed to joint preparation of contingency plans. The Area Committee planning process is a proactive effort to deal with potential oil releases inherent in California's petroleum dependant economy and culture. This planning process is open to all stakeholders and has involved representatives from over 50 agencies, including environmental groups, city and county planners, California State agencies, the Federal government, and industry. These organizations have come together to produce a landmark comprehensive planning document that serves as a "one stop" marine pollution response plan for the three port areas and the included six geographical sections of the California Coast (North Coast, San Francisco Bay and Delta, and Central Coast/Monterey) (U.S. Coast Guard *in litt*. 2009). The three Area Contingency Plans provide guidance for the first 24 hours of response and are living documents, the respective area committees meeting regularly to update, review, and revise the documents as needs become apparent.

More information regarding contaminants and their observed and potential effects to sensitive wildlife can be found in **Appendix E**.

Risk of small populations

Small populations are typically at greater risk of extinction than larger ones (Terborgh and Winter 1980, Diamond 1984, Pimm *et al.* 1988, Morris and Doak 2003). Because California tidal marsh species have lost so much habitat, their populations are much reduced in size. There are many causes of the increased risk of extinction characteristic of small populations. For example, small populations have increased vulnerability to extinction due to catastrophic events like severe droughts, storms, fires, pollution spills, non-native species invasion, or epidemics (Schonewald-Cox *et al.* 1983). Another factor is natural variability in birth and death rates: a chance cluster of years of high death rates or low birth rates may result in the extirpation of small populations. At low population sizes, genetic and evolutionary effects can become increasingly important, particularly if loss of genetic diversity due to *founder* effects leads to *inbreeding* depression or reduced ability to adapt to environmental change. Additionally, genetic drift (random changes in a population's genotypes) may result in populations being less well-adapted to their surrounding environment.

Incomplete understanding of recovery needs

As we note under Species Accounts in section II, none of the species covered by this recovery plan is completely understood. Recovery and conservation actions considered most urgent and most beneficial must be implemented, but in the absence of full understanding, actions may fail to help certain species, or even inadvertently set back their recovery. In these situations, ecosystem restoration is clearly a benefit, thereby letting species recover along with their ecosystem. However, this approach alone is not adequate. The Service and its partners will promote research, gather further information, and develop a better understanding of species' and ecosystem's recovery needs to better plan and undertake recovery and conservation work.

Combined factors. Few of the above causes of habitat degradation are independent of one another; rather, they interact. For example, construction and subsequent maintenance of a levee may restrict tidal circulation, focus the impacts of any fresh wastewater discharges, provide predator corridors and nest/den sites, compress high-tidal refugial vegetation to a narrow strip, and promote weed growth. It may also mobilize contaminants buried in marsh sediments. The presence of the levee may provide recreational access for people and their pets, potentially causing increased disturbance and litter attractive to animal pests.

In summary, the above overarching threats of habitat loss and fragmentation, habitat degradation and disturbance, invasive non-native species, predation, risk of small populations and climate change affect the tidal marsh ecosystem upon which the species covered in this recovery plan depend. Many of these threats are severe and immediate and most are combined with additional threats to individual species, discussed in the respective species accounts in Chapter II.

E. Tidal marsh conservation, restoration, and management

Tidal marshes in California today are the focus of numerous diverse conservation efforts. Because great strides have been made in habitat acquisition in the last 25 years, this document places an emphasis on the restoration and management of acquired lands. Indeed, many significant preservation, restoration, management, education, monitoring, and research projects are being planned or are underway, and new initiatives are emerging continuously. Any attempt to catalog these efforts here is certain to be dated by the time of publication, and to neglect many important participants and projects. Therefore, with appreciation and apologies to the other partners in conservation, this section is limited to a selective review of conservation of California tidal marsh environments for emphasis of certain principles or historical developments. Other organizations and agencies offer useful information about tidal marsh conservation efforts. Their contact information, including weblinks, is available in **Appendix D**. Specifically, the San Francisco Estuary Institute's Bay Area Wetland Project Tracker, San Francisco Bay Joint Venture, Bay Conservation and Development Commission, San Francisco Bay Wetlands Restoration Program, Invasive Spartina Project, South Bay Salt Pond (SBSP) Restoration Project, and Suisun Marsh Program websites contain extensive information and maps about tidal marsh conservation and projects around the San Francisco Bay Estuary.

Following increased public awareness of tidal marsh destruction in the 1960s, public agencies (primarily CDFW and the U.S. Fish and Wildlife Service, but including regional conservation districts, state and regional parks, and the State Lands Commission) acquired title to and protected many remaining tidal marshes throughout the San Francisco Bay Estuary. Tidal marshes in public ownership at Greco Island, Mowry and Dumbarton Marshes, Petaluma Marsh, Fagan Slough Marsh, Rush Ranch, China Camp, Point Pinole, BSRA, and Hill Slough contain irreplaceable pre-historical tidal marshes. These agencies also acquired many diked baylands under threat of development to reserve them for future restoration to tidal marsh (*e.g.*, Cullinan Ranch, Vallejo; Bair Island, Redwood City; Eden Landing Tract, Hayward; Bel Marin Keys, Novato; Hamilton Field, Skaggs Island, etc.). Currently, restorations totaling more than 4,000 hectares (10,000 acres) have been completed and over 4,000 hectares (10,000 acres) more are in the planning phase (www.wetlandtracker.org). During the 1990s, the scale of proposed restoration projects generally increased from tens of acres typically in a mitigation context, to hundreds and thousands of acres in a restoration context. Current projects range from simple levee breaching to the use of dredge spoil to raise subsided historic baylands to elevations suitable for marsh establishment.

Many historically diked baylands have reverted to tidal mudflats and marsh following accidental or deliberate restoration of tidal flows. During the 1930s, unrepaired levee breaches caused the spontaneous restoration of tidal marsh at two former salt ponds along the central Alameda County shoreline, Ideal Marsh and Whale's Tail Marsh. Today these marshes appear as mature tidal marsh, showing only traces of their breached salt pond origins in the form of relict berms and ditches. Diked baylands at White Slough on the Napa River in Vallejo, Solano County, were accidentally breached in 1977. By the 1990s they had reverted to extensive low brackish marsh and mudflat. On the opposite shore of the Napa River, a marina left derelict in the 1950s has reverted to brackish low marsh and middle marsh (Pritchett Marsh, east of Guadalcanal Village). Derelict marinas at Port Sonoma and Alviso have silted in and become dense tidal marsh and brackish marsh, respectively. A 200 hectare (550 acre) former salt pond (Pond 2A) in the former Leslie (Cargill Incorporated) Salt Napa facility in San Pablo Bay was breached deliberately by the CDFW in 1995, resulting in a reactivated relict tidal creek network and prevalence of *Bolboschoenus maritimus* by 1998. In the Suisun Marsh area, spontaneous reversion to tidal marsh has occurred through gradual levee breach enlargement at Ryer Island, portions of Chipps Island, and a few other sites where low brackish marsh has re-established. Large fetches (open-water distances over which wind-generated waves propagate) so far have not precluded marsh restoration at any of the older established large restored marsh sites, probably because of the wave energy-damping properties of marsh vegetation (Woodhouse *et al*. 1976, Newcombe *et al*. 1979, Knutson *et al*. 1982, Moeller *et al*. 1996).

Many smaller tidal marsh restorations, mostly performed as mitigation for wetland destruction, have been conducted throughout the estuary. Some have relied on moderate to elaborate engineering (Pond 3, Alameda County; Oro Loma Marsh, Hayward; Cogswell Marsh, Hayward; Muzzi Marsh, Corte Madera; Sonoma Baylands, near Port Sonoma; Warm Springs Marsh, Fremont; LaRiviere Marsh, Newark), while others used minimal or no engineering (Toy Marsh and Carl's Marsh, lower Petaluma River; Faber Tract, Palo Alto).

The habitat quality and success rates of restored tidal marshes have been variable due to many factors, including maturity of the restored site, design features, site selection and environmental setting, invasion pressures by exotic species, tidal circulation and sediment supply, and initial site elevations and substrate conditions. Dredged materials have been used in some projects to raise initially low subsided elevations in diked baylands (Pond 3 Alameda, Muzzi Marsh, Sonoma Baylands), but placement of dredged materials to elevations approaching mean higher high water (mature marsh plain) appears to inhibit development of tidal drainage networks. Rapid development of high quality tidal marsh can occur with little or no engineering (Carl's Marsh, Pond 2A, Ideal Marsh, White Slough), especially given optimal starting conditions (*i.e*., not highly subsided, raised elevations, adjacent to an adequate sediment source). While a degree of engineering may sometimes be necessary, engineering of tidal restoration can be overdone, as numerous engineered tidal marshes have required corrective measures, developed slowly, or developed mostly habitats or vegetation other than those originally planned (Warm Springs, Sonoma Baylands, Muzzi Marsh, Oro Loma Marsh, Cogswell Marsh).

The results of both planned and spontaneous tidal reflooding of diked baylands (discussed above) indicate that tidal marsh restoration is highly feasible in the San Francisco Bay Estuary. The spontaneous and unexpectedly rapid restoration of low tidal marsh and tidal creek networks over very large tracts (greater than 200 hectares [500 acres]) at Pond 2A, Napa, where subsidence of the original marsh surface was only moderate, suggests high feasibility of restoring low tidal marsh. Similar extensive low marsh has developed in south San Francisco Bay at outer Bair Island (San Mateo County), breached in 1970. Middle marsh plains have regenerated over longer periods of time on narrower tidally reflooded diked baylands (Ideal Marsh, Whale's Tail Marsh). At least one large (greater than 80 hectares [200 acres]) deeply subsided and over-excavated diked basin (Warm Springs, Fremont) has developed mudflats and brackish low marsh after a decade of rapid sedimentation in a prolonged subtidal lagoon phase. A few tidal restoration projects that had initially obstructed tidal circulation (Sonoma Baylands, Tolay Creek mitigation site) developed shallow microtidal lagoons with abundant submerged aquatic vegetation (*Ruppia maritima*), resulting in unexpectedly high value waterfowl and shorebird habitat similar to solar salt intake ponds. Many of the restored tidal marshes have been spontaneously recolonized by endangered California clapper rails and salt marsh harvest mice (*e.g.*, Toy Marsh, White Slough, Faber-Laumeister, Carl's Marsh, Ideal Marsh, Whale's Tail Marsh).

The longer-term development of middle marsh plains and creek bank levees in tidally restored basins in the face of rapid sea level rise and uncertain sediment supplies is less certain (Goals Project 1999; Pethick 1993, Warren and Niering 1993, Pye 1995). A high rate of sea level rise does not preclude the feasibility of low marsh restoration in the San Francisco Bay Estuary, but it raises the possibility that some local engineering may be necessary to speed restoration of middle and high marsh near the landward edges of large restored marshes.

Substantial amounts of tidal marsh restoration or enhancement in the San Francisco Bay area have resulted from minimization of impacts from development. In the South Bay, several sites proposed for full development in the 1980s were modified significantly to minimize areas and impacts in tidal marsh habitat, and provide habitat protection and enhancement over the remaining habitat. Outstanding examples are Roberts Landing (Citation Homes, San Leandro) and Mayhews Landing (Newark). In both these sites, the majority of habitat was protected and enhanced by *re-engineered tidegates* to improve salinity and moisture of tidal marsh, while providing tidal drainage to prevent prolonged impounding of flood waters. Monitoring and reporting requirements of project permits were limited, however, so the long-term ecological and population trends of these sites will be difficult to determine.

The engineered tidal marsh restoration at Pond 3 (Alameda Creek), among the oldest in San Francisco Bay, was constructed by the U.S. Army Corps of Engineers using dredged materials from the adjacent flood control channel. Although the project had some unanticipated and undesirable outcomes—notably spread of introduced non-native *Spartina alterniflora*—it has resulted in a large high-elevation tidally influenced *Sarcocornia* marsh and an expanded population of salt marsh harvest mice. The overfilling of the site above design criteria minimized clapper rail habitat, but provided exceptionally thick *Sarcocornia* habitat that may be somewhat buffered against sea level rise, providing important refuge from extreme tides and storms at upper tidal elevations.

Renzel Marsh (ITT Marsh, Palo Alto) was protected and enhanced by the City of Palo Alto and the California Coastal Conservancy to minimize impacts of Palo Alto wastewater discharge (conversion to brackish marsh). The marsh has been re-engineered with tidegates to minimize impoundment of floodwater and hasten flood drainage, and to provide limited managed tidal flows to enhance *Sarcocornia* habitat for the salt marsh harvest mouse. Quality and abundance of *Sarcocornia* habitat has increased, though water management will require ongoing adjustment (Woodward-Clyde 1996, Shellhammer pers. comm. 1998).

One south San Francisco Bay mitigation site, the engineered *Sarcocornia* "mouse pasture" at Bayside Business Park at Warm Springs (Fremont) has been colonized by a continually low population of salt marsh harvest mice. The adjacent Bayside Business Park II development nearer Dixon Landing Road on Coyote Creek was configured to minimize urban fill in *Sarcocornia* habitat. The remaining marsh is in a long-term phased conversion from diked non-tidal *Sarcocornia* /salt pan habitat, subsided well below sea level, to a tidal marsh with a wide sloping high tidal brackish marsh zone along the landward edge. Both sites are small and relatively isolated, and the long-term outcome of this habitat restoration remains to be seen. The Pacific Commons project, also near Warm Springs (Fremont), reduced on-site impacts and preserved roughly 160 hectares (390 acres) of vernal pool grasslands adjacent to high marsh (Shellhammer pers. comm. 1998).

Around San Pablo Bay, to minimize impacts of a median barrier/shoulder widening project along the highway, the California Department of Transportation (Caltrans) engineered flood drainage enhancements to the Highway 37/Mare Island strip marsh, the eastern half of which suffered flooding and drainage problems caused by the intake canal berm. The project resulted in rapid sediment accretion, and decreased the depth and duration of flooding from storm surges and rain. The project would have restored 650 hectares (1,600 acres) to highly valued tidal marsh habitat. However, though initially successful, infilling and waves eventually re-built the berm, and the added drainage was lost after approximately 6 years (Baye *in litt*. 2007).

A number of other efforts are ongoing in the Delta to conserve species and habitats:

- The Delta Stewardship Council was officially formed in 2010, but evolved from a group previously named CALFED and is a unique collaboration among 25 State and Federal Agencies to improve water supplies in California and the health of the San Francisco Bay/ Sacramento-San Joaquin Delta. In 2000, CALFED completed a 30-year plan that sets forth general goals and a science-based planning process for making future decisions on Bay-Delta programs and projects. The scientific branch of the Delta Stewardship Council is now named the Delta Science Program.

- Delta Vision was created by a 2006 Executive Order of the California Governor to find a durable vision for sustainable management of the Sacramento-San Joaquin Delta, so it could continue to support environmental and economic functions critical to the people of California. The Delta Vision Strategic Plan was completed in 2008 and recommended actions to address the full array of natural resource, infrastructure, land use and governance issues necessary to achieve a sustainable Delta.

- The Bay-Delta Conservation Plan (BDCP) is a planning and permitting process that will manage water resources in the Delta in a way that reliably delivers water to 25 million Californians while at the same time protecting and restoring sensitive species and habitats. The BDCP is being developed in coordination with Federal and State agencies, environmental organizations, water contractors and other interested stakeholders. Once completed, the BDCP will serve as both a Habitat Conservation Plan and a Natural Communities Conservation Plan for the purposes of permitting the incidental take of protected species.

The vision of restoration of a significant portion of the Bay's tidal marsh was first articulated by the Bayland Ecosystem Habitat Goals Project and is currently the subject of a large restoration planning effort. In 1994, CDFW purchased 3,986 hectares (9,850 acres) of former salt ponds in the North Bay from Cargill Incorporated . Of that, CDFW has restored 1,902 hectares (4,700 acres) and will restore an additional 757 hectares (1,870 acres) for a total of 2,659 hectares (6,570 acres) of restored habitat. Phases I and II of the project were completed in 2006 and 2007, respectively. Phase I opened 1,214 hectares (3,000 acres) of salt ponds to tidal action and Phase II involved restoration of 688 hectares (1,700 acres) to managed ponds for waterfowl and shorebirds. Phase III includes restoration of the final 757 hectares (1,870 acres) and design and construction of a recycled water pipeline to aid in bittern removal.

<u>South Bay Salt Pond (SBSP) Restoration Project</u>

In March 2003, an additional 6,677 hectares (16,500 acres) of salt ponds were sold and donated by the Cargill Incorporated to CDFW and U.S. Fish and Wildlife Service for phased restoration as a mosaic of tidal marsh and nontidal managed ponds. The acquisition, which included approximately 607 hectares (1,500 acres) of salt ponds in the Napa River watershed and approximately 6,070 hectares (15,000 acres) of salt ponds in the South Bay (specifically at the Eden Landing, Alviso, and Ravenswood areas), will enable the largest tidal restoration project in west coast history, and will be the single most significant step toward California clapper rail and salt marsh harvest mouse recovery.

The Eden Landing site, formerly proposed as a racetrack and park complex (Shorelands), is one of many key sites now protected in San Francisco Bay, and one of three major pond complexes comprising the SBSP Restoration Project. The Eden Landing site is owned and managed by the CDFW. The other two pond complexes at Alviso and Ravenswood are owned and managed by the Don Edwards San Francisco Bay National Wildlife Refuge. Tidal wetland restoration in these areas will add significant high quality habitat for tidal species as well as many species of shorebirds. While the final habitat acreage suitable for restoration to tidal marsh habitat is yet to be determined, thousands of acres of suitable habitat for tidal marsh species may eventually be enhanced or restored, and existing populations protected. Phase I of the restoration is nearly complete and the partners are currently engaged in the planning and environmental review for Phase II in all three complexes.

Because former salt ponds provide important habitat for shorebirds and other waterfowl in San Francisco Bay, the importance of retaining ponded habitat for those species during the larger tidal marsh restoration is clear. Agreement was made by the involved scientists to strive for a dynamic mosaic of both tidal marsh and nontidal managed ponds. The Final EIR/EIS details a plan for progress toward tidal marsh restoration, but, through an adaptive management framework, builds in a feedback loop via species and habitat monitoring to cease additional tidal restoration before non-tidal bird species are affected negatively. Within each site the final proportion to be restored to tidal marsh will be between 50 and 90 percent with the remaining area to be restored to managed pond.

Suisun Marsh Habitat Management, Preservation, and Restoration Plan

The Suisun Marsh Principals Group is a collaboration formed in 2001 to resolve issues of amending the Suisun Marsh Preservation Agreement (SMPA), obtain a Regional General Permit, implement the Suisun Marsh Levee Program, and recover endangered species. The Principals Group was charged with developing a regional implementation plan that would outline the actions needed in Suisun Marsh to preserve and enhance managed seasonal wetlands, restore tidal marsh habitat, implement a comprehensive levee protection/improvement program, and protect ecosystem and drinking water quality.

The *Suisun Marsh Habitat Management, Preservation, and Restoration Plan*would be consistent with the goals and objectives of the Delta Science Program, and would also balance them with the SMPA, Federal and State Endangered Species Acts, and other management and restoration programs within the Suisun Marsh in a manner responsive to the concerns of all stakeholders, and based upon voluntary participation by private landowners. The *Suisun Marsh Habitat Management, Preservation, and Restoration Plan* would also provide for simultaneous protections and enhancement of (1) the Pacific Flyway and existing wildlife values in managed wetlands; (2) endangered species; (3) tidal marshes and other ecosystems; and (4) water quality, including, but not limited to, the maintenance and improvement of levees.

In addition, as of 2007, a total of 1,012 hectares (2,500 acres) made up of twelve individual parcels owned by the CDFW (10 parcles), the Suisun Resources Conservation District (1 parcel), and the Department of Water Resources (1 parcel) are managed as Mouse Conservation Areas. The establishment of these areas and development of the *Suisun Marsh Habitat Management, Preservation, and Restoration Plan* were requirements of the U.S. Fish and Wildlife Service's 1981 biological opinion (U.S. Fish and Wildlife Service 1981) on the Suisun Marsh Management Study. The study was developed by the U.S. Bureau of Reclamation and California Department of Water Resources to discuss development of a number of water conveyance facilities that would change the "major intake for marsh water supplies from Grizzly Bay to the Sacramento River near Collinsville, by introducing municipal waste water, and by redistributing water in major marsh channels". After the completion of the initial facilities and the Suisun Marsh salinity control gates, no additional facilities were constructed and, therefore, this change of intake has not happened, to date.

The biological opinion specified via a conservation measure that the agencies set aside at least 405 hectares (1,000 acres) of preferred salt marsh harvest mouse habitat (plus an additional 607 hectares [1,500 acres] approved by the USFWS as conservation areas for multi-species benefit) to protect the species from the project impacts. These Mouse Conservation Areas are surveyed every three years to monitor salt marsh harvest mouse populations. In addition, aerial surveys are flown every three years to monitor preferred mouse habitat throughout the marsh and determine if pickleweed habitat is being lost.

Invasive Spartina Project

The Invasive Spartina Project (ISP) was established in 2000 as a cooperative regional effort among local, state and federal organizations including the California Coastal Conservancy, East Bay Regional Park District, U.S. Fish and Wildlife Service, and many others. The overall goal of the project is to develop a regionally coordinated project to address the rapid spread of four introduced and invasive *Spartina* species in the San Francisco Estuary. The ISP surveys the Bay annually to assess and map the distribution of introduced *Spartina* species. The project collects location and ecological data for each found population, then plant material is sent to the UC Davis Spartina Lab where genetic testing is conducted to confirm identification of *S. alterniflora* hybrids. All collected data are integrated into a Geographic Information System (GIS) layer for analysis, and used in planning the regionally coordinated *Spartina* control program. The control program, the action arm of the ISP, is coordinated by contractors and staff of the ISP, and implemented by the many land managers, land owners, environmental groups, and others who are working to arrest and reverse the invasion of non-native cordgrasses in the San Francisco Estuary. For a calendar of past and future treatment events, please see the ISP website, listed in **Appendix D**.

As mentioned above under Invasive Species, the ISP has reduced the coverage of invasive *Spartina* baywide by nearly 90 percent (from 324 net hectares [800 acres] to less than 40 net hectares [100 acres]) since peak *Spartina* coverage in 2005-2006 (Olofson *in litt.* 2011). However, a substantial decrease in rail numbers has been observed since the physical breakdown of treated invasive *Spartina*. The U.S. Geological Survey and East Bay Regional Park District are currently conducting critical research into the use of artificial islands by California clapper rails as high tide refugia following loss of invasive *Spartina* at Arrowhead Marsh. It is hoped that these islands will provide important refugia to rails while native vegetation becomes established. Preliminary results show that the islands were indeed immediately inhabited by rails and show promise for providing interim refuge (Takekawa *et al*. 2011). However, the islands cannot support the number of rails present in the absence of invasive *Spartina*. For example, no rails are seen on the treated half of Arrowhead marsh and numbers of rails on the other half of Arrowhead marsh are still in decline, even when considering rail use of the islands following the treatment.

Other vital tidal marsh conservation efforts, carried out by numerous organizations and agencies including the Service, involve public outreach, education, management (including invasive species control), monitoring, and research.

Given that restoration of tidal marsh ecosystems is a continuously evolving science, and that an authoritative guide to the latest understanding and sources about restoration of tidal habitats is available (Philip Williams and Associates, Ltd. and Faber 2004), technical prescriptions for tidal marsh restoration methods will not be offered here. The Bayland Ecosystem Goals Project (Habitat Goals, notably chapter 6: 1999) also reviews restoration considerations, past projects, and lessons learned (Goals Project 1999). An update to the Habitat Goals document which incorporates anticipated effects of global climate change to tidal marsh species and habitats and proposed management actions to help ameliorate those effects, is currently under development.

II. SPECIES ACCOUNTS

A. Focal Listed Species

a. *Cirsium hydrophilum* var. *hydrophilum* (Suisun thistle)

1) Brief Overview

Cirsium hydrophilum var. *hydrophilum* (Suisun thistle) was listed as endangered in its entire range on November 20, 1997 (U.S. Fish and Wildlife Service 1997*a*). It has a recovery priority number of 3C, based on a high degree of threat, a high potential of recovery, and its taxonomic standing as a subspecies. The "C" ranking indicates some degree of conflict between the conservation needs of the species and economic development (U.S. Fish and Wildlife Service 1983). It is not listed as endangered or threatened by the State of California. Habitat loss is the primary cause of decline in this species. Currently, two or three populations, are thought to be extant.

2) Description and Taxonomy

Description. *Cirsium hydrophilum* (E. Greene) Jepson var. *hydrophilum* (Suisun thistle) is a perennial herb in the Asteraceae (aster) family (**Figure II-1**). In the pre-flowering phase it grows as a short, broad, vegetative *rosette* with large leaves, approximately 0.3 to 0.9 meter (0.31 to 1 yd) long. The leaves have deep lobes with spines up to 1 centimeter (nearly 0.5 inch) long at the tips. The upper leaf surface of the youngest basal leaves are covered with hairs, but typically become smooth and somewhat glossy with maturity. In contrast, the lower leaf surface retains a thick white covering of hairs even when mature. The juvenile vegetative phase lasts until plants are large enough to flower (Keil and Turner 1993). During the mature phase the rosette bolts, and develops a tall (1 to 1.5 meters [1.09 to 1.6 yds]) leafy stem in the second year or later. Stems are typically branched above the middle of the main stem, but up to 15 stems may occasionally branch from the base of single large plants (P. Baye unpubl. data 2000). Leaves on stems are much smaller, more deeply lobed, and spinier than juvenile leaves of the rosette. The reduced stem leaves either clasp the stem at their bases, or have ear-like appendages near the stem. Stem leaves become progressively smaller near the top of the plant. The egg-shaped flowerheads (2.5 centimeters [1 inch] long) are composed of small individual *florets* united into a single unit. Many rose-purple *corollas* protrude. Flowerheads occur either as solitary units or in clusters. The bracts of the flowerheads have a distinct green, glutinous ridge on the back that distinguishes *C. hydrophilum* var. *hydrophilum* from other *Cirsium* species in the area. The cypsalae (seed-like dry fruits similar to an *achene*), are about 4 to 5 millimeters (0.2 inch) long, and glossy dark brown to black with thick, hard outer walls (Munz 1959, Keil and Turner 1993, P. Baye unpubl. data 1999-2000).

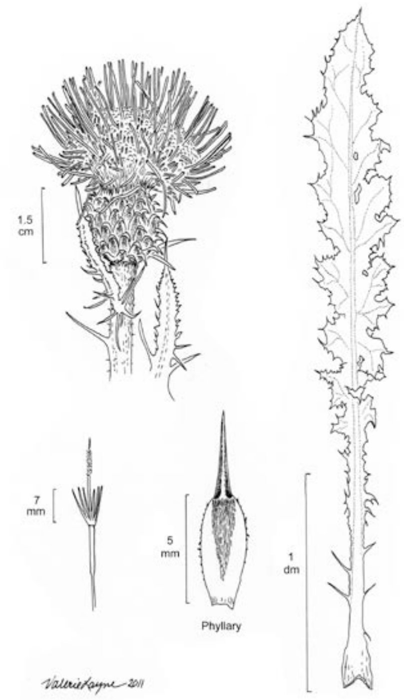


FIGURE II-1. ***Cirsium hydrophilum*** **var.** ***hydrophilum*** (illustration credit: Valerie Layne, USFWS)

Taxonomy. *Cirsium hydrophilum* var. *hydrophilum* was originally described as *Cnicus breweri* Gray var. *vaseyi* Gray (Gray 1888). *Cnicus breweri* is a taxon now placed in *Cirsium douglasii* DC var. *breweri* (A. Gray) (Keil and Turner 1993). Subsequent synonyms, now invalid, include *Carduus hydrophilus* Greene (Greene 1892) and *Cirsium vaseyi* (Gray) Jepson var. *hydrophilum* (Greene) Jepson (Jepson 1925). Jepson (1901) was the first to apply the combination *Cirsium hydrophilum.* The species *Cirsium hydrophilum*, as now interpreted, (Howell 1969, Keil and Turner 1993) comprises two morphologically similar varieties: *C. hydrophilum* var. *vaseyi*, (synonym: *Cirsium vaseyi* [A. Gray] Jepson), a related rare thistle endemic to seeps in serpentine soils on Mount Tamalpais, Marin County, and *C. hydrophilum* var. *hydrophilum*, endemic to brackish tidal marshes in Suisun Marsh, Solano County.

The two varieties of *C. hydrophilum* are weakly separable by a few morphological traits: flower heads 3 centimeters (1.25 inches) or less in var. *hydrophilum*, and 3 centimeters (1.18 inches) or more in var. *vaseyi*, and continuous variation in achene size with slightly larger achenes in var. *hydrophilum*. Jepson (1925) and Howell (1949) did not distinguish the Suisun and Mt. Tamalpais populations as distinct varieties, treating both as a single variety of *Cirsium vaseyi*. Munz (1959) separated taxa equivalent to *C. hydrophilum* var. *hydrophilum* from var. *vaseyi* and *Cirsium douglasii* by the presence of a fringe of tiny spines along the margins of upper stem leaves and bracts in var. *hydrophilum*. Otherwise, the two varieties of *C. hydrophilum* are distinguished mostly by ecology (coastal mountain serpentine seep versus brackish tidal marsh) and geography (Mt. Tamalpais versus Suisun Marsh).

Cirsium hydrophilum is closely related to two other wetland thistles, the widespread *Cirsium douglasii* (swamp thistle), which also occurs around San Francisco Bay, and *Cirsium mohavense* (Mohave thistle), which is restricted to wet habitats within portions of the Great Basin floristic province (Mohave Desert, east of the Sierra Nevada; Keil and Turner 1993). *Cirsium hydrophilum* can be distinguished from *C. douglasii* mainly by the persistent covering of white, felt-like hairs on both the upper and lower sides of the leaves of *C. douglasii*.

Cirsium hydrophilum resembles several other thistles that occur in wetlands, but only one is likely to occur near or in the same brackish tidal marsh habitat in Suisun Marsh. *Cirsium vulgare* (bull thistle), a European weed, is generally found in physically disturbed marsh locations where soil salinity is low. Plants identified as *C. vulgare*, but with traits intermediate between *C. vulgare* and *C. hydrophilum*, have been reported (Horenstein *in litt.* 1987), and the possibility of hybrid intermediates has been noted (U.S. Fish and Wildlife Service 1997*a*); no verified specimens of these hybrids have been collected. In mixed local large populations of *C. vulgare* and *C. hydrophilum* at Rush Ranch (Suisun Marsh), no intermediate thistles were found (B. Grewell and P. Baye pers. observ. 2000). However, hybridization is not uncommon in thistles (Wells 1983, Dabydeen 1987, Keil and Turner 1993). *Cirsium vulgare* can be distinguished from *C. hydrophilum* within the limited range of *C. hydrophilum* in Suisun Marsh by several useful field characteristics summarized in **Table II-1**.

Table II-1. Summary of field characters for discrimination between *Cirsium vulgare* and *Cirsium hydrophilum* var. *hydrophilum* populations found in Suisun Marsh, Solano County, California *(adapted from Keil and Turner 1993, with additions by B. Grewell and P. Baye.)*

Trait	*Cirsium vulgare*	*Cirsium hydrophilum*
upper leaf surface, basal leaves	coarsely hairy to bristly and dull in maturity	glabrate (few hairs) to glabrous (hairless) in maturity, lacking bristles, somewhat glossy to glossy
lower leaf surface, basal leaves	thin covering of short woolly hairs, appearing pale green	thick covering of long white cob-webby to woolly hairs, appearing white
rosettes	low number of leaves, most large and few-lobed	large number of leaves, continuous size range, mostly with many lobes
Stems	with well-developed wings extending from leaf bases; wings strongly spiny	weakly developed or lacking spiny wings
leaf lobes	straight, parallel edges; spines thicker, longer, harder than *C. hydrophilum*	curved edges; spines more slender, shorter, less hard than *C. vulgare*
flowerheads	wide at top of egg-shaped head	tightly constricted at narrow top of egg-shaped head
cypselae	tan to brown, with thin walls, dull surface, frequently attached to *pappus* after dispersal	black to dark brown, thick walls, glossy surface, soon detached from *pappus* before, during, or after dispersal

Other wetland thistles of the San Francisco Bay area that somewhat resemble *C. hydrophilum* include *C. fontinale*, *C. brevistylum*, and *C. andrewsii*. *Cirsium fontinale* has nodding flower heads in contrast with the erect flowerheads of *C. hydrophilum*. *Cirsium brevistylum* and *C. andrewsii* have flowerheads held above clusters of leafy bracts, while *C. hydrophilum* has flowerheads held immediately above a single leaf, but not clusters of leafy bracts (Keil and Turner 1993).

3) Population Trends and Distribution

Historical distribution. There is scarce information on the historical distribution of *Cirsium hydrophilum* var. *hydrophilum*. There are no locality descriptions in older regional floras (Jepson 1911, Greene 1894) or herbarium records more specific than "Suisun Marsh (es)," which suggests that it probably did not occur outside the Suisun Marsh area. No records of any form of *C. hydrophilum* occur between the Mount Tamalpais serpentine seep population of var. *vaseyi* and the tidal marsh populations of var. *hydrophilum* in Suisun Marsh, despite abundant brackish tidal marsh habitat along the Petaluma River, Sonoma Creek, and Napa River. One description of the species' distribution by Greene (for the synonym *Carduus hydrophilus* Greene; Greene 1894) indicates that it was formerly a common plant within the Suisun Marsh region in the late 19th century before marsh reclamation prevailed: "Very common in the brackish marshes of Suisun Bay, California, where it grows within reach of tide water, and is associated with the equally local *Cicuta bolanderi* [synonym: *Cicuta maculata* var. *bolanderi*]...." Subsequent range descriptions (Jepson 1911, 1925; Mason 1957; Munz 1959) do not indicate frequency or range within the marsh. It is likely that the elimination of habitat caused by extensive levee construction between the 1870s and 1930s in Suisun Marsh (Thompson and Dutra 1983) caused a major decline in species abundance and distribution.

Current distribution. Since the time of listing and in the absence of recent surveys, the species is thought to be present at the two sites known prior to listing (Peytonia Slough Ecological Reserve and Rush Ranch), plus upper Hill Slough and the Joice Island portion of Grizzly Island Wildlife Area, all in Suisun Marsh (California Natural Diversity Database 2006) **(Figure II-2**); however the colonies at Rush Ranch and the colonies at Joice Island, which are at the eastern end of Rush Ranch have generally been interpreted as one population (B. Grewell pers. comm. 2000), for a total of three populations. Potential habitat exists on private land directly adjacent to the three known populations on California Department of Fish and Wildlife (CDFW) and Solano Land Trust properties. The status of the species on private land is unknown.

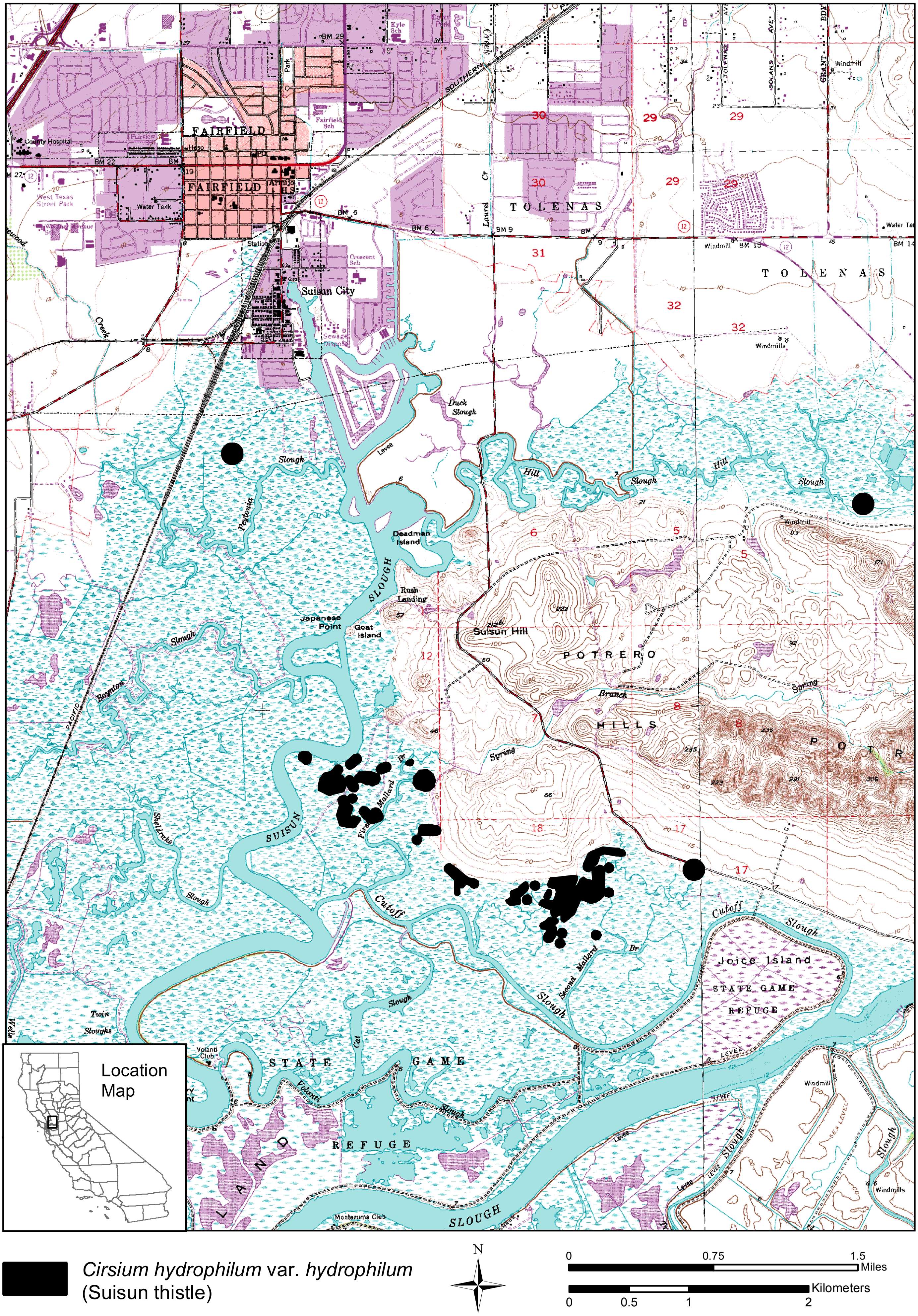


Figure II-2. Distribution of Cirsium hydrophilum var. hydrophilum

map revised: 3/2013

Peytonia Slough is a small population that fluctuates near extirpation. The population was in significant decline in the 1990s, reduced to a single plant in 1996, and totaling only 18 to 30 plants between 1992 and 1994 (B. Grewell pers. comm. 2000). Additionally, it is not known whether a 2001 fire may have affected or eliminated this population, as no survey data since 2001 is available (Grewell pers. comm. 2007). The other localities are narrowly associated with large pre-historical tidal brackish marsh remnants in northwestern Suisun Marsh: Rush Ranch (in the vicinity of Cutoff Slough and First Mallard Branch) and Rush Ranch/Joice Island (in the vicinity of Second Mallard Branch). The Rush Ranch and Rush Ranch-Joice Island population consists of numerous discrete colonies totaling hundreds of plants to a few thousand, but these were also in decline during most of the 1990s (B. Grewell pers. comm. 2000).

The most recent comprehensive survey of *Cirsium hydrophilum* var. *hydrophilum* within its range was conducted at Rush Ranch by L.C. Lee and Associates (LCLA) for the Solano County Water Agency in June and July 2003. This study documented 209 patches grouped into 47 subpopulations across approximately 8.55 acres. All were considered to belong to a large, single population of approximately 22,300 to 873,200 individuals, with a best estimate of 137,500 individuals (LCLA 2003). This survey demonstrates a population size of *C. hydrophilum* var. *hydrophilum* which far exceeds previous estimates made at the time of listing. The population in a fully tidal area in the upper reaches of Hill Slough was discovered in June 2007 and was estimated at 10 plants (Estrella *in litt*. 2009).

4) Life History and Ecology

Reproduction. *Cirsium hydrophilum* var. *hydrophilum* is an annual plant, dying after one year of seed reproduction. Its vegetative period is usually one year (biennial), but if small vegetative plant size or unfavorable environmental conditions delay flowering, it may regenerate from the central root crown for more than one year. Flowering occurs throughout the summer in most years, and continues through production of ripe seedheads.

Pollination ecology of *C. hydrophilum* var. *hydrophilum* has not been studied, but field observations indicate that thistle colonies in the marsh (both native and non-native species) attract large swarms of bees (species undetermined) that visit and apparently pollinate the flowers. Bees working thistle colonies are otherwise infrequent in the tidal marsh (B. Grewell and P. Baye pers. observ. 2000), although bees commonly act as pollinators of other thistles (Keddy and Keddy 1984, Proctor *et al.* 1996). The abundance of bees pollinating thistles in the tidal marsh is probably related to the abundance of potential nest sites and primary nectar/pollen foraging sources in adjacent uplands. At Rush Ranch (Suisun Marsh), bees are common and active in extensive stands of invasive non-native star-thistles (*Centaurea solstitialis, C. calcitrapa*) short distances from *C. hydrophilum* var. *hydrophilum* colonies. The dispersion pattern of *C. hydrophilum* var. *hydrophilum* (California Department of Water Resources *in litt.* 1996) in discrete colonies or clusters of small patches suggests there may be limited seed dispersal.

The reproductive output of individual plants and colonies of *C. hydrophilum* var. *hydrophilum* has not been quantified. No quantitative data are available on seed set, seed abortion, or seed predation. Individual branched plants may produce hundreds of seedheads. Seedheads observed in July 2000 ranged from 3 to 15 ripe seeds per seedhead, but many contained all aborted seeds, and some were found with larvae engaged in active seed predation (P. Baye unpubl. data 2000). Soil core samples indicate that soil *seed bank* density of the closely related *C. hydrophilum* var. *vaseyi* may be significant, but the longevity of buried dormant seed in wetland soils is unknown. Cypselae (seed-like dry fruits) walls are hard, and artificially stored seed of *C. hydrophilum* var. *vaseyi* has retained high viability for at least five years (J. Herr pers. comm. 1998). Other thistle species with similar life histories also have persistent soil seed banks (Clark and Wilson 1994, Cavers *et al.* 1998). These comparative data with other *Cirsium* species, particularly *C. hydrophilum* var. *vaseyi*, suggest the likelihood of a persistent soil seed bank for *C. hydrophilum* var. *hydrophilum*.

Predation. Plant-eating insects can significantly limit seed production and impact plant *demography* as seen in several other *Cirsium* species (Louda and Potvin 1995, Palmisano and Fox 1997, Rose *et al.* 2005). The introduced thistle weevil (*Rhinocyllus conicus*) has been documented in the Rush Ranch population of *Cirsium hydrophilum* var. *hydrophilum* where the California Departement of Water Resources found that many flowers contained weevil larvae and no seeds (U.S. Fish and Wildlife Service 1997). Louda *et al*. (2003) found that two introduced weevil species (*R. conicus* and *Larinus planus* [Canada thistle bud weevil]) caused population decline in native thistle species in the central prairie states. The same year, L.C. Lee and Associates found *R. conicus* present on *C. hydrophilum* var. *hydrophilum* at Rush Ranch. This weevil destroyed about 15 percent of viable seeds produced by the closely related *C. hydrophilum* var. *vaseyi* in serpentine seep habitats, but only early in the flowering season before the end of June. Late flowers escaped predation by the weevil (J. Herr pers. comm. 1998). If this seasonal window applies to Suisun Marsh populations, the impact on reproductive output of *C. hydrophilum* may not be highly significant. Flowering time in Suisun Marsh varies with climate, ranging from June to July. This implies the potential for significant weevil impacts at least in some years (B. Grewell pers. comm. 2000).

In addition, larvae of the Mylitta crescent butterfly (*Phyciodes mylitta*) were found to damage vegetative plants of *Cirsium hydrophilum* var. *hydrophilum* (California Department of Water Resources *in litt.* 1996). Seeds of *C. hydrophilum* var. *hydrophilum* may be subject to pre- and post-dispersal predation, as in other thistle species (Harper 1977), but no data are available. Though documented in the listing rule to have occurred previously at Rush Ranch, *Phycoides mylitta* caterpillars were not located there during the L.C. Lee and Associates study (LCLA 2003). The rare endemic Suisun song sparrow (*Melospiza melodia maxillaris*) is a potential predator of thistle seed, as are American goldfinches (*Carduelis tristis).* Rodents are also likely seed predators (Klinkhamer and de Jong 1993, Palmisano and Fox 1997); mice that inhabit or visit tidal marshes (*e.g.,* salt marsh harvest mice, western harvest mice, house mice) may reduce seed bank size. The significance of post-dispersal seed predation on reproductive success is unknown.

No information is available on fungal diseases affecting reproduction of *Cirsium hydrophilum* var. *hydrophilum*. No parasitism of *C. hydrophilum* var. *hydrophilum* by the salt marsh plant *Cuscuta salina* (salt marsh dodder) has been reported.

Dispersal. Plumed cypsalae of thistles are adapted to wind dispersal. The relatively thick-walled, heavy cypsalae of *Cirsium hydrophilum* var. *hydrophilum*, however, readily detach from the plumed pappus, sometimes before it disperses (P. Baye pers. observ. 2000). Dispersal patterns of *C. hydrophilum* var. *hydrophilum* seed, therefore, may not necessarily be comparable to those of other thistles with light seeds and persistent pappus attachment. There is no evidence of successful long-distance dispersal and colonization of *C. hydrophilum* var. *hydrophilum*. A majority of seed disperses short distances from parent plants. All new colonies detected since listing have been clustered around known populations in Suisun Marsh (B. Grewell pers. comm. 2000). The height of the point of seed release has a large effect on dispersal distances of plumed seeds (Harper 1977). The relatively tall stature of *C. hydrophilum* var. *hydrophilum* compared with most other associated broadleaf tidal marsh plants, combined with the flat topography of the marsh and plumed seeds, suggests the potential for long-distance dispersal of those seeds with persistent attached pappus. The smooth seed coat of *C. hydrophilum* var. *hydrophilum* makes dispersal by attachment to animal fur or feathers unlikely.

Specific conditions for germination and establishment of *Cirsium hydrophilum* var. *hydrophilum* are not known, but field observations suggest they are associated with small gaps or sparsely vegetated areas within the marsh plain. Most seedlings of this species established in *Distichlis spicata* (saltgrass)-dominated brackish tidal marsh vegetation in the early 1990s, years of relatively high local abundance (B. Grewell pers. comm. 2000). Like most tidal *marsh* species, germination presumably depends on periods of very low marsh salinity in winter and early spring (Woodell 1985). Thus, conditions that promote favorable germination may differ from those that maintain favorable seedling habitat structure (*i.e.*, small gaps or locally sparse vegetation cover established by temporary harsh or disturbed conditions, or species interactions).

5) Habitat Characteristics/Ecosystem

Habitat and environmental conditions. Cirsium hydrophilum var. *hydrophilum* is associated with the upper intertidal marsh plain along the steep, peaty banks of natural, mature, small tidal creeks, banks, ditches, and marsh edges that are very infrequently flooded (B. Grewell pers. comm. 2000) but generally *not* along gently sloping terrestrial edges. Artificial ditch edges and natural creek bank habitats are similar in size, form, and vegetation, but ditches are less stable and more prone to invasion by non-native plants. Creek bank edges are typically slightly better drained than other portions of the marsh plain. All *C. hydrophilum* var. *hydrophilum* populations today occur in peaty organic marsh soils, old bay muds of fine estuarine sediments (silty clays) with relatively high organic content in the upper horizons, and increasing mineral content with depth (Joice series soils). The soil requirements of the species have not been determined, but they are not known to occur in recently deposited bay muds with lower organic content. It is not known whether the taxon's reduced range is due to limitations associated with dispersal, colonization potential, competition, or to specific soil requirements of the species.

Little is known about the salinity tolerance of *Cirsium hydrophilum* var. *hydrophilum*. However, it is known to be restricted to freshwater-influenced brackish marshes, and is absent in the freshwater tidal marshes of the west delta and the tidal marshes of central San Pablo Bay to the west. Experimental determination of growth and reproduction responses to soil salinity is needed to predict the physiological and ecological limits of *C. hydrophilum* var. *hydrophilum*.

More complex ecological responses of this *brackish* tidal marsh plant to salinity should be determined by its growth in mixed vegetation composed of associated species in variable salinity conditions, including sequences of fresh and saline pulses (Howard and Mendelssohn 1999). The absence of *C. hydrophilum* var. *hydrophilum* in west delta marshes may indicate an inability to compete successfully in the tall, dense vegetation of tidal freshwater marsh and woody riparian thickets. The observed decline in abundance during a period of above-average rainfall and below average marsh salinity is consistent with the hypothesis that C. hydrophilum var. hydrophilum is at a competitive disadvantage in freshwater habitats (B. Grewell pers. comm. 2000). During this period, freshwater marsh species increased in relative abundance in Suisun Marsh (P. Baye pers. observ. 1996-1998).

Seedling habitat of *Cirsium hydrophilum* var. *hydrophilum* has not been studied. Juvenile plants are found in relatively dense cover of *Distichlis spicata* and even *Juncus arcticus* ssp. *balticus* (wire rush), but seedlings may require gaps in vegetation or sparse areas to establish. Seedlings and juveniles have been found in the vegetation gaps left by large dead plants after exhaustive seed production (P. Baye unpubl. data 2000). Years of high rainfall and concomitant dense growth of tall brackish marsh vegetation have been observed to correspond with declines in seedling establishment (B. Grewell pers. comm. 2000). Dense patches of invasive *Lepidium latifolium* (perennial pepperweed) appear to displace tidal marsh vegetation positively associated with *C. hydrophilum* var. *hydrophilum* (B. Grewell pers. comm. 2000; P. Baye pers. observ. 1994-1998). Potential seedling habitat in brackish marsh may be provided by vegetation dieback associated with growth of the parasitic *Cuscuta salina* var. *major* (B. Grewell pers. comm. 2000), or episodes of high soil salinity in the tidal marsh plain. Thus, temporary harsh, adverse growing conditions for mature plants may be important in regenerating seedling habitat.

Plant associations. Cirsium hydrophilum var. *hydrophilum* is associated with various tidal brackish marsh plant species of the middle and high marsh zones. The earliest information on plant associations was provided by Greene (1894), who emphasized its association with the now-rare *Cicuta maculata* var. *bolanderi* (Bolander's spotted water-hemlock), today seldom if ever found in close association with *C. hydrophilum* var. *hydrophilum*. Little else is known about changes in historical vegetation associated with *C. hydrophilum* var. *hydrophilum*.

The local species composition and relative abundance of marsh vegetation in Suisun Marsh is highly variable, and is apparently influenced by soil salinity and drainage. Tidal marsh plant associations of *Cirsium hydrophilum* var. *hydrophilum* appear to vary with climate cycles. During the relatively drier years of the early 1990s, when *C. hydrophilum* var. *hydrophilum* grew in local relative abundance, low *Distichlis spicata*-dominated vegetation was most often associated with both mature stands and seedling colonies. During the wetter years of the late 1990s, during the period of decline of *C. hydrophilum* var. *hydrophilum* abundance, *Distichlis* associations were largely displaced with dense, tall stands dominated by *Juncus arcticus* ssp. *balticus* (Baltic rush), *Schoenoplectus americanus* (Olney's bulrush), and *Lepidium latifolium* (Grewell *et al*. 1999; B. Grewell pers. comm. 2000). Native tidal marsh plant species frequently associated with *C. hydrophilum* var. *hydrophilum* include *Distichlis spicata*, *Sarcocornia pacifica* (pickleweed), salt rushes of the *Juncus arcticus* ssp. *balticus/J. lesueurii* complex, *Frankenia salina* (alkali-heath), *Schoenoplectus americanus* (threesquare bulrush), *Potentilla anserina* (silverweed), and *Jaumea carnosa* (fleshy jaumea). The frequency of association does not necessarily imply long-term coexistence, however. Expansion of rush colonies appears to smother seedlings and juvenile thistles in the tidal marsh (P. Baye pers. observ. 2000). The rare and endangered *Chloropyron molle* ssp. *molle* (soft bird's-beak) has been associated with *C. hydrophilum* var. *hydrophilum* in at least one locality. At Peytonia Slough, plant species growing in the vicinity of *C. hydrophilum* var. *hydrophilum* included *Euthamia* (=*Solidago*) *occidentalis* (western goldenrod), *Calystegia sepium* (presumably ssp. *limnophila*; morning-glory), *Oenanthe sarmentosa* (water celery), *Triglochin* spp. (sea-arrowgrass), and *Grindelia camporum* (giant gumplant), *Grindelia stricta* var. *angustifolia* (Suisun gumplant) (Horenstein *in litt.* 1987, California Natural Diversity Database 1997). Non-native plant species commonly associated with *C. hydrophilum* var. *hydrophilum* include *Lepidium latifolium*, *Cirsium vulgare*, *Sonchus* spp. (*e.g., Sonchus asper* [spiny sowthistle], *Sonchus oleraceus* [common sowthistle]), and *Apium graveolens* (wild celery).

6) Critical Habitat

A final rule designating critical habitat for this species was published April 12, 2007 (U.S. Fish and Wildlife Service 2007*a*).

7) Reasons for Decline and Threats to Survival

Most species covered in this recovery plan are threatened by similar factors because they occupy the same tidal marsh ecosystem. These general threats, faced by all covered species, are discussed in greater detail in section I. Specific threats to *Cirsium hydrophilum* var. *hydrophilum* are described below.

Factor A
The fundamental cause of the decline of *Cirsium hydrophilum* var. *hydrophilum* from a locally common to very rare plant was the historical diking of almost all of Suisun Marsh and the conversion of extensive tidal brackish marsh to non-tidal wetlands (Atwater *et al*. 1979, Dedrick 1989). Tidal marsh area in Suisun Marsh was reduced from 29,000 hectares (71,100 acres; ca. 1850) to less than 4,000 hectares (9,500 acres; Dedrick 1989). Most remaining tidal marsh consists of narrow strips of marsh prograded between the edges of levees and the banks of narrowed tidal sloughs; relatively little of the pre-historic marsh remains. These strip marshes usually support minimal or no tidal creek or high marsh/upland transition zone habitat suitable for *C. hydrophilum* var. *hydrophilum*. The significant reduction in habitat area and population size left *C. hydrophilum* var. *hydrophilum* much more vulnerable to formerly minor threats, such as seed predation/herbivory by insects and invasion by non-native vegetation.

Rapid invasion of brackish tidal marsh by *Lepidium latifolium* is a very significant threat to the persistence of *Cirsium hydrophilum* var. *hydrophilum* colonies. *Lepidium latifolium* can readily invade both diked and tidal brackish marshes with low salinity during the growing season, and its colonies are especially dense and vigorous in better-drained marsh areas where *C. hydrophilum* var. *hydrophilum* is most likely to occur. *Lepidium latifolium* is especially invasive on physically disturbed marsh soils and where vegetation cover has been reduced. It can permanently establish a continuous leaf canopy, eliminating the vegetation gaps that may be essential for seedling establishment of *C. hydrophilum* var. *hydrophilum.* Dense, tall stands of *L.*

latifolium appear to inhibit survival and growth of juvenile thistles as well. Colonies of *C. hydrophilum* var. *hydrophilum* have not been observed to persist in colonies of this invasive brackish marsh species (B. Grewell and P. Baye pers. observ.). Also, the non-native competitor *Apium graveolens* (wild celery) occurs within the very restricted high marsh subhabitats of *C. hydrophilum* var. *hydrophilum* and has been documented over the last ten years of vegetation change at Rush Ranch.

Cattle grazing and trampling impacts in tidal Suisun marshes are currently remote from most existing colonies of *Cirsium hydrophilum* var. *hydrophilum*, but are locally intensive in unoccupied suitable habitat. This includes areas that support the endangered *Chloropyron molle* ssp. *molle,* such as eastern Hill Slough and Peytonia Slough Marshes (B. Grewell pers. comm. 2000). Trampling impacts may be limiting natural colonization or reintroduction of *C. hydrophilum* var. *hydrophilum* into suitable unoccupied habitat. Evidence of feral pig (*Sus scrofa*) foraging and disturbance has been observed in *Distichlis*-dominated brackish marsh within meters of existing *C. hydrophilum* var. *hydrophilum* populations at Rush Ranch. Feral pigs pose a significant threat to this critically important population (B. Grewell and P. Baye pers. observ. 2000). Limited feral pig hunting has been allowed in portions of Suisun Marsh but a regional-scale eradication effort should be coordinated with CDFWto decrease impact on habitat for sensitive plants.

The historical population of *Cirsium hydrophilum* var. *hydrophilum* at Peytonia Slough was reportedly impacted by Suisun Slough dredging activities that altered tidal creek hydrology for urban drainage and flood control in Suisun City (B. Grewell pers. comm. 2000). Increased residential and commercial development in the expanding Fairfield/Suisun City areas could result in increased urban runoff, freshwater discharges from stormwater and wastewater outflows, and adverse hydrological impacts resulting from additional flood control public works projects. Sustained high levels of nonsaline urban wastewater discharges into Suisun Slough could cause intensive conversion from relatively saline to freshwater brackish marsh vegetation. Such conversion could eliminate suitable habitat in the last remaining major population near Rush Ranch, resulting in near extinction of the species.

The California Department of Water Resources operates salinity control gates at Montezuma Slough to mitigate impacts of water projects and to meet artificially low and stable channel water salinity standards established to protect water quality for waterfowl marsh management (State Water Resources Control Board 1999). Operation of the gates lowers the salinity of the marsh upstream, and incidentally raises tidal elevations on the order of centimeters (Suisun Ecological Workgroup 2001). Preliminary evidence suggests that the altered salinity and tidal regime may subtly, but significantly, threaten long-term survival of *Cirsium hydrophilum* var. *hydrophilum*. Variation in salinity and waterlogging of marsh soils over climate cycles causes periodic shifts in structure and composition of the Suisun Marsh brackish marsh vegetation resulting in growth inhibition or dieback of more salt-sensitive species. Expansion of low-growing salt-tolerant plants prevails during drought periods, and the reverse occurs in series of wet years. The potential for vegetation gaps to develop apparently increases during environmentally harsh periods of low rainfall and relatively high salinity in the tidal marsh. Species interactions in California tidal marsh plant communities, both positive and negative, are probably mediated by this fluctuating environment (Callaway *et al.* 1990, Callaway 1994, Callaway and Sabraw 1994, Kuhn and Zedler 1997). Water management to enforce artificially low channel salinity during droughts, particularly during the summer, is likely to provide a competitive advantage to more robust salt-sensitive, freshwater-preference marsh vegetation, and reduce sub-habitats needed by fugitive gap-colonizing species. *Cirsium hydrophilum* var. *hydrophilum* colonies have been observed to decline during above-average rainfall years (California Department of Water Resources *in litt.* 1996, B. Grewell pers. comm. 2000). Long-term data are needed to clarify this phenomenon and track long-term responses of *C. hydrophilum* var. *hydrophilum* populations to fluctuations in marsh salinity and tidal regimes.

Conversely, persistently elevated salinities caused by diversion of freshwater outflows from the west delta (Sacramento-San Joaquin Rivers) could also cause conversion to more saline tidal brackish marsh and inhibit seedling establishment of *C. hydrophilum* var. *hydrophilum,* causing long-term population decline. Of the two potential trends, artificially high salinity by water management is probably the greater current threat, since Bay-Delta water quality standards have adopted a delta outflow-based approach that maintains a seasonal 2 parts per thousand salinity zone (X2 isohaline) within Suisun Bay (State Water Resources Control Board 1999). Even this X2 standard probably reduces Suisun Marsh salinity fluctuations below those that prevailed prior to marsh reclamation and water diversions.

Factor C
As described under Life History and Ecology above, pre- and post- dispersal seed predation and rosette herbivory are a threat to this species' survival. The introduced thistle weevil (*Rhinocyllus conicus*) has been documented in the Rush Ranch population of *Cirsium hydrophilum* var. *hydrophilum* and may be negatively affecting seed production. Louda *et al.* (2003) found that two introduced weevil species (*R. conicus* and *Larinus planus* [Canada thistle bud weevil]) caused population decline in native thistle species in the central prairie states. LCLA (2003) found *R. conicus* present on *C. hydrophilum* var. *hydrophilum* at Rush Ranch. *Phyciodes mylitta* caterpillars, collected on a population of *C. hydrophilum* var. *hydrophilum* in September 1996, have caused significant damage to the rosettes of plants that will flower the following year (U.S. Fish and Wildlife Service 1997*a*). Though documented in the listing rule to have occurred previously at Rush Ranch, *Phyciodes mylitta* caterpillars were not located there during LCLA's 2003 study. They did not collect sufficient data to assess whether *R. conicus* or *P. mylitta* pose a significant threat to *C. hydrophilum* var. *hydrophilum.* Additional research is necessary to better our understanding of these threats to the species. No management is currently occurring at known locations to ameliorate these threats (Grewell pers. comm. 2007).

Factor D
All three populations of *Cirsium hydrophilum* var. *hydrophilum* occur on conservation lands owned and managed by the CDFW or the Solano Land Trust. However, part of the Peytonia Slough population may occur on privately owned lands. Public lands are protected from urbanization and agricultural conversion, but many activities that are either unregulated or weakly regulated (*e.g.,* mowing, grazing, ditching) may degrade wetland habitat on privately owned lands. Wetlands owned by the CDFW have been managed primarily for waterfowl hunting in the Suisun Marsh, and some remnant tidal marshes were considered for conversion to non-tidal waterfowl managed marshes as recently as the early 1990s. Wetland management practices in Suisun Marsh were in partial non-compliance in the 1990s with requirements of the

1981 biological opinion (Service 1981) (U.S. Fish and Wildlife Service, file information), which illustrates the possibility of ongoing threats even on protected lands. Conversion of tidal marsh to non-tidal marsh is currently unlikely to be permitted, but remains a threat because of variability in compliance and enforcement of endangered species regulations.

Factor E
With strongly reduced modern populations of *Cirsium hydrophilum* var. *hydrophilum*, and relatively larger surrounding populations of non-native *C. vulgare* (bull thistle), there is a risk that either competitive displacement, interspecific hybridization and assimilation, or both, could corrupt the genetic integrity or population viability of *C. hydrophilum* var. *hydrophilum*. Warwick *et al*. (1989) have shown that populations of the thistle *Carduus nutans* have been assimilated in hybrid swarms involving *Carduus acanthoides*. Some preliminary morphological evidence of hybridization between *C. hydrophilum* var. *hydrophilum* and *Cirsium vulgare* has been reported (Horenstein *in litt*. 1987, California Natural Diversity Database 1997), but has not been confirmed by more recent field observations (B. Grewell and P. Baye 2000). Scientific reviews have confirmed the threat to rare plants posed by genetic assimilation in hybrid swarms (Rieseberg 1991, Levin *et al*. 1996). Even in the absence of hybridization, "pollen swamping" can lower the fitness of insular populations of rare species by reducing successful fertilization and seed set (Levin *et al*. 1996).

Sea level rise and associated flood control responses may impose signficant long-term threats to conservation of *Cirsium hydrophilum* var. *hydrophilum*. Conservation of high marsh zones is critically dependant upon landward transgression (displacement) of the marsh profile on broad sloping plains. Many alluvial terraces and valleys adjacent to the estuary are bordered by steep levees or are already converted to agriculture, residential, or commercial development. In Suisun Bay, however, some undeveloped grazing land remains. If rates of sea level rise increase, conflicting needs for flood protection, agriculture, and marsh transgression could effectively compress tidal marsh zones to a point at which they could not support *C. hydrophilum* var. *hydrophilum* habitat. Land use planning and economic pressures that favor conversion of "underdeveloped" grazing lands without conservation protections contribute to the loss of potential *transgressive* high marsh habitat for long-term viability of the species.

A fire started by vandals at Peytonia Slough Ecological Reserve in 2001 may have affected or eliminated this population of *Cirsium hydrophilum* var. *hydrophilum* (Grewell pers. comm. 2007). There have not been any surveys for the species at either the burned or unburned portions of the Reserve since this fire.

b. Chloropyron molle ssp. *molle* (soft bird's-beak)

1) Brief Overview

Chloropyron molle ssp. *molle* (soft bird's-beak) was listed as endangered in its entire range on November 20, 1997 (U.S. Fish and Wildlife Service 1997*a*) with a recovery priority number of 9C, based on its subspecific status, moderate degree of threat, and high recovery potential. The

“C” ranking indicates some degree of conflict between the conservation needs of the subspecies and economic development (U.S. Fish and Wildlife Service 1983). It is a California State rare plant (California Department of Fish and Game 2005). *Chloropyron molle* ssp. *molle* grows in the coastal tidal marshes and brackish marshes from San Pablo Bay to Suisun Bay in Napa, Solano, and Contra Costa counties. The plant also once occurred in Marin and Sonoma counties, but much of its habitat has been lost or fragmented due to marsh alteration and development. There are 11 existing occurrences.

2) Description and Taxonomy

Description. *Chloropyron molle* ssp. *molle* is an erect annual herb in the Orobanchaceae (broomrape) family (**Figure II-3)**. Mature plants range from approximately 10 to 40 centimeters (4 to 16 inches) tall. Plants are typically branched from the middle or above. Stems and leaves are gray-green, often purple-tinged, and covered with very fine hairs bearing *glands* as well as longer soft non-*glandular* hairs. Leaves and stems are sparsely to heavily covered with crystals of salt exuded from leaf glands. Leaves are typically 1.0 to 2.5 centimeters (less than 0.5 to 1.5 inches) long, oblong, and may be entire or pinnately lobed (three to seven lobes). The tubular flowers are pale cream to yellowish at the tip, and crowded together in spikes 5.0 to 15.0 centimeters (2 to 6 inches) long. These spikes support about 3 to 30 flowers, each partially covered by a leafy gray-green to purplish lobed bract that resembles a *calyx*. The calyx is sheath-like, and encloses most of the corolla tube. The corolla is densely tomentose (woolly) with yellowish white or greenish yellow lips, and often bears purplish pollinator guides. The upper lip of the corolla is beak-like, and encloses the two *stamens* and a *style*; there is also an undeveloped sterile pair of stamens. The lower lip of the corolla is pouch-like, and divided into three lobes with the middle rolled or folded (Abrams 1951, Chuang and Heckard 1993). The fruit is a capsule, approximately 8 millimeters (0.3 inch) long (Ruygt 1994). Seeds are 2 to 3 mm (0.1 inch) long.

Taxonomy. At the time *Chloropyron molle* ssp. *molle* was listed (as *Cordylanthus mollis* ssp. *mollis),* the genus *Cordylanthus* was placed in the Scrophulariaceae (figwort family). However, based on molecular systematic studies using DNA sequences of three *plastid* genes, Olmstead *et al.* (2001) transferred the hemiparasitic group Castillejiinae, including *Cordylanthus,* to the Orobanchaceae, thereby placing it in the genus *Chloropyron*. This systematic treatment will be followed in the upcoming revision of the Jepson Manual. Additional molecular *phylogenetic* analysis, initiated as part of the above cited studies, indicates that *Chloropyron* is not a monophyletic genus (Tank and Olmstead 2008, p. 614). In accordance with these findings Tank *et al*. (2009) recognize the genus *Chloropyron* and a previously published name *Chloropyron molle* (A. Gray) A. Heller subsp. *molle* for soft bird’s-beak. This combination will also be recognized in the upcoming revision of the Jepson Manual. Though the taxon continues to be called *Cordylanthus mollis* ssp. *mollis* on the Federal List of Threatened and Endangered Wildlife and Plants (List) pursuant to the Endangered Species Act (Act) (16 U.S.C. 1531 et seq.), here we use (except for directly below) the currently accepted name, *Chloropyron molle* ssp. *molle*.

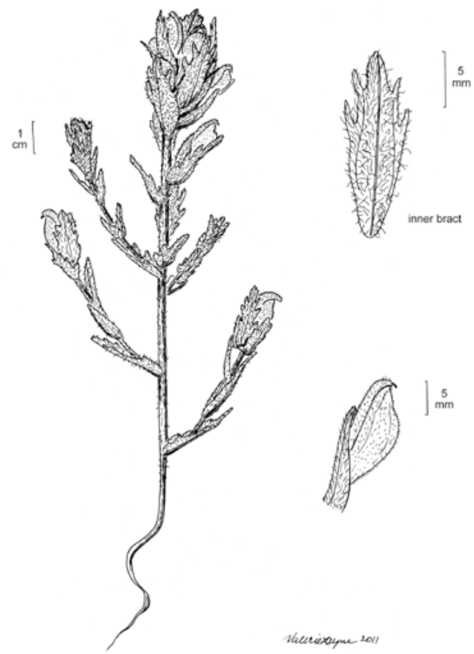


FIGURE II-3. *Chloropyron molle* ssp. *molle* (illustration credit: Valerie Layne, USFWS)

Cordylanthus mollis was placed in the subgenus *Hemistegia*, a group of species with *inflorescences* in spikes and an affinity for saline or alkaline wetlands. The species *Cordylanthus mollis* was split into two subspecies by Chuang and Heckard (1973), based on geographic variation in spike length, branching pattern, corolla hair density, seed size, and hair stiffness. *Cordylanthus mollis* ssp. *mollis* included all estuarine populations and the type of the species. *Cordylanthus mollis* ssp. *hispidus* (= *Cordylanthus hispidus* Pennell) included the non-tidal inland populations from saline basins and marshes of interior valleys, including saline vernal pools in Solano County near the northeastern reaches of Suisun Marsh. *Cordylanthus mollis* ssp. *mollis* and *hispidus* probably represented coastal and interior forms that have differentiated from an ancestral complex including another interior alkali basin species, *C. palmatus* (palmate-bracted bird's-beak, also listed as endangered; Chuang and Heckard 1973).

The former *Cordylanthus mollis* ssp. *mollis* A. Gray (1868) was originally based on a type collection by Charles Wright from Mare Island tidal marshes (San Pablo Bay, Solano County) in 1855. Synonyms now regarded as invalid include *Adenostegia mollis* Greene (1868) and now, *Cordylanthus mollis* ssp. *mollis*.

Chloropyron mollis ssp. *hispidus* is distinguished from ssp. *molle* by its pronounced bristly stem and leaf hairs, and its growth habit of branching strongly from the base of the plant. The flowers of ssp. *hispidus* are sparsely hairy, not densely tomentose (woolly) as in ssp. *mollis*. The Denverton area, Solano County (Suisun Marsh), includes geographic and ecological links between these two subspecies, and is known to support some populations of *C. molle* ssp. *hispidus* in non-tidal alkaline seasonal wetlands (Ruygt 1994). These populations near the estuary edge potentially provide opportunities for intercrosses between the subspecies, the existence and importance of which are unknown.

Within its range, *Chloropyron molle* ssp. *molle* can be distinguished from two other taxa in the Scrophulariaceae that occur in brackish tidal marshes: *Chloropyron maritimum* ssp. *palustre* (Point Reyes bird's-beak) and *Castilleja ambigua* (Johnny-nip, salt marsh owl's-clover). Both are also hemiparasitic annual herbs with affinity for saline wetland soil. *Chloropyron maritimum* ssp. *palustre* has ecological similarities to *C. molle*. It has become very rare in the San Francisco Bay Estuary (restricted to the Petaluma Marsh, Heerdt Marsh, and Richardson Bay, all in Marin County), overlapping only slightly the historical range of *C. molle*. When in flower, *C. maritimum* ssp. *palustre* in the San Francisco Bay Estuary is readily distinguished from *C. molle* by its rose-purple and pinkish-white flowers, and the presence of four fully developed stamens (not two plus two vestigial stamens, as in *C. molle*). The inner bracts of *C. maritimum* ssp. *palustre* are notched, not lobed, while the bracts of *C. mollis* are pinnately lobed.

Castilleja ambigua (synonym *Orthocarpus castillejoides*) is now very narrowly distributed within the San Francisco Bay Estuary. The only known population occurs at Point Pinole tidal marshes, with some individuals near *Chloropyron molle* colonies. *Castilleja ambigua* occurs in high tidal marsh and the upland ecotone with relatively low, sparse vegetation cover. The population of *C. ambigua* in San Francisco Bay flowers in spring (variably late March to May) before *C. molle*. The bracts and leaves of *C. ambigua* are palmately cleft, not pinnately lobed as in *C. molle*. Although typical *C. ambigua* ssp. *ambigua* has white and yellow flowers like *C. molle*, the Point Pinole population of ssp. *ambigua* and other historical San Francisco Bay *populations* have flowers that mature and senesce with a purplish tinge (P. Baye unpubl. data 1997-2000), as do the white-tipped bracts (Chuang and Heckard 1993). In contrast, the bracts of *C. molle* are gray-green or a blend of gray-green and dull dark purplish highlights, and its flowers are creamy yellow or yellowish-green and lack an open beak tip that allows the *stigma* to protrude (Chuang and Heckard 1993).

3) Population Trends and Distribution

Historical distribution. Early California floras describe the range of *Chloropyron molle* either from Mare Island/Vallejo alone (Brewer *et al*. 1880, Behr 1888), or Vallejo and Suisun (Greene 1894, Jepson 1911). The western limit of historically verified populations extended to the tidal marshes between the Petaluma River and San Rafael (Howell 1949), where it was described as "not common" in 1897. *Chloropyron molle* ssp. *molle* was collected from the Burdell locality (Marin County) along the western Petaluma River as recently as 1966. In its western (Marin County) range, it was locally sympatric (occurring in the same geographical range) with *C. maritimum* ssp. *palustre* (Howell 1949). The eastern range of *C. molle* ssp. *molle* extends to brackish tidal marshes at the mouth of the Sacramento River. A population west of Antioch Bridge (California Natural Diversity Database 1997) was observed only once and apparently did not persist (B. Grewell pers. comm. 2000). Grewell *et al*. (2003) report a population between Pittsburg and Antioch in Contra Costa County.

It is questionable whether the range of *Chloropyron molle* ssp. *molle* actually extended to the tidal marshes of San Francisco. Howell *et al*. (1958) include *C. molle* in the flora of San

Francisco, based on a single collection by C.C. Parry from 1881 with a label indicating San Francisco as the location. Chuang and Heckard (1973) suggest that this location may refer to the vicinity of San Francisco Bay rather than the county itself. San Francisco marshes were relatively well surveyed floristically compared with other locations, and no other records of *C. molle* in San Francisco were reported by Brandegee (1892), Behr (1888), Greene (1894), Jepson (1901), or other early botanists. Either *C. molle* was extirpated very early from San Francisco tidal marshes or, more likely, this locality is based on misinterpreted or erroneous specimen labeling.

Current distribution. There are currently 11 populations with documented occurrences in nine general areas: Rush Ranch, Hill Slough, Joice Island, Benicia State Recreation Area (BSRA), Point Pinole, Concord Naval Weapons Station, Fagan Slough, McAvoy Boat Harvor and Denverton (**Figure II-4**). Understanding of the current distribution of *Chloropyron molle* ssp. *molle* is based on limited and opportunistic survey data. No recent comprehensive rangewide status survey has been conducted for *C. molle* ssp. *molle*. The largest populations today are located mostly in old relict tidal marshes of Suisun Marsh. The most recent near-comprehensive census was conducted in 2000 (Grewell *et al*. 2003). This census covered Hill Slough Marsh and Rush Ranch, both in Suisun Marsh, Solano County. It also included BSRA (Solano County) and Fagan Slough Ecological Reserve (Napa County; Grewell *et al*. 2003). The largest population was found at Hill Slough Wildlife Area and covered approximately 2 hectares (4.7 acres).

A more recent population distribution and status evaluation was conducted in 2004 strictly for reference populations at BSRA and the populations at the site of a 2000 experimental reintroduction at Rush Ranch (Grewell 2005). The Rush Ranch population was estimated to be 95,510 individuals occupying 0.08 hectares (0.2 acres). The estimated population at BSRA had 99,005 individuals, the highest numbers ever recorded for a population of *Chloropyron molle* ssp. *molle*, occupying a total area of 0.31 hectares (0.77 acres; Grewell 2005). Many annual plants are known to have large fluctuations in population sizes among years, and the high numbers recorded in 2004 may be a reflection of this characteristic. It is also possible that this was the most thorough search ever conducted, based on micro-habitats surveyed (Grewell 2005). Although population monitoring at Rush Ranch and BSRA indicated continued population growth from 2000 to 2004, seed production of the reintroduced population at Rush Ranch plummeted for unknown reasons in 2004 (Grewell 2005). Long-term monitoring of population sizes will be more useful in determining viability of the population than a single season census.

Each population of *Chloropyron molle* ssp. *molle* is composed of many shifting colonies or subpopulations. Discrete populations consist of widely spaced stands or clusters of colonies with significant dispersal barriers. Most colonies have locally high densities of plants, but some may be diffuse or scattered. Population size and distribution are extremely variable among years. Subpopulations may fail to appear entirely some years and reappear later. Because of the great variability in population size and distribution, short-term (one or two years) estimates of population location and size are not meaningful as indices of actual population size. Population viability, or trends of growth and decline, must be interpreted over a number of years. The area regularly inhabited is also an important measure of the security of the species.

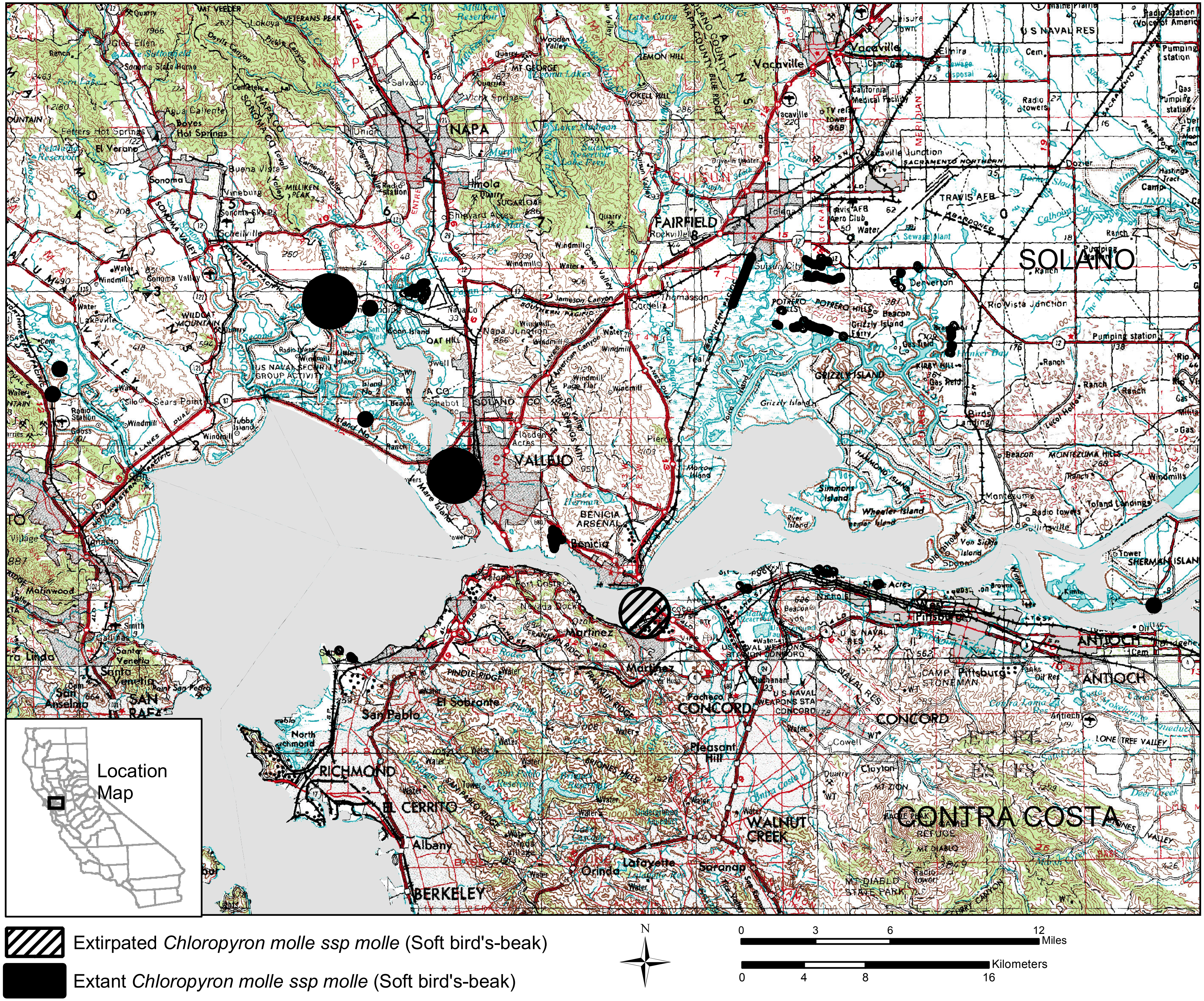


Figure II-4. Distribution of Chloropyron molle ssp. molle

map revised: 11/2013

Because colonies may fail to emerge in some years, it can be difficult to determine with confidence when a population has become extirpated. Sites where the species has not been detected for many years, but where suitable habitat with potentially intact seed banks persists, should be interpreted cautiously. Sites where populations have only recently declined or which have not been rigorously surveyed may be presumed extant but latent. The size and distribution of viable seed banks in marsh soils would probably be a more meaningful indicator of population size. However, data on soil seed banks are not currently available.

In 2000, six of the main populations were estimated to contain a total of roughly 300,000 individuals in about 200 patches or stands (Grewell *et al.* 2003). According to some estimates, the important Hill Slough population has experienced a persistent decline from 1993 through 1999 and 2001 (Grewell *et al.* 2003, Grewell 2004).

4) Life History and Ecology

Reproduction. Chloropyron molle ssp. *molle* is an annual plant that evidently regenerates from a persistent dormant seed bank. The longevity of the seed bank is unknown. However, some colonies have failed to emerge for several years and then reappeared. Population densities vary from isolated individuals (fewer than 0.5 per square meter [0.60 per square yd] to more than 450 per square meter [538 per square yd]), with densities of 100 to 200 per square meter (120 to 239 per square yd) common (Ruygt 1994).

Between the years 2009 and 2012, a relatively healthy population at BSRA, the number of capsules produced per plant ranged from 5 to 35 and the number of seeds produced per plant ranged from 91 to 790, both depending on year and microhabitat sampled (Futrell *in litt.* 2013).

The netted surface of *Chloropyron molle* ssp. *molle* seeds traps microscopic air pockets, making them buoyant and well-adapted for flotation. Although this trait may enable seeds to disperse long distances on tidal currents, dispersion patterns determined by repeated surveys indicate that most dispersal occurs over short distances (Ruygt 1994) on the order of 10 meters [11 yds] or less (Grewell *et al*. 2003). However, studies of dispersal generally are unlikely to detect rare long distance dispersal. Seed germination is correlated with fall/winter rainfall, from December to April, and occasionally earlier or later (B. Grewell pers. comm. 2000). Peak germination rates are in February and March (Ruygt 1994). Although most tidal marsh plants have seed germination tied to periods of tidal marsh flooding with low soil salinity (Woodell 1985), germination of *C. molle* ssp. *molle* in Suisun Marsh has been observed to be greatest in areas with extended tidal *hydroperiods* and somewhat higher soil salinity (Grewell 2004). However, central areas of *scalds* and other areas with low plant density support fewer *C. molle* ssp. *molle*, whether due to salinity or lack of host plants (see below) is unknown.

Hemiparasites, such as *Chloropyron molle* ssp. *molle*, are parasitic plants that have chlorophyll and are capable of some photosynthesis. While *C. molle* ssp. *molle* plants can survive independently under ideal greenhouse conditions, a host plant (or plants) is needed to survive and reproduce in the wild (Ruygt 1994, Grewell *et al*. 2003). Seedling survival is critically dependent on establishing an early connection with a suitable host plant. The parasitic root connections, called haustoria, are short at the seedling stage (less than 5 cm [2 inches]) and rather fragile (Grewell *et al*. 2003). Photosynthate and water are major constituents transferred from the host to the hemiparasite via the haustoria. *C. molle* ssp. *molle* sometimes establish *haustorial* connections with other conspecific individuals, and it may be that photosynthate from a host can be transferred indirectly via another intervening plant to one not immediately connected to the host.

Seedlings of *Chloropyron molle* ssp. *molle* will attach to a broad range of hosts, but not all plants make suitable hosts for the species. Known beneficial hosts include many summer-active native species, including *Sarcocornia pacifica* (pickleweed), *Distichlis spicata* (saltgrass), and *Jaumea carnosa* (fleshy jaumea). Winter annuals such as *Juncus bufonius* (toad rush) and many non-native annual grasses and forbs (*e.g.*, *Polypogon monspeliensis* [annual beard grass], *Hainardia cylindrica* [barbgrass], and *Cotula coronopifolia* [brass-buttons]) do not appear to be suitable hosts because they typically are dying by the time *C. molle* ssp. *molle* plants need to flower and set seed. Seedlings of *C. molle* ssp. *molle* suffered increased mortality when they happened to germinate in the near neighborhood of these unsuitable hosts or in an area with low biomass of hosts (Grewell *et al*. 2003). Invasion of non-native plants is a threat to *C.molle* ssp. *molle* both because many non-natives are unsuitable hosts and because they may compete with and reduce the density and biomass of native host plants.

Branching and flower development begin as early as May (Ruygt 1994) and continue throughout the summer. Flower production in *Chloropyron molle* ssp. *molle* correlates with the degree of branching and plant size (Ruygt 1994, Grewell *et al*. 2003, Grewell 2004). Fruits and seeds mature from July to November. At Fagan Slough in 1993, flowering reached a peak in late July-early August, and declined strongly by late August. Flowering has been observed to occur, however, as late as November, indicating a significant overlap between flowering and fruiting (seed production) time. Some fruits begin to mature around early July.

Several types of generalist native bees and other potential pollinators have been observed visiting *Chloropyron molle* ssp. *molle* flowers. Bumblebees (*Bombus californicus*, possibly other *Bombus* species [Apidae]) were the most frequent visitors in a study by Ruygt (1994). Leaf cutter bees (*Anthidium edwardsii*: Megachilidae) and a sweat bee (*Halictus tripartitus*: Halictidae) also were seen visiting flowers, but their significance as pollinators is uncertain. *Anthidium edwardsii* was the most abundant visitor to *C. molle* ssp. *molle* flowers in a study by Grewell *et al*. (2003), followed by *Lasioglossum* sp., *Halictus* sp. (both Halictidae), and individuals of *Bombus californicus* and *Bombus vosnesenskii*. Other occasional visitors were another native solitary bee (*Melissodes*: Anthophoridae) and a bee fly (Diptera: Bombyliidae). Grewell *et al*. (2003) note the possibility that non-native and native flowers of other species may compete for the attention of available pollinators, and specifically referenced yellow star thistle (*Centaurea solstitialis*). The pollinators known to visit *C. molle* ssp. *molle* are generalists, that is, they will visit a variety of flowers, and could be attracted away by an abundance of another flowering species.

Relatively low numbers of pollinators were observed visiting *Chloropyron molle* ssp. *molle* populations that had high reproductive output at Hill Slough, suggesting some degree of self-pollination. This is consistent with preliminary experimental work in which pollinators were excluded and some seeds were still produced (Ruygt 1994). Nevertheless, the degree to which reproductive output is dependent on or limited by pollinators is uncertain. Grewell *et al*. (2003) believe the species is dependent on insect pollinators for full reproductive output. Parsons and Zedler (1997) found that even a self-compatible population of *C. maritimum* ssp. *maritimum* required insect pollinators to achieve high seed set.

Predation. Seed output of at least some *Chloropyron molle* ssp. *molle* populations is strongly constrained by seed predation, or granivory (Ruygt 1994). Insects that feed on flowers, fruits, and seeds caused substantial reduction in fruit and seed set. Salt marsh snout moth larvae (*Lipographus fenestrella*: Pyralidae) caused significant damage to flowers at the large Hill Slough population, and have been inferred to damage populations at Fagan Slough and Joice Island (Ruygt 1994). Seed capsules filled with insect *frass* are common at BSRA as well (P. Baye pers. observ. 1997-2000, Grewell *et al*. 2003). Another moth species (initially identified as *Ptycholoma* sp., now thought to be *Saphenista* [Tortricidae]) caused flower damage at the Fagan and Hill Slough populations (Ruygt *in litt.* 1993), and in 2001 was the main seed predator at Hill Slough (Grewell *et al*. 2003). Losses of seed to larval feeding can be very high, with up to 71 percent of flowering branches in a population affected (Ruygt 1994), or mature seed output 50 to 70 percent lower in populations with high moth damage (Grewell *et al*. 2003). Other *Lepidopteran* larvae identified on *C. molle* ssp. *molle* were the common buckeye butterfly (*Junonia coenia*: Nymphalidae) and another moth, *Perizoma custodiata* (Geometridae; Grewell *et al*. 2003).

Herbivorous insect populations often go through boom and bust cycles, which may not be *synchronous* among different population locations. This suggests the importance of multiple *peripheral* populations of *Chloropyron molle* ssp. *molle* that may escape large outbreaks of plant-eating insects. For example, the Rush Ranch reintroduction site was not discovered by seed predators in the first year, and also escaped significant damage in its second year (Grewell *et al*. 2003). The soil seed bank may be important for buffering the long-term effects of seed predation on population viability.

Seed predators themselves have predators, notably vespid wasps (yellowjackets and potter wasps) that search *Chloropyron molle* ssp. *molle* inflorescences for larvae with which to feed their young (Grewell *et al*. 2003). Preserving and managing nearby native habitat for these and other predators, parasites, and diseases of the seed-damaging species would likely benefit *C. molle* ssp. *molle* population dynamics.

Seeds may also be subject to predation after they have been shed from the maternal plant. Some granivorous species observed in the vicinity of *C. molle* ssp. *molle* at the time of seed drop include savannah sparrows (*Passerculus sandwichensis*), western meadowlark (*Sturnella neglecta*), and salt marsh harvest mice (*Reithrodontomys raviventris*; Grewell 2004). It is not suggested that native granivores be controlled. If other threats to populations of *C. molle* ssp. *molle* are reduced or eliminated, the species will likely tolerate the pressure of native granivory without ill affect.

Other species that could affect *Chloropyron molle* ssp. *molle* include rabbits and deer, which are relatively indiscriminate grazers of plants. Unrestricted cattle grazing and trampling also occur in some populations (Ruygt 1994), and their effects appear to be harmful to population regeneration (California Department of Water Resources *in litt.* 1996, Fiedler *in litt.* 1996). Livestock can spread non-native invasive plants. Uprooting of marsh soils by feral pigs may also cause at least short-term adverse impacts to adult and seed bank populations, but no direct evidence has yet been reported. Soil disturbance, such as digging by pigs, heavy trampling by cattle, and a wide variety of human activities, often facilitates non-native weed invasion, which adversely impacts *C. molle* ssp. *molle* survival.

In spite of its parasitic habit, *Chloropyron molle* ssp. *molle* has beneficial effects on some species in the ecosystem, and has even been called an "ecosystem engineer" (Grewell 2004). Dominant species (*e.g.*, *Sarcocornia*, *Distichlis*) are reduced by *C. molle* ssp. *molle* presence, and less abundant species are able to increase (*e.g.*, *Atriplex prostrata* [spearscale], *Triglochin maritima* [seaside arrowgrass]), allowing for a more diverse community. *Chloropyron molle* ssp. *molle* also modifies the soil environment where it occurs, causing increased soil oxygenation and lowered soil salinity by enhancing translocation of salty water out of the soil. High nutrient content in decomposing *C. molle* ssp. *molle* plants may further diversify the spatial pattern of soil conditions in the marsh. These factors probably result in increased ecosystem diversity when *C. molle* ssp. *molle* is present (Grewell 2004).

5) Habitat Characteristics/Ecosystem

The principal habitat of *Chloropyron molle* ssp. *molle* is the high marsh zone or upper middle marsh zone of brackish marshes with full tidal range (Peinado *et al*. 1994). It is rarely found in non-tidal conditions (a single collection is known: *L.R. Heckard 4665*, JEPS76417). *Chloropyron molle* ssp. *molle* abundance is often greatest in or near the upper marsh-upland ecotone (Chuang and Heckard 1973, Ruygt 1994). Large, dense patches are sometimes found along the margins of emergent salt pans, or scalds (Ruygt 1994).

Colonies of *Chloropyron molle* ssp. *molle* may occur on different kinds of soils, including peaty clay-silt tidal marsh soils along natural low-relief levees of tidal creek banks (*e.g.,* Point Pinole, BSRA; Ruygt 1994), or on primarily mineral alluvial sediments at the margins of shallow salt pans at the upper marsh edge (southwestern BSRA near Dillon Point; P. Baye pers. observ. 1997-2000). Plants have been found to colonize marsh soils formed on top of artificial fill (Ruygt 1994).

Ruygt (1994) found that soil salinity peaked at the margins of barren scalds near the upper marsh edge. Despite the extreme salinity potential of this subhabitat, the edges of these scalds may be associated with high local abundance of *Chloropyron molle* ssp. *molle* (Ruygt 1994). The overall geographic range of this species, however, is freshwater-influenced, brackish tidal marshes of the estuary. Only one modern population (Point Pinole) is in tidal marsh vegetation with little freshwater influence. Parasitism of neighboring plant roots may buffer soil moisture and salinity stresses (Chuang and Heckard 1971).

Studies of the ecologically similar species *Chloropyron maritimus* indicate that its distribution in tidal marshes corresponds with vegetation that is sparse, low, or contains small gaps to enable seedlings to establish in the absence of strong competition and shade. *Chloropyron maritimus* is negatively correlated with dense, tall, or continuous vegetation patches with low species diversity (Parsons and Zedler 1997, U.S. Fish and Wildlife Service 1985*a*, Pickart and Miller 1988, Kelly and Fletcher 1994). These habitat traits are broadly applicable to *C. molle* ssp. *molle* as well, with important exceptions. *Chloropyron molle* ssp. *molle* has been observed in areas of past disturbance where vegetation cover is suppressed, including on old dredge spoils along ditches (Ruygt *in litt.* 1993), old roads, and footpaths (B. Grewell pers. comm. 2000, P. Baye pers. observ. 1997-99). Vigorous plants in dense patches have also been observed overtopping thick *Sarcocornia pacifica* (pickleweed) vegetation along salt pan edges (P. Baye pers. observ. 2000). Environmental and *biotic* factors that cause sparse vegetation patches include driftlines (smothering by tidal litter deposits; Chapman 1964, Hartman *et al*. 1983, Parsons and Zedler 1997), parasitism by *Cuscuta salina* var. *major* (salt marsh dodder; Grewell *et al*. 2003, Grewell 2004), and low rainfall and salinity stress (Allison 1992, Callaway 1994). Variation in soil conditions along upland tidal marsh edges also appears to influence species distribution, and the density and cover of tidal marsh vegetation in the San Francisco Bay Estuary, especially around summer-dry salt pans (Baye *et al*. 1999).

Plant associations. Native plant species typically associated with *Chloropyron molle* ssp. *molle* in the brackish high marsh and upper middle marsh zone (marsh plain) include dominant species *Sarcocornia pacifica*, *Distichlis spicata*, and *Cuscuta salina* var. *major* (salt marsh dodder), and associates *Frankenia salina* (alkali-heath), *Jaumea carnosa*, *Atriplex prostrata*, *Triglochin maritim*, *Plantago subnuda* (Mexican plantain), *Plantago maritima* (seaside plantain), *Grindelia stricta* var. *angustifolia* (salt marsh gumplant), and *Limonium californicum* (sea-lavender; Ruygt 1994, California Natural Diversity Database 1997, Grewell *et al*. 2003). Non-native plants may also be locally abundant associates of *C. molle*, including low annuals such as *Hainardia cylindrica*, and tall dominant perennial herbs such as *Lepidium latifolium* (perennial peppergrass). *Sarcocornia* and *Distichlis* are host species, and *Cuscuta* was the most closely associated species in the study of Grewell *et al*. (2003).

Although *Chloropyron molle* ssp. *molle* is *hemiparasitic*, the specific plant host-parasite relationships have not been closely studied. Based on studies with other *Chloropyron* species, the primary benefit of parasitism appears to be water availability during drought periods (Chuang and Heckard 1971, Vanderweir and Newman 1984). *Chloropyron* species are generally capable of completing their life-cycles under favorable soil conditions even in the absence of a host, but may require hosts to survive severe soil moisture stress caused by high salinity (Chuang and Heckard 1971).

Parasitic *Cuscuta salina* has been observed to parasitize *Chloropyron molle* ssp. *molle* occasionally (Ruygt 1994; P. Baye pers. observ. 1999, 2000; Grewell *et al.* 2003), but it is seldom parasitized as heavily as *Sarcocornia*. *Cuscuta salina* may be of greater indirect benefit to *C. molle* ssp. *molle* by causing local dieback and vegetation gaps, allowing annuals to colonize open patches (Grewell 2004).

6) Critical Habitat

A final rule designating critical habitat for this species was published April 12, 2007 (U.S. Fish and Wildlife Service 2007*a*).

7) Reasons for Decline and Threats to Survival

Most species covered in this recovery plan are threatened by similar factors because they occupy the same tidal marsh ecosystem. These general threats, faced by all covered species, are discussed in greater detail in section I. Specific threats to *Chloropyron molle* ssp. *molle* are described below.

Factor A

There are many current threats that place populations of *Chloropyron molle* ssp. *molle* at risk of local extinction, but the principal cause of the species' current rarity and decline is the extensive loss of its narrow habitat caused by diking of large tracts of tidal marshes. Diking for agricultural reclamation destroyed most of the original tidal marshes in the northern part of the San Francisco Bay Estuary, reducing tidal marsh acreage to approximately 15 percent of historical area overall (Goals Project 1999). Most of this residual tidal marsh was formed by recent sedimentation, with very little of the pre-historic marsh area actually remaining (Dedrick 1989). Most populations of *C. molle* ssp. *molle* are associated with areas of relict old tidal marshes.

The impacts of diking on *Chloropyron molle* ssp. *molle* were probably greater than the total tidal marsh loss suggests, because overall loss estimates do not distinguish the subhabitats lost. It is very likely that there was a proportionally larger loss of high and upper middle tidal marsh zones near the landward edge of tidal marshes and along larger tidal sloughs (optimal *Chloropyron* topography and habitat), because levees were normally constructed precisely along these natural shoreline boundaries (Ver Planck 1958, Thompson and Dutra 1983). Large-scale loss of habitat caused by diking and reclamation probably isolated many of the populations of *C. molle* ssp. *molle,* which survived in remnant tidal marsh outside of levees. Fragmentation of populations increases the likelihood of their local extinction.

Vineyard expansion in North Bay counties increased rapidly in the 1990s, and vineyard plantings have been attempted in diked agricultural baylands within San Pablo Bay. Economic pressures to convert relatively unproductive agricultural land to grape production could foreclose many opportunities to restore tidal marsh within the historical range of *Chloropyron molle* ssp. *molle*, and may preclude its recovery in substantial portions of its range.

The reduction of total habitat area available to *Chloropyron molle* ssp. *molle,* and the isolation of its populations, magnifies the impacts of localized threats in remnant habitats. These threats include levee repair and maintenance, ditch maintenance, grading and stabilization activities at marsh edges (*e.g.,* Belden's Landing), and poor grazing management (*e.g.,* Hill Slough). Even natural processes such as channel bank erosion (*e.g.,* Point Pinole) can threaten small populations that have lost resilience because of long-term reduction in their size and extent, and increased dispersal distances to neighboring populations. Some impacts, like ditch maintenance, may have both adverse and beneficial effects in different time-scales. Initial disturbance may cause elimination or reduction of small populations, but may also open vegetation gaps and create microtopography that favors long-term colonization by *C. molle* ssp. *molle*. However, vegetation gaps caused by disturbance also invite establishment of invasive non-native plants, an adverse effect to *C. molle* ssp. *molle*. Adverse impacts caused by such disturbances are easily predictable, but it is difficult to predict the likelihood or magnitude of recolonization or population increases because of the influence of random factors. Prediction of population changes, and detection of impacts on population size, is very difficult because of the high natural annual fluctuation of populations.

The most significant threats to remaining *Chloropyron molle* ssp. *molle* populations are region-wide. One of the most potentially detrimental is the invasion of the middle and upper brackish tidal marsh zones by non-native *Lepidium latifolium*, a tall clonal herb in the mustard family that establishes in dense stands. *Lepidium latifolium* generally excludes *C. molle* ssp. *molle*. There are no reports of its populations regenerating annually under spreading tall canopies of *Lepidium latifolium*. The invasion of brackish tidal marshes by *Lepidium latifolium* has proceeded rapidly in the last two decades. It currently threatens at least portions of *C. molle* ssp. *molle* populations at Hill Slough, Joice Island, Rush Ranch, and BSRA where it has spread rapidly in the last decade, particularly in high rainfall years (B. Grewell, P. Baye pers. observ. 1991-1999). Other invasive plants threatening the survival of *C. molle* ssp. *molle* seedlings include the grasses *Hainardia cylindrica* and *Polypogon monspeliensis* (annual beard grass; Grewell 2005). These species serve as inappropriate host plants because they die off before *C. molle* ssp. *molle* completes its life cycle. The effect of *Cotula coronopifolia* (brass-buttons) may also deserve further examination.

Another potential regional threat to *Chloropyron molle* ssp. *molle* is the large-scale alteration of salinity regimes, particularly attempts to stabilize low salinities in the Suisun Marsh to promote water quality standards for selective public beneficial uses. These do not adequately consider the needs of endangered plant species. In recent decades, water quality standards for salinity in Suisun Marsh emphasized conditions specifically favorable for waterfowl habitat (State Water Resources Control Board 1999). Non-tidal flooding of diked marshes inevitably results in some evaporative concentration of salts (like salt ponds), and may result in salt accumulation if drainage is poor. Relatively saline Suisun tidal water is brackish in spring and fall during droughts. It is less saline than San Francisco Bay water, but conducive to producing hypersaline conditions after evaporation. Water quality standards were modified in light of broader estuarine ecological considerations (State Water Resources Control Board 1999). Although water quality standards for salinity have been modified in western Suisun Marsh to allow for climate-driven fluctuation, the artificially narrow low salinity range is still enforced for the eastern Suisun Marsh.

Under natural conditions Suisun Marsh salinity would be closely linked with delta outflows and drainages of the Suisun Marsh watershed. In the early 1990s, the California Department of Water Resources constructed and operated tidegates in Montezuma Slough to maintain low summer and fall salinities regardless of delta outflows. Operation of the salinity control gates has widespread effects on tidal marsh soil and water salinity, and even *tidal datums*, in the Suisun Marsh area. Persistent low summer soil salinity during high rainfall years favors conversion of middle tidal marsh zones to *Schoenoplectus*-dominated vegetation, with concomitant loss of *Sarcocornia-Distichlis* vegetation associated with *Chloropyron molle* ssp. *molle*. During dry years *Sarcocornia-Distichlis* vegetation re-establishes dominance, and *Schoenoplectus* species abundance declines (Suisun Ecological Workgroup 2001). Artificially stabilizing salinities at low levels during the summer and fall by operation of salinity control gates would subdue this pattern of climate-driven vegetation fluctuations, and probably reduce suitability and extent of *C. molle* ssp. *molle* habitat in Suisun Marsh.

Reduced freshwater outflows caused by dams and diversions on the Sacramento and San Joaquin rivers could induce artificially high salinity in otherwise brackish marsh soils, causing declines in growth and reproduction in *Chloropyron molle* ssp. *molle* (U.S. Fish and Wildlife Service 1997*a*). This hypothesis, however, is not supported by field evidence that indicates *C. molle* ssp. *molle* is often particularly abundant in the more saline portions of the brackish tidal marshes in which it occurs (salt pan edges, high marsh zone). It occurs in true tidal marsh rather than brackish marsh (Point Pinole; historically also near San Rafael). Based on observation of the widespread decline in population sizes throughout its range in the late 1990s following several years of above-average rainfall (B. Grewell pers. comm. 1997-1998; P. Baye pers. observ. 1997-1998), it appears more likely that long-term tidal marsh freshening or dampening of salinity variation, rather than progressive salinization, are the greater threats to the species.

In a 2004 survey at Rush Ranch, direct destruction of *Chloropyron molle* ssp. *molle* habitat by feral pigs was frequently encountered (Grewell 2004). Feral pigs were observed rooting and overturning vegetation in former *C. molle* ssp. *molle* population sites. Although Solano Land Trust has permitted limited hunting of feral pigs during closed hours of the reserve, the threat to habitat remains. Hazardous waste remediation at Middle Point (U.S. Navy) resulted in partial destruction of a *C. molle* ssp. *molle* population prior to the species listing as endangered (Ruygt 1994).

Public access and recreation trails (*e.g.*, jogging trails, bike trails) are often placed at the edges of tidal marshes, and sometimes branch directly through *Chloropyron molle* ssp. *molle* populations (*e.g.,* formerly at northeast BSRA). Trail disturbances have dual effects on populations. Initial disturbance may harm *C. molle* ssp. *molle*, but may also reduce density and cover of closed marsh vegetation and create favorable semi-open conditions suitable for expansion into unoccupied habitat. Chronic or increasing trampling, or progressive expansion of marsh footpath networks, however, may cause decline or local extinction of *C. molle* ssp. *molle*.

Some habitat restoration projects may paradoxically have adverse impacts on *Chloropyron molle* ssp. *molle*, at least in the short term. When brackish marshes with limited tidal range are restored to full or increased tidal action, rapid increase in tidal range can cause “drowning” of populations. Although marsh succession in restored marshes is likely to result in additional habitat for *C. molle* ssp. *molle* in the long term, there are random factors that may result in failure to recolonize suitable habitat. The risk of recolonization failure would be high if refugial populations are not protected and managed in the interim succesional phases of restoration.

Factor C

In the final listing rule, intense seed predation by insects was reportedly observed at Joice Island and Hill Slough within the Suisun Marsh in Solano County (U.S. Fish and Wildlife Service 1997*a*). Insect predation reportedly was responsible for decline in one of the largest populations of *Chloropyron molle* ssp. *molle*. Since the time of listing, much light has been shed on the specifics of *C. molle* ssp. *molle* seed predation which may pose a threat to populations in Suisun Marsh.

Chloropyron molle ssp. *molle* seed production can be significantly influenced by pre-dispersal seed predation from moth larvae (*Saphenista* spp., Tortricidae and salt marsh snout moth, *Lipographis fenestrella*, Pyralidae) (Ruygt 1994; Grewell *et al*. 2003). Areas with muted tidal regimes can support the subspecies (California Department of Water Resources 1994), but increased tidal muting can constitute a threat to *C. molle* ssp. *molle* by increasing the prevalence of unsuitable host plants, and by changing the balance of seed production to seed predation maintained between the plant and seed-eating moths, such as various *Saphenista* species (Grewell 2004, Grewell *in litt.* 2006*a*). The moth larvae burrow in the sediment during part of their life cycle, so reduced tidal flooding may improve their survivorship. Under full tidal regimes, the interaction between the rare Lepidopteran moth *(C. molle* specialist) and its rare plant host appears to be in balance (Grewell *et al.* 2003, Grewell 2004).

The extent of granivory at BSRA and Fagan Slough Ecological Reserve were low and these populations did not appear to be limited by granivores. From 2009 to 2012, the average number of seeds per capsule at BSRA, a relatively healthy population, was 20 (Futrell *in litt*. 2013). However, at sites where hydrology was muted, pre-dispersal granivory was extremely high. This has been especially problematic in the Hill Slough area of Suisun Marsh, where the *Chloropyron molle* ssp. *molle* population remains persistent, but under muted tidal regimes population fecundity has continued to decline (Grewell *in litt.* 2006*a*).

Factor D

Wetland regulation policies can have a great impact on habitat and population viability of *Chloropyron molle* ssp. *molle*. Development, expansion, or improvement of urban shoreline facilities (*e.g.*, marinas, docks, utility pipes, dredge disposal/re-use facilities, road improvements, or residential/commercial development) can directly eliminate or indirectly degrade suitable habitat or populations. The Federal and State permitting processes do not lend themselves to comprehensive impact assessments for rare plants as a result of their project-by-project focus, short timeframes, and limited resources. Federal and state authorization of activities that impact wetlands often assess impacts based on acreage. Assessment often assumes that if *C.molle* ssp. *molle* individuals lie outside a project "footprint" at the time a survey is conducted, the species will not be adversely affected if habitat acreage loss is minimized. Minimization requirements emphasizing compensation for acreage of direct impacts sometimes do not consider biogeographic context, regional function, or demographic importance of the particular sites or populations for endangered plants. It is important to realize the influence of indirect impacts to population viability, and that small patches of restored new habitat are not equivalent to established areas within larger marshes.

Evaluation of potential impacts to endangered plants, such as *Chloropyron molle* ssp. *molle,* for wetland permit applications is sometimes limited to incomplete surveys, or based on inconclusive short-term negative surveys in the brief permit application and review process. The practice of focusing regulatory review only on sites proven to be occupied by endangered plant species is biased against protection of suitable habitat for long-term conservation. Population levels of annual plants are not static. Brief survey periods are particularly biased against detection of annual plants, such as *C. molle* ssp. *molle,* with fluctuating populations that may fail to emerge from persistent seed banks in some years. Wetland regulatory agencies have sometimes issued authorizations before adequate survey results were conducted, deferring surveys and avoidance requirements to pre-construction surveys after permits were issued. In some cases of regional (general) wetland permits for activities such as levee repair or ditching in tidal marshes, there have been no adequate rare plant surveys required. Overall, these regulatory practices increase the probability of harming undetected latent populations due to false negative surveys for colonies that emerge intermittently.

Wetland regulatory agencies with jurisdiction in the geographic range of *Chloropyron molle* ssp. *molle* have tended to be permissive towards projects with small acreage impacts and low levels of public comment, and have performed limited analysis of cumulative impacts of those projects. This practice is likely to cause progressive losses of suitable habitat for the species, since most tidal wetland fill projects are located at the upper landward margins of marshes or along levees.

Factor E

Sea level rise and associated flood control responses may impose signficant long-term threats to conservation of *Chloropyron molle* ssp. *molle*. Conservation of high marsh zones is critically dependant upon landward transgression (displacement) of the marsh profile on broad sloping plains. Many alluvial terraces and valleys adjacent to the estuary are bordered by steep levees or are already converted to intensive agriculture, residential, or commercial development. In Suisun and northern San Pablo Bay, however, some undeveloped grazing land remains. If rates of sea level rise increase, conflicting needs for flood protection, agriculture, and marsh transgression could effectively compress tidal marsh zones to a point at which they could not support *C. molle* ssp. *molle* habitat. Land use planning and economic pressures that favor conversion of “underdeveloped” grazing lands contribute to the loss of potential *transgressive* high marsh habitat for long-term viability of the species.

Other potential threats to *Chloropyron molle* ssp. *molle* include spills of crude oil or refined petroleum products. Crude oil spills tend to deposit near the high tide line where the species is most abundant. Oil spills could have adverse effects on seedling emergence if they occur in winter-spring, and could injure flowering populations in summer. In the event of an oil spill, cleanup activities would be concentrated in the high marsh zone. Oiling or raking for removal of oiled debris could adversely affect soil seed banks of *C. molle* ssp. *molle*, impairing its regeneration. More volatile refined petroleum products, such as gasoline, with greater potential to penetrate into marsh sediments, may require sediment removal for remediation. For example, a gasoline line leak on October 4, 2000 contaminated brackish tidal marsh near Bay Point, Contra Costa County, in suitable *C. molle* ssp. *molle* habitat. Soil or sediment removal in tidal marshes supporting *C. molle* ssp. *molle* could cause irreversible damage to populations and habitat. This is particularly pertinent to seed banks that take many decades to accumulate. These are a rich genetic reservoir. Avoidance of populations during oil response may be difficult or ineffective during the non-flowering seasons.

c. Suaeda californica (California sea-blite)

1) Brief Overview

Suaeda californica (California sea-blite) was listed as a federally endangered species over its entire range on December 15, 1994 (U.S. Fish and Wildlife Service 1994) with a recovery priority number of 8, based on a moderate degree of threat, high potential of recovery, and its taxonomic standing as a species (U.S. Fish and Wildlife Service 1983). It is not listed as endangered or threatened by the State of California. Naturally-occurring *S. californica* is now restricted to the southernmost area of its historical range on the shorelines of Morro Bay, where it grows on sandy tidal marsh edges and high tide lines of sheltered estuarine beaches. Numerous threats, both natural and human-caused, exist and are exacerbated by the very low number of individuals, restricted geographic range, and narrow habitat requirements.

2) Description and Taxonomy

Description. *Suaeda californica* S. Watson (California sea-blite, **Figure II-5**) is a salt-tolerant (*halophytic*) member of the Chenopodiaceae (goosefoot family). It grows as a spreading or mounding *subshrub*, woody only at the base. It is usually about 60 centimeters (2 feet) in height, but sometimes reaches over 80 centimeters (3 feet), and spreads up to about 200 centimeters (6 to 7 feet) in width. Individual plants do not appear to form clonal colonies. Leaves are generally pale to *glaucous* green, densely crowded and overlapping, nearly lacking a leafstalk, narrow to nearly needle-like, and up to 3.5 centimeters (nearly 1.5 inches) long. Flowers are not confined to the ends of branches, but occur in scattered clusters of one to three (rarely up to five) at the base of leaves. Flowers are radial, 2 to 3 mm (about 0.1 inch) in diameter, and are either perfect (both pollen- and seed-bearing) or carpellate (seed-bearing only). When flowers occur in clusters of three, the terminal flower is typically perfect and the lateral ones smaller and carpellate. There are five protruding stamens, and a cone-shaped ovary with three stigmas. The calyx lobes are glabrous (hairless) and rounded, or hooded (Munz 1959, Ferren and Whitmore 1983, Ferren 1993).

Taxonomy. *Suaeda californica* was first described by Sereno Watson in 1874, based on type material collected by Bolander and Kellogg in San Francisco Bay tidal marshes. Amos Heller published the name *Dondia californica* in 1898, recognizing the genus name used by Michel Adanson in 1763. However, the name *Suaeda* has been conserved (Abrams 1944). Munz (1959) recognized several previously recognized taxa as subspecies of *S. californica*, and described the range as extending from San Francisco Bay south to Lower (Baja) California. Ferren and Whitmore (1983) noted that much of what had been identified as *S. californica* in southern California was a distinct taxon, which they named *S. esteroa.* Further study revealed that the only extant populations of *Suaeda* that resemble the type specimen of *S. californica* are those that occur in the vicinity of Morro Bay. In his revision of the genus, Ferren (1993) recognized *S. californica* as a full species.

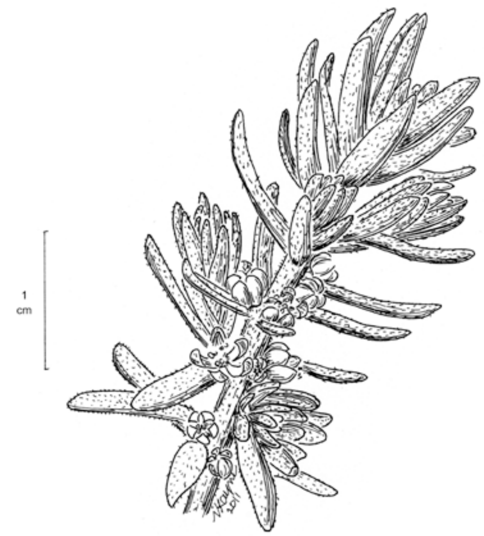


FIGURE II-5. ***Suaeda californica*** (illustration credit: Valerie Layne, USFWS)

The previous taxonomic ambiguity of the genus in California has resulted in confusion in reports of the geographical ranges of *Suaeda* taxa on the California coast (Fisher *et al.* 1997, Ferren and Whitmore 1983). Even herbarium collections contain some misidentified specimens. *Suaeda taxifolia*, woolly sea-blite of the southern California coast, has been treated by some authors as varieties of *Suaeda californica* (vars. *pubescens* Jeps. and *taxifolia* [Standl.] Munz). *Suaeda taxifolia*, in addition to morphological distinctions (pear-shaped ovary, dense hairiness), typically colonizes coastal bluffs as well as tidal marshes. In contrast, most collections of *S. californica* are from tidal marsh edges or estuarine beaches; it is rarely reported from bluffs at elevations much above sea level.

Many reports of *Suaeda californica* from southern California are erroneous due to confusion with *S. esteroa* (Ferren and Whitmore 1983). *Suaeda esteroa* is restricted to estuaries of southern California (south of Point Conception) and Baja California. It is ecologically similar to *S. californica*, but can be distinguished by a number of morphological traits.

Several species found within the overall geographic range of *Suaeda californica* may be casually misidentified as it. The most similar is *Suaeda moquinii* (alkali blite or bush seepweed), which is generally found in the Great Valley. In the San Francisco Bay area, *S. moquinii* has historically been restricted to saline or alkaline seasonal wetlands. Most populations of *S. moquinii* in the San Francisco Bay area are from inland, non-tidal localities, but near Fremont and Milpitas it occurs in non-tidal alkaline/subsaline wetlands very close to the bay, even in some diked historical baylands. *Suaeda moquinii* is generally absent in tidal shorelines where *S. californica* would occur, and there are no valid historical records of *S. californica* known from southeastern San Francisco Bay. *Suaeda moquinii* is distinguished from *S. californica* by its open inflorescences of flowers clustered at upper ends of stems only, smooth leaf-scars, and widely spaced, non-overlapping (to slightly overlapping) leaves and leaf-like bracts. It also has a pear-shaped ovary. Nonetheless, specimens of *S. moquinii* collected from San Francisco Bay area localities have occasionally been erroneously identified as *S. californica*.

3) Population Trends and Distribution

Historical distribution. *Suaeda californica* was originally reported to range from San Francisco Bay to southern California because of past taxonomic confusion with *S. taxifolia* and *S. esteroa*. As the taxon is now narrowly interpreted, the historical range of *S. californica* was limited to the San Francisco Bay Estuary south to Morro Bay. In recent ecological time (latter part of the Holocene epoch), its distribution was probably disjunct with few, if any, plants between the two population centers around San Francisco Bay and Morro Bay.

Based on historical accounts and herbarium collections, it appears that the distribution of *Suaeda californica* was concentrated in the central part of the San Francisco Bay Estuary, with most collections from the Oakland-Alameda area. It was sparsely distributed from approximately Point San Pablo, Contra Costa County ("San Pablo Landing" of Jepson 1911), to San Leandro, Alameda County, and San Francisco County. One disjunct collection is known from Palo Alto (Santa Clara County). Assuming correct identifications, early reports suggest that *S. californica* was an infrequent component of the tidal marsh vegetation of San Francisco Bay.

Brandegee (1892) described the distribution of *Suaeda* in San Francisco County from two localities, south San Francisco (the southeastern portion of San Francisco south of Hunters Point; Howell *et al*. 1958) and Visitacion Bay, both along the city's east shore near the San Mateo County border. These locations appear on early U.S. Coast Survey maps as pocket tidal marshes in drowned valleys between headlands associated with narrow beach ridges derived from coarse sediments such as sand or shell hash (Greene 1894, Jepson 1911). The same early topographic maps depict in detail another larger sand spit and backbarrier tidal marsh that occurred in the Presidio. No known reports of *S. californica* exist from the Presidio Marsh.

Best *et al*. (1996) cite a putative record of *Suaeda californica* (as "*Dondia California*" [*sic*]) near the Petaluma River based on the remnant plant content of local adobe bricks dating from the 1830s and 1840s (Hendry and Kelley 1925); however, the accuracy of this identification is highly doubtful because no other *Suaeda* species are reported in the floras of Marin or Sonoma counties (Howell 1949, Best *et al*. 1996), and this area lacks tidal marsh habitat. Regardless, the dubious adobe brick report is repeated in plant databases (California Natural Diversity Database 1997, CalFlora 2000, California Native Plant Society 2008).

No valid reports or collections of *Suaeda californica* from San Francisco Bay have occurred since the mid-twentieth century. Despite extensive surveys (P. Baye unpubl. data 1991-1999), the last confirmed historical occurrence was a 1958 collection in San Leandro.

Current distribution. Until 1999, *Suaeda californica* was considered extant in Morro Bay, but extirpated at its type locality, San Francisco Bay. It now is known from five locations in the

Morro Bay area as well as at four known reintroduced locations in San Francisco Bay: Pier 98 (Heron's Head Marsh), Pier 94, Emeryville Crescent, and Robert's Landing.

Suaeda californica has a brief history of reintroduction to San Francisco Bay. Two pilot projects were implemented in 1999 at Crissy Field (National Park Service) and Pier 98 (Port of San Francisco) using clonal stock originating from Morro Bay plants (Baye 2006). Both reintroduced populations failed; Crissy Field failed because of impaired tidal hydrology and the Pier 98 population declined because of unsuitable substrate (Baye 2006). The Pier 98 reintroduction, however, resulted in several years of seed reproduction and apparent natural recruitment of a small population of highly vigorous *S. californica* on the thin shell hash (fine oyster shell fragments) beach ridges along an adjacent unrestored urban shoreline. In 2003, the population comprised 20 mature plants, producing many tens of thousands of seeds (Baye 2006).

In 2006 the Port of San Francisco and Golden Gate Audubon Society initiated a local reintroduction of *Suaeda californica* to a reconstructed sand beach ecotone along a small urban tidal marsh at Pier 94, San Francisco (Baye 2006). The founder population was grown from seed collected at Pier 98. At last monitoring all individuals were surviving and growing rapidly.

In 2007, 14 transplants of *Suaeda californica* were introduced along the high tide line of East Bay Regional Park's Eastshore State Park near Emeryville Crescent, Alameda County, in coordination with the U.S. Fish and Wildlife Service and its contractor. Though four transplants died rather quickly due to low rainfall, the remainder were thriving and many were observed flowering at last monitoring (P. Baye pers. comm. 2007). An additional reintroduction of eight plants at Robert's Landing Marsh, Alameda County, was conducted in 2008 (Bloom pers. observ. 2008); however, it is too soon to know if this population will be self-sustaining. This site is owned and managed by the City of San Leandro.

In Morro Bay, *Suaeda californica* occurs along the tidal marsh edges, estuarine beaches, and low bluffs and *scarps* along the shoreline of Morro Bay, San Luis Obispo County and also at the mouths of Old and Villa creeks and the bluffs at San Geronimo Creek near Cayucos, north of Morro Bay (**Figure II-6 and Figure II-7**). The species distribution was mapped after comprehensive field surveys of Morro Bay in 1992 (Hillaker 1992), and resurveyed by the U.S. Fish and Wildlife Service from 1997 to 2000 (P. Baye unpubl. data 2000). Several factors indicate that the numerous colonies in Morro Bay constitute a single population: (1) Morro Bay is a natural hydrologic unit for seed dispersal, comprising a sheltered, enclosed embayment; (2) Morro Bay is separated from similar sheltered embayments; and (3) the nearest suitable habitats of significant size are occupied by other species of *Suaeda*.

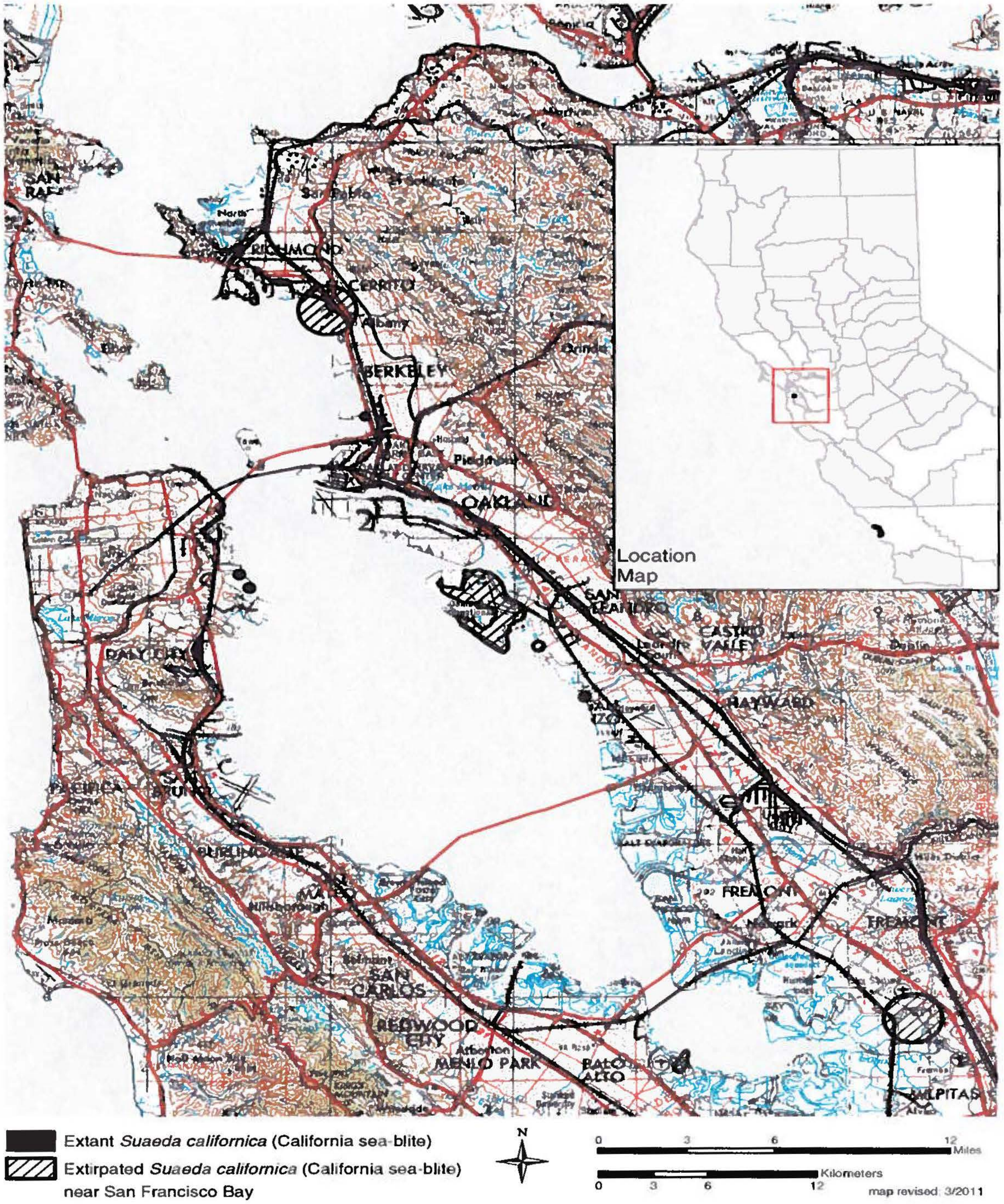


Figure II-6. Distribution of *Suaeda californica* in San Francisco Bay

Figure II-7. Distribution of *Suaeda californica* in Morro Bay

Morro Bay subpopulations of *Suaeda californica* include:

(1) North Shore: vicinity of Morro Bay State Park and the tidal inlet throat (Morro Channel, Morro Bay harbor; heron rookery, Fairmount Point);

(2) Sand spit backbarrier shoreline: Morro Dunes Nature Preserve;

(3) Southeast Morro Bay: Sweet Springs Nature Preserve and Los Osos/Cuesta-by-the Sea shoreline;

(4) Baywood Park bluffs vicinity: pocket marshes and low bluffs in ancient dunes, near end of Santa Ysabel Avenue; and

(5) Cayucos: mouths of Old and Villa creeks and bluffs at San Geronimo Creek.

Small colonies have been identified along the urbanized Embarcadero shoreline of Morro Bay tidal inlet, approximately between the end of Morro Bay Boulevard and the Morro Bay boat launch (Hillaker 1992). Large gaps in distribution exist at the tip of the sand spit where unstable mobile dunes migrate directly into the bay and along the dredge disposal site at the extreme north end. The species is largely absent along the high marsh shoreline of the marsh deltas of Chorro and Los Osos creeks. It occurs only at the northwest corner of the Chorro Creek delta marsh, at Morro Bay State Park.

Suaeda californica in Morro Bay declined dramatically during the late 1990s when it was reported along nearly all of the shoreline, with colonies growing often continuously from the southern end of the bay to the northern reaches of the sand spit. It was absent only along shoreline segments with highly mobile unvegetated dunes (Hillaker 1992, P. Baye unpubl. data 1997). The severe winter storms of 1997-98 scoured away all but small remnants of this formerly extensive colony. The driftlines in eroded gaps briefly supported a flush of *S. californica* seedlings in 1998, but few survived by the spring of 1999 (P. Baye unpubl. data). Relatively sheltered, smaller *S. californica* colonies in the northern part of the bay were less heavily impacted by erosion, and were relatively intact. Between 1998 and 2000, nearly all known occupied habitat of *S. californica* in Morro Bay was resurveyed after the mass dieback of the 1998 flush of seedlings (Baye pers. comm. 2004). The total Morro Bay population size of the species was estimated to be nearly 360 mature plants in 2000.

There are no reported field estimates of the total *Suaeda californica* population prior to the 1997-1998 storms when most of the plants along the spit shoreline grew in continuous colonies, not as discrete identifiable individuals. However, a conservative estimate suggests that the spit subpopulation alone probably supported at least 1,700 to 2,400 plants (Baye pers. comm. 2004). This estimate may be low because of the irregular shoreline and the presence of smaller plants mixed in colonies.

In 2002, California Department of Parks and Recreation initiated a reintroduction project aimed at restoring *S. californica* habitat through removal of non-native vegetation along the estuary edge. The expansion of the known range of *S. californica* was also augmented by propagation, then introduction. A population census of the reintroduction areas was conducted in December 2004 (California Department of Fish and Game 2006) where population estimates using two different methods, ranged from 2,934 to 3,597 individuals. Restoration resulted in an expanded population at one site at the North Shore subpopulation. The exotics removal work at Morro Estuary Natural Preserve allowed the population to naturally expand and persist in 2005 as reproductive plants.

Herbarium records indicate occasional historical occurrences of *Suaeda californica* outside of Morro Bay in the vicinity of creek mouths (*Hardham 2710*, 1957) and coastal bluffs (R. Ferris, 1929, DS206274) near Cayucos. California Department of Parks and Recreation's 2005 survey of *S. californica* in and around Morro Bay revealed a total of 28 to 30 plants surviving near Cayucos at the mouths of Old Creek and Villa creek and on clay soils on coastal bluffs at San Geronimo Creek (California Department of Fish and Game 2006). These could be significant populations because of their isolation and the environmental extremes to which they are adapted.

4) Life History and Ecology

Suaeda californica produces seeds throughout its lifespan. Reproduction appears to be entirely by seed (sexual); there are no known reports of natural regeneration from vegetative fragments. The spread of individual plants can be extensive, and sometimes resembles clonal populations. However, they have not been observed to spread clonally. Vegetative stem cuttings of *S. californica* treated with synthetic auxins (hormones) are easily rooted for artificial propagation (P. Baye pers. observ. 1991-1999).

Reproductive maturity may in some cases be reached in as little as one year (P. Baye unpubl. data 1998). Flowering occurs on portions of the current year's shoot growth, usually on lateral branches of older wood. Flowers typically appear from May to October, but mostly in late summer. Occasional flowers may be found at other times of the year, sometimes emerging as early as late spring (McMinn 1939, Baye pers. observ.). Differences in flowering phenology may be an indication of genetic variation. One entire colony of *Suaeda californica* on Pickleweed Island, Morro Bay, was observed to flower precociously in April, while adjacent plants and all other colonies were entirely vegetative (P. Baye unpubl. data 2000). The longevity of individual plants is unknown, but large woody plants in stable substrate appear to live for over a decade.

Very little information is available on the breeding system of *Suaeda californica;* however, a predominantly outcrossing breeding system would be expected for this wind-pollinated, often colonial, shrub. Abundant seed (many hundreds per plant) is produced on fruiting plants at Morro Bay. The ability of isolated plants in cultivation to produce seed (P. Baye pers. observ. 1998) suggests that at least some individuals possess a degree of self-compatibility. Abundant seed set occurred spontaneously in outdoor container-grown nursery plants at the Golden Gate National Recreation Area nursery in San Francisco in 1998. These seeds were *viable* and produced vigorous seedlings (E. Heimbinder pers. comm. 1999).

Based on observations by marsh ecologist Peter Baye, abundant seedling establishment at Morro Bay appears to be episodic, corresponding to storm events that cause both vegetation gaps and deposits of driftline debris with seeds. Seedlings were widespread and abundant along the backbarrier shoreline following the erosive winter storms of 1998. Many thousands of seedlings and multiple-branched juvenile plants had established in the erosion zone in driftlines and litter rafts by late April 1998. Seedlings rooted in debris rafts without roots in the marsh substrate were subject to high mortality. No evidence of long distance dispersal and colonization was observed. Re-survey of the extensive 1998 seedling colonies in April of 1999 and 2000 revealed only regeneration of remnant mature shrubs that survived erosion. No juvenile or young mature plants were detected, indicating extremely high mortality of the post-storm cohort of seedlings. In contrast, the colonies of mature *Suaeda californica* at the north end of Morro Bay were mostly unaffected by the 1998 storm. These narrow, dense colonies acted as a significant refugia for survival and seed production during the catastrophic mortality that affected most of the population along the bayshore of the central sand spit.

5) Habitat Characteristics/Ecosystem

Suaeda californica is largely restricted to the narrow high tidal marsh zone in Morro Bay, often within the wrack line of storm tides. In Morro Bay this habitat occurs mostly on sandy substrates or pure sand, such as scarps in ancient Pleistocene dunes (Morro Channel and harbor shore, Baywood Park, Los Osos), modern dunes and estuarine beaches (Morro Spit), and small low spits and marsh berms (Sweet Springs Marsh, Pickleweed Island). *Suaeda californica* also occurs among rocks placed over sandy fill material in artificial shorelines (northern Morro Bay sites), and on well-drained sandy marsh peat at the edge of eroding marsh scarps (Baywood Park near the end of St. Ysabel Street). *Suaeda californica* exists on shell hash beach ridges in San Francisco. The most environmentally extreme habitat occupied by *S. californica* is the guano-enriched bluffs below the cormorant and heron rookery along Morro Channel. Intensive local deposition of urea- and ammonia-containing guano has killed eucalyptus trees and all terrestrial vegetation except *S. californica*, which develops luxuriant growth with rich blue-green plants many meters across that grow from the base of the bluff upwards. This situation well illustrates the affinity of specialized Chenopodiacea species for extreme levels of soil sodium or nitrogen (Waisel 1972).

Suaeda californica habitat, estuarine sand beaches within tidal marsh, is very scarce in San Francisco Bay Estuary today. There is currently only one remnant historical sandy tidal marsh in the estuary (Whittell Marsh, Point Pinole), and a few small pockets of recently formed sandy tidal marshes where artificial fill has eroded and been redeposited (*e.g.*, Albany dump shoreline, frontage road along I-80 south of Albany; portions of the southeastern San Francisco shoreline). Only one sand spit has naturally reformed along the San Leandro shoreline within the last two decades (Robert's Landing, San Lorenzo Creek mouth). Bayward edges of tidal marshes and levees in the vicinity of Redwood City and Palo Alto today still develop low ecotonal beach ridges about 0.5 meter (0.55 yd) above the marsh plain composed of shell hash. These beach ridges become marsh berms covered with high tidal marsh vegetation, including native species such as *Grindelia stricta* var. *angustifolia* (gumplant), *Frankenia salina* (alkali-heath), and *Sarcocornia pacifica* (pickleweed). These shell hash beach ridges probably provided habitat for *S. californica* in this portion of the bay where sand supplies were minimal.

High rates of sand deposition and erosion limit growth and survival of *Suaeda californica* at Morro Bay. Colonies occur occasionally at the advancing edges of dunes where they grow through and at least temporarily keep pace with sand accretion. At some locations along the bay shoreline, vigorous growth persists at elevations up to 1.2 meters (1.3 yds) above the high tidal marsh surface. More often, however, rapidly moving dunes bury and kill *S. californica* colonies and other marsh-edge vegetation in their path.

A significant source of nutrients to *Suaeda californica* colonies at Morro Bay is provided by thick wracks of decomposing *Zostera marina* (eelgrass), which form driftlines in the zone of highest tidal influence. This provides nitrogen for plants growing in nutrient-deficient sand. Colonies that grow in local conditions that discourage deposition or retention of *Zostera* driftlines (*e.g.*, steep artificial rock slope of the marina, low bluffs in ancient dunes) often have sparse yellowish gray-green foliage, compared with the luxuriant grayish blue-green foliage of plants in driftlines and guano-enriched sandy soils at the heron rookery (P. Baye unpubl. data 1997-2000). Other major mineral nutrients (particularly potassium and calcium) are presumably provided by seawater.

The salt tolerance of *Suaeda californica* has not been evaluated experimentally, but limited field evidence suggests that subsurface flow of groundwater from adjacent dunes may reduce salinity of the root zone in many situations (P. Baye unpubl. data 1999).

Plant associations. Although described as a species of tidal marsh habitats (Munz 1959, Hickman 1993, Sawyer and Keeler-Wolf 1995), *Suaeda californica* occurs only in a narrow ecotone between the extensive middle tidal marsh zone characterized by *decumbent* to prostrate *Sarcocornia pacifica*, *Triglochin concinna* (creeping arrow-grass), and *Jaumea carnosa* (fleshy jaumea); and below upland vegetation at the edge of the marsh, often dominated by stable dune scrub with *Eriophyllum staechadifolium* (woolly sunflower) or non-native *Carpobrotus edulis* (iceplant) and hybrids. This high marsh ecotone in Morro Bay is typically only about 1 to 2 meters (1.09 to 2.19 yds) wide depending on slope. Within this zone, *S. californica* associates with *Distichlis spicata* (saltgrass), *Atriplex watsonii* (Watson's saltbush), *Atriplex prostrata* (spearscale), *Atriplex californica* (California saltbush), *Sarcocornia pacifica*, *Frankenia salina*, and *Jaumea carnosa*. *Isocoma veneta* ssp. *vernonioides* also occurs locally in the high marsh zone with *S. californica*. Occasionally, *Cuscuta salina*, a parasitic dodder, occurs on *S. californica* in this zone, but no lasting injury has been observed (P. Baye pers. observ.). *Suaeda californica* also occurs adjacent to colonies of the rare *Chloropyron maritimum* ssp. *maritimum* (salt marsh bird's-beak) and *Lasthenia glabrata* ssp. *coulteri* (Coulter's goldfields) in high tidal marsh at Sweet Springs Marsh. *Suaeda californica* is probably associated with the corresponding northern varieties/subspecies of these taxa in San Francisco Bay. Native dune plant species include *Ericameria ericoide* (mock-heather), *Croton californicus* (California croton), *Senecio blochmaniae* (Blochman's leafy-daisy), *Amsinckia menzieseii* (common fiddleneck), and *Achillea millefolium* (yarrow). The most frequent and important non-native species that associate with *S. californica* are *Carpobrotus edulis* and hybrids with *Carpobrotus chilense*. Competition with creeping, mat-forming *Carpobrotus* is evident where it extends down from dunes and through, up, and over narrow colonies of *S. californica*.

6) Critical Habitat

Critical habitat has not been designated for *Suaeda californica*.

7) Reasons for Decline and Threats to Survival

Most species covered in this recovery plan are threatened by similar factors because they occupy the same tidal marsh ecosystem. These general threats, faced by all covered species, are discussed in greater detail in section I. Specific threats to *Suaeda californica* are described below.

There are numerous threats to the survival of *Suaeda californica*. The impacts of these threats are intensified by the very restricted geographic range and extremely narrow ecological distribution of this species.

Factor A

Alteration and Loss of Habitat

The historical rarity of *Suaeda californica* in San Francisco Bay may have been due in part to the natural rarity of its sandy high marsh and beach habitat, but its extirpation seems related to the early spread of urban and port development over the East Bay shoreline from Richmond to Alameda, centered around Oakland (P. Baye pers. comm. 2004). This heavily urbanized area was the center of both the bay's sandy shorelines and *S. californica* distribution. Oakland and Alameda Marshes were filled and urbanized before the 20th century, eliminating populations there, but it was the destruction of Bay Farm Island for the construction of the Oakland International Airport in the 1950s and 1960s that probably destroyed the only remaining *viable* population in San Francisco Bay. Other species with affinity for sandy tidal marsh edges, such as *Atriplex californica*, were also described as occurring either along sandy beaches or sandy marsh edges within San Francisco Bay (Brewer *et al*. 1880, Jepson 1911, Greene 1894). These, too, have become extirpated.

The Morro Bay population has suffered little habitat loss compared with San Francisco Bay, and has relatively abundant habitat there, despite declines following El Niño winter storm erosion. However, it is subject to strong fluctuations in abundance due to natural disturbances, particularly dune migration and shoreline erosion, and its regeneration following disturbance is vulnerable to numerous threats. Though the population has in the past been threatened by strong residential and commercial real estate development pressures on the east shore of Morro Bay, centered at Baywood Park and Los Osos, these pressures have been reduced drastically (J. Vanderweir pers. comm. 2009). Loss of habitat and individuals, and failed regeneration after natural catastrophes could cause extirpation of this population. Other threats include interference by non-native vegetation, trampling, oil spills, sea level rise associated with climate change, excessive dune mobilization, and alteration of shoreline dynamics due to stabilization and shoreline repair projects.

Recruitment failure

Trampling of seedlings in Morro Bay may contribute to the failure of *Suaeda californica* regeneration following catastrophic shoreline erosion caused by major storms. Trampling results from both recreational activities (hiking) and by black-tail deer (*Odocoileus hemionus*) populations on the sand spit, and represents a relatively infrequent threat. However since seedling recruitment is episodic and local, impacts to seedlings (which are difficult to detect) could be severely detrimental at times. This is indicated by tracks and footprints along the Morro Bay shoreline in a devegetated zone nearly 0.5 meter (0.55 yd) wide (P. Baye pers. observ. 1997-1999). As recreational pressure on the Morro Bay shoreline increases with local residential population and increased visitor use at Montaño de Oro and Morro Bay State Parks, this impact is likely to become more severe.

Competition with non-native species
Exotic invasive vegetation, primarily *Carpobrotus edulis* X *chilensis* hybrids (iceplant), *Eucalyptus globulus* (blue gum), and *Cupressus macrocarpa* (Monterey cypress; a native to the Monterey peninsula only), cause significant damage to *Suaeda californica* by direct interference and indirect adverse habitat modification. *Carpobrotus edulis* establishes clonal colonies in adjacent uplands above saline influence, and can encroach by transporting nonsaline soil moisture from portions of the clone above the high tide line (P. Baye unpubl. data 1997). Most stands of *S. californica* along the perimeter road to Morro Beach State Park have been partially smothered by *C. edulis,* which grows through and over the *S. californica* colonies there. *Carpobrotus edulis* impacts are particularly significant for seedling regeneration along the backbarrier shore of Morro Bay spit. As the sandy backbarrier shoreline retreats into dense continuous stands of *C. edulis* on the dunes, *C. edulis* overhangs the erosional scarp and forms a canopy that drapes over the base of the scarp and upper shoreline. This sharply reduces or eliminates open seedling habitat for *S. californica*—its regeneration niche. It may also inhibit regeneration of storm-eroded remnants of *S. californica*. Therefore, spread of *C. edulis* along the dunes of the backbarrier shoreline is likely to reduce population resilience of *S. californica*. In fact, removal of *C. edulis* near *S. californica* populations has had a striking effect of recovery of the later (Baye *in litt*. 2009).

Heavy leaf litter and canopy shade from non-native trees, *Cupressus macrocarpa* and *Eucalyptus globulus*, are detrimental to seedling habitats for *Suaeda californica*, and apparently cause decline in vigor of remnant stands of mature plants (*e.g.,* near the entrance of Morro Bay State Park and in Baywood Park). Degradation of the ecological niche for seedling regeneration is probably a more severe long-term threat to the viability of the *S. californica* population than local disturbance of existing mature colonies. Stands of *S. californica* have been damaged directly by broken and fallen limbs of *E. globulus* adjacent to Morro Beach State Park (P. Baye unpubl. data 1997-2000).

The persistence of suitable and restorable habitat for reintroduction of *Suaeda californica* to San Francisco Bay is also threatened by non-native vegetation. In San Francisco Bay, the spread of invasive *Spartina* (Daehler and Strong 1996) caused the conversion of open mudflat into stabilized tidal marsh that traps sediment and moderates estuarine wave energy. This invasive vegetation intercepted alongshore transport of sand in the middle and lower intertidal zone, and inhibited the wave deposition of the sandy higher elevation marsh-beach ecotone that is important for establishment of *S. californica*. Invasive *Spartina* eradication efforts have likely eliminated the further spread of the species which could have precluded the long-term viability of *S. californica* reintroduction.

Dredging
Navigational dredging may threaten stands of *Suaeda californica* that have colonized the marina shoreline at Morro Bay State Park. Dredging of the inlet channel steepens the subtidal shore profile, probably resulting in shoreline erosion along the unarmored eroding south shore of the interior shoreline of the marina, which could threaten the *S. californica* colony there. The marina subpopulation of *S. californica* is particularly significant to the species' conservation because it is highly sheltered from storm wave erosion that threatens the main population along the spit's backbarrier shoreline.

Other threats to *Suaeda californica* include factors that preclude its recovery outside of Morro Bay. The main cause of its regional extinction in San Francisco Bay—urbanization of the original natural sandy marsh habitats—is irreversible. However, the maintenance of steep levees constructed of bay mud along portions of San Francisco Bay prevents re-establishment of potential wave-deposited marsh berms or sand beach ridges and spits, which could provide habitat for reintroduction. Historical San Francisco Bay levee designs, and application of traditional methods of levee repair and maintenance, are major impediments to habitat restoration and reintroduction of the species to the only other historical habitat in its natural range. The three sites in San Francisco Bay where reintroduction has already occurred were carefully selected as some of the few sites where existing levees or the maintenance thereof would not negatively affect the plants. Care was also taken to select sites where recreational activities or other pressures would not threaten possible future populations.

Factor C
Predation
In the absence of natural predators, hunting, or management in Morro Bay, deer populations are likely to forage intensively along the backbarrier shoreline where seeps provide fresh water, soft herbaceous vegetation, and flat travel corridors.

Factor E
Small number of populations
Suaeda californica is vulnerable to extinction in the wild largely because it has been reduced to a very small number of populations distributed in a very narrow zone of the Morro Bay and San Francisco Bay shorelines. In Morro Bay, most of the colonies occur along the erodible backbarrier shore of the Morro Bay sand spit, which is susceptible to erosion by occasional extreme storm tides and high wind-generated waves, and rapid burial by migrating dunes. Severe storm erosion occurred along this shoreline in the winter of 1997-1998, creating an extensive erosional scarp in the narrow *S. californica* zone. The population has not yet rebounded from this event. Although this was a natural catastrophe and rebound may occur in time, erosion events may become a recurrent threat if climate change increases storm intensity, frequency, and sea level rise rates.

Climate change
Extreme local fluctuations of climate (winter storms, high winds, summer drought) may be associated with global climate change. A series of severe winter storms followed by years of drought could cause catastrophic reproductive failure of the species. Global climate change and

associated sea level rise may also cause long-term changes in the stability of sand beach and dune shorelines (SCOR Working Group 1991), such as those of Morro Bay spit. *Suaeda californica* occurs in abundance only where the backbarrier shoreline is adjacent to dune scrub vegetation that stabilizes dunes. It is sparse or absent where bare mobile dunes retreat over the backbarrier shoreline. Many of the remaining colonies are being encroached on by mobile dunes, and are not expected to survive more than a few years. The formation of new "marsh coves" (potential *S. californica* habitat) in the lee of stabilizing dunes may occur in the future, but none are foreseeable now. A combination of shoreline retreat and increased dune movement could significantly reduce the largest subpopulation of *S. californica*.

Accelerated sea level rise and shoreline retreat could also force conflicts between natural movement of the *Suaeda californica* zone on the east shore of Morro Bay and landowner needs. Where costly residential developments are threatened by shoreline retreat, response typically involves armoring (structural stabilization) of the shoreline (*e.g.*, revetments, seawalls, rip-rap, etc.). Currently, *S. californica* appears to be able to migrate with the slowly retreating shorelines of eastern Morro Bay (Baywood Park, heron rookery).

Oil spills
Oil spills and clean-up operations may have significant adverse effects on *Suaeda californica* populations at Morro Bay, particularly on seedlings. Spilled oil tends to accumulate near the high tide line, the narrow marsh zone in which *S. californica* is largely restricted. Oil would probably cause high mortality of seedlings and juvenile plants during years of seedling regeneration by coating and smothering small plants with oil, and possibly by direct toxicity. Oil clean-up operations involving mechanical removal (raking, excavation) of oiled sand would also cause significant disturbance of *S. californica* habitat. Direct toxic effects of oil on older woody *S. californica* are uncertain, but are probably less damaging than effects of clean-up operations.

d. California Clapper Rail
(Rallus longirostris obsoletus)

1) Brief Overview

California clapper rails were recognized as endangered by the Federal government and added to the List of Endangered Species on October 13, 1970 (U.S. Fish and Wildlife Service 1970). California clapper rails were added to the State endangered species list on June 27, 1971 (California Department of Fish and Game 2005). The species has a recovery priority number of 3C, based on a high degree of threat, a high potential of recovery, and its taxonomic standing as a subspecies. The additional "C" ranking indicates some degree of conflict between the conservation needs of the species and economic development (U.S. Fish and Wildlife Service 1983). The first recovery plan for the species was published November 16, 1984 (U.S. Fish and Wildlife Service 1984). Factors currently impacting rail numbers baywide include predation, contaminants, and habitat loss/alteration/degradation.

2) Description and Taxonomy

The California clapper rail (*Rallus longirostris obsoletus*) belongs to the order Gruiformes, in the family Rallidae, which includes rails, gallinules, and coots. The genus *Rallus* consists primarily of *marsh*-dwelling birds with short rounded wings, large feet, and long toes. Clapper rails generally inhabit coastal tidal or brackish marshes.

Description.—The California clapper rail is one of the largest species of the genus *Rallus*, measuring 32-47 centimeters (13-19 inches) from bill to tail (Ripley 1977; **Figure II-8**). Males generally weigh 300-350 grams (0.66-0.77 pound) and females 248-301 grams (0.55-0.66 pound; Taylor 1996). The clapper rail has a hen-like appearance, with a long slightly decurved orange bill, a rufous breast, black and white barred flanks, and white undertail feathers. Juveniles have a paler bill and darker plumage, with a gray body, black flanks and sides, and indistinct light streaking on flanks and undertail coverts. Downy young are black with dark legs (Eddleman and Conway 1998).

Clapper and Virginia rails are morphologically similar and may co-occur in tidal marshes. Clapper rails are larger than Virginia rails, and lack the gray cheeks characteristic of Virginia rails. In addition, the brown back feathers of clapper rails are edged with gray, while the back plumage of Virginia rails is chestnut colored.

Clapper rail call. Because of their secretive habits, clapper rails are most often detected by their calls; visual detection is infrequent. Clapper rails have a wide variety of calls, although few are commonly heard. All calls are variants on a single note, with differences due to changes in intensity, pitch, note length, and interval between notes. Massey and Zembal (1987) grouped clapper rail vocalizations into eight calls, of which four are commonly heard: clapper, kek, kek-burr, and agitated kek. The clapper is the basic species call, serving as a territory pronouncement and for mutual mate recognition. Both sexes clapper year-round, with daily peaks at dawn and dusk. In central San Francisco Bay, vocal activity by California clapper rails was greatest from November through April (Evens and Page 1983). The clapper call is used as the basis for aural population censuses (Evens and Collins 1992, Collins *et al.* 1994, Evens 2000*a*); however, time of day, tidal height, and weather conditions all affect the frequency of calling (Zembal and Massey 1987).

The kek is the second most frequent call, and is confined to the advertisement of non-mated males during the breeding season (Massey and Zembal 1987, Zembal and Massey 1987). The kek-burr is the advertisement of non-mated females, and is only heard during the breeding season. It consists of one or more keks, evenly spaced, usually followed by a burr (Zembal and Massey 1985). Zembal and Massey (1987) suggest that an uneven number of kek calls relative to kek-burrs may represent a skewed sex ratio of rails in a marsh. The agitated kek is a response to intrusion or disturbance (Massey and Zembal 1987). Newly hatched chicks emit peeping sounds (U.S. Fish and Wildlife Service unpubl. data).

Taxonomy.—The California clapper rail was first described as a king rail (*Rallus elegans* var. *obsoletus*; Ridgway 1874) until Ridgway (1880) reclassified it as a geographically distinct form of clapper rail. Van Rossem (1929) demonstrated that all Pacific coast populations of clapper rails were geographical races of one species, and designated the California race as *Rallus obsoletus obsoletus*. Subsequently, Oberholser (1937) described 25 clapper rail forms as subspecies of the same species, and the California clapper rail became *Rallus longirostris obsoletus.*

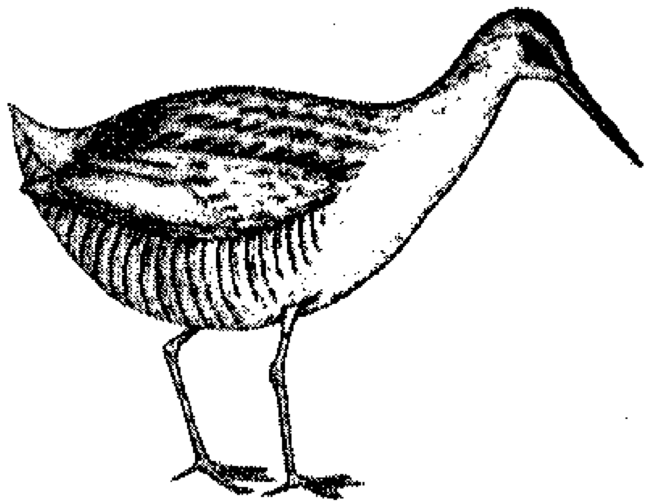


FIGURE II-8. California clapper rail (from California Department of Fish and Game 2000, with permission)

Although the taxonomic status of clapper rails is a matter of some debate, the American Ornithologists' Union (1957) distinguishes five subspecies of clapper rails in North America. The California clapper rail is the only subspecies that inhabits the coast of northern California and San Francisco Bay.

3) Population Trends and Distribution

Historical distribution. The California clapper rail population was estimated at 4,200 to 6,000 birds between 1971-1975, of which 55 percent occurred in the South Bay and 38 percent in the Napa Marshes (Gill 1979, Collins *et. al*. 1994). Based on surveys from the mid-1980s, the total population was estimated to be 1,200 to 1,500 individuals (Harvey 1988). In 1988, the population estimate dropped to 700 individuals and in 1990-1991, the estimate dropped further to 300-500 (Albertson and Evens 2000). In the mid to late 1990s, the population increased to an estimated 1,040 to 1,264 (Albertson and Evens 2000).

California clapper rails were historically abundant in all tidal and brackish marshes in the San Francisco Bay vicinity (Cohen 1895), as well as in all of the larger tidal estuaries from Marin to San Luis Obispo counties. The tidal marshes of south San Francisco Bay, including portions of San Mateo, Santa Clara, and Alameda counties, supported the largest populations of California clapper rails (Grinnell 1915, DeGroot 1927, Williams 1929, Grinnell and Miller 1944).

The clapper rail population in the eastern portion of the South Bay decreased substantially, from 400-500 individuals in the early 1980's to 50-60 in 1991-92 (Harvey 1980, U.S. Fish and Wildlife Service unpubl. data). In response to predator management and the spread of invasive *Spartina*, the total South Bay rail population rebounded after the low of the early 1990s (Harding *et al.* 1998), and was estimated to be approximately 650 to 700 individuals in 1997-1998 (U.S. Fish and Wildlife Service unpubl. data).

Gill (1979) identified the Napa River as a North Bay population center, which supported approximately 40 percent of the entire population. There are isolated records of rails occurring in urbanized areas of San Francisco (Orr 1939), Oakland, and Berkeley (Lindsdale 1936). Rails were also reported from Point Isabel in Contra Costa County (Williams 1957). Small populations existed in San Pablo Bay along Wildcat Creek/San Pablo Creek in western Contra Costa County (Grinnell and Miller 1944). Newberry (1857) reported clapper rails as very common in the marshes of Petaluma. Bryant (1931) reported rails in Richardson Bay, and an egg set was collected from Corte Madera in 1931 (Gill 1979). In Solano and Sonoma counties, Gill (1979) and Harvey (1980) observed rails at numerous locations in the Napa Marsh complex. Surveys conducted in the early 1990s (Evens and Collins 1992, Collins *et al.* 1994, California Department of Fish and Game unpubl. data) indicated a temporary decline in San Pablo Bay clapper rail populations. Surveys conducted in the late 1990s indicated that the White Slough area continued to support a moderate number of clapper rails (Evens 2000*b*). In contrast, rail numbers detected in the Sonoma Creek/Napa Slough area declined after the early 1990s, from estimates of 13 pairs in 1992 (Evens and Stallcup 1994) to 2 birds detected in 2000 (Evens 2000*a*).

According to survey data, the historical distribution of clapper rails within San Francisco Bay was restricted to marshes west of Suisun Bay. However, systematic survey data from the Suisun Marsh area were not available until the 1970s. Clapper rails have been sporadically detected in the Suisun Marsh area since the 1970s, in low abundance when detected (Gould 1973, Harvey 1980). It is likely that low numbers of clapper rails were present in this area prior to large-scale marsh reclamation.

North of the San Francisco Bay area, clapper rails formerly occurred in Humboldt Bay, Humboldt County (Grinnell and Miller 1944, Gill 1979), and in the Marin-Sonoma embayments, which include Bodega Harbor, Tomales Bay, Drakes/Limantour Esteros, and Bolinas Lagoon (Storer 1915, Brooks 1940, Grinnell and Miller 1944). The last record for Humboldt Bay was in 1947 (Wilbur and Tomlinson 1976). There have been several records of clapper rails in Tomales Bay in the late 1990s (Evens *in litt.* 2007) and one record more recently in 2012 (Invasive Spartine Project *in litt.* 2012). Prior to these observations, clapper rails had not been documented in Tomales Bay since 1914 (Storer 1915), and were presumed extirpated as of 1973.

South of the San Francisco Bay area, clapper rails formerly occurred in Elkhorn Slough, Monterey County (Silliman 1915), and Morro Bay, San Luis Obispo County (Brooks 1940). Clapper rails were consistently detected in Elkhorn Slough up to 1972, when an estimated 10 pairs were observed (Varoujean 1972). Subsequently, rails were observed only sporadically (Winter and Laymon 1979), and were last documented there in 1980 (Roberson 1985). There are few records of clapper rails in Morro Bay since 1942 (Wilbur and Tomlinson 1976). Despite a

1977 record for Morro Bay (Gill 1979), Harvey (1980) found no evidence of clapper rails there in 1979.

Transient California clapper rails have been occasionally observed at other locations along the coast of California, including the Farallon Islands (Bryant 1888), Pacific Grove (Kimball 1922), Pescadero Marsh (Orr 1942), and Bolinas Lagoon (Harvey 1980).

Current distribution. California clapper rails are now restricted almost entirely to the marshes of the San Francisco Bay Estuary where the only known breeding populations occur (**Figure II-9 and Figure II-10)**. Though populations were increasing by the late 1990s, another decline began in 2005. Substantial increases in population may be difficult to achieve due to the current disjunct distribution of their habitat (Albertson and Evens 2000).

PRBO Conservation Science conducted estuary-wide surveys of the San Francisco Bay for California clapper rail between 2005 and 2008. Results of this survey estimate a minimum average population between 2005 and 2008 of 1,425 rails (Liu *et al*. 2009), however, densities declined during that period at a per-year rate of 20 percent. The downward trend for 2005 to 2008 is driven by a negative change (-57 percent) from 2007 to 2008 in the South Bay. The population appeared relatively stable from 2005 to 2007. However, the decrease from 2007 to 2008 likely represents a true decrease in the Estuary-wide population and is correlated with ongoing control and removal (through chemical and mechanical means) of invasive *Spartina*.

PRBO Conservation Science's 2010 surveys resulted in detection of 601 clapper rails at 52 sites, specifically showing increases in number of detections in San Pablo and South San Francisco Bays (Liu and Wood 2011). However, the Invasive Spartina Project found declining numbers of detections in other parts of the Estuary, such as the San Francisco peninsula (Liu and Wood 2011). The PRBO Conservation Science estimate represents a minimum estimate, as they did not calculate densities based on the detections and apply the densities to non-surveyed suitable habitat at the sites (Liu and Wood 2011). Also, an updated Bay-wide population estimate was not developed as part of that study.

Central/South Bay. The highest population densities for clapper rails continue to be located in south San Francisco Bay, where clapper rail populations presently occur in all of the larger tidal marshes. The largest populations currently occur in Arrowhead, Dumbarton, Mowry, and Cogswell marshes in the East Bay, and in East Palo Alto and Greco Island in the west bay (Herzog *et al*. 2006). In Alameda County, rails are known to occur in the Emeryville Crescent, Hayward, Old Alameda Creek, Ideal, La Riviere, and Coyote Creek marshes. In San Mateo County, rails currently occur in marshes along Faber/Laumeister, Ravenswood, Seal slough, and the Colma Creek area. In Santa Clara County, rails occur along Alviso and Charleston sloughs, and in outboard marshes of Moffett Field and Guadalupe Slough. Clapper rails can also be found in tidal marshes fringing the South Bay outboard of salt evaporation pond levees and along major tidal sloughs.

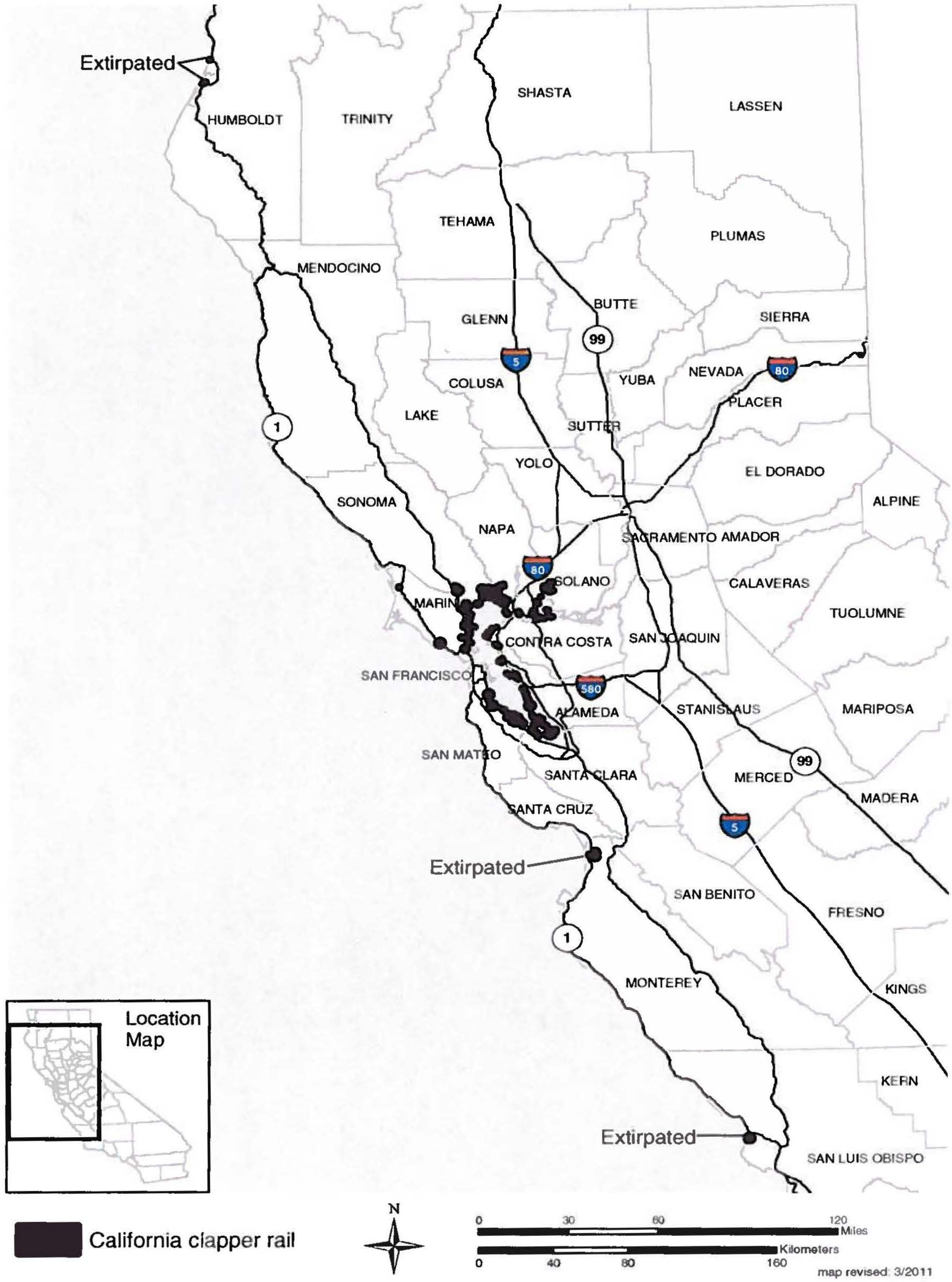


Figure II-9. Distribution of California clapper rails, overview

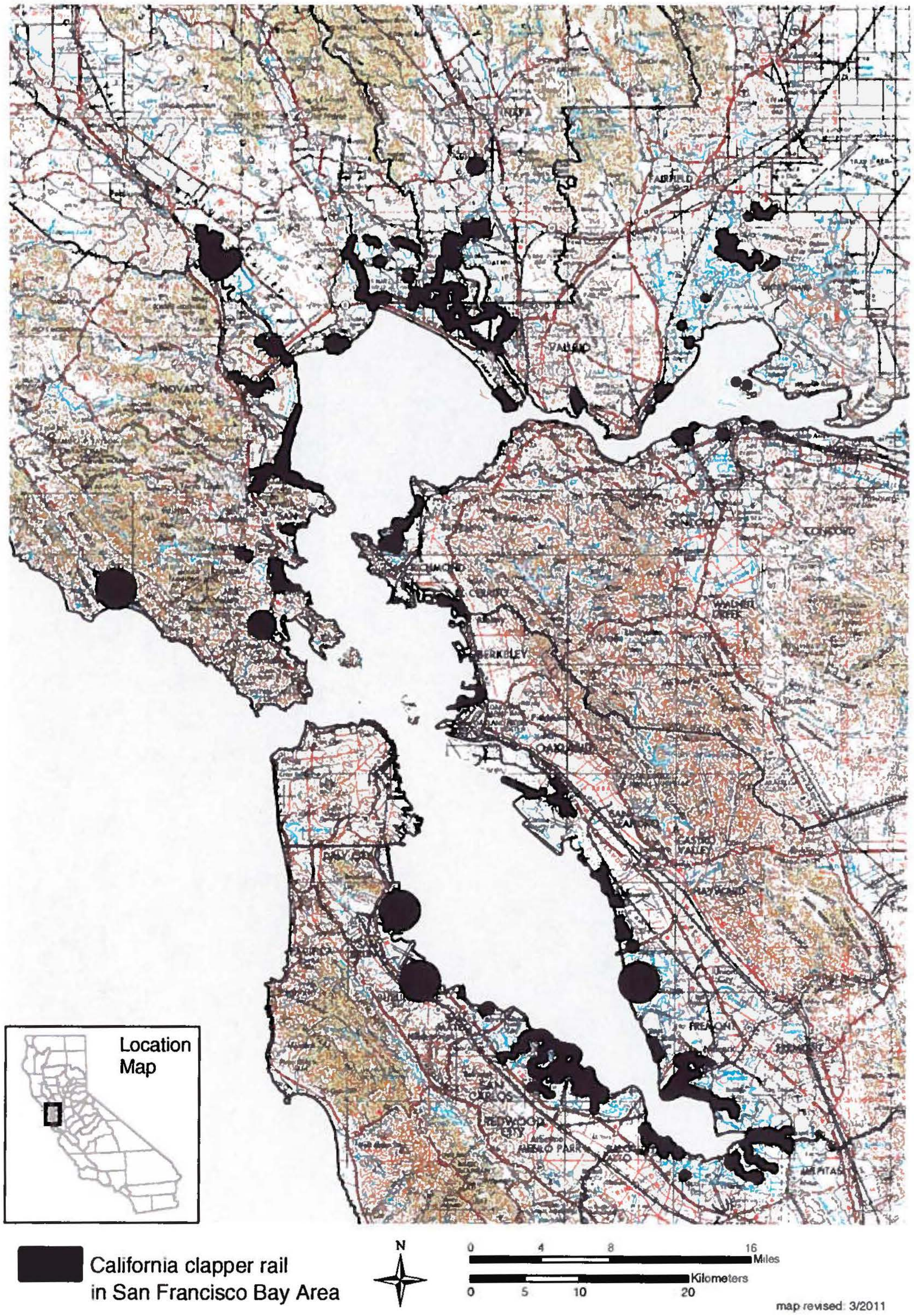


Figure II-10. Distribution of California clapper rails, San Francisco Bay

In 2006, the central San Francisco Bay experienced highest numbers of clapper rails in Corte Madera (Heerdt) and Muzzi Marshes in Marin County (Herzog *et al*. 2006). Other occupied areas include Wildcat Marsh and Oakland Inner Harbor in southern Contra Costa County and Richardson Bay and Creekside Marsh in Marin County (Albertson and Evens 2000).

San Pablo Bay. Small populations of clapper rails are patchy and discontinuously distributed throughout San Pablo Bay in small isolated tidal marsh habitat fragments (Collins *et al.* 1994). In 2004 there were between 84 and a few hundred pairs (not individuals) in the San Pablo Bay region (Avocet Research Associates 2004). Highest numbers of clapper rails in San Pablo Bay currently occur along Gallinas Creek and Hamilton Army Airfield marshes (Herzog *et al*. 2006). Clapper rails also occasionally occur along the Petaluma River as far north as Schultz Creek, Lower Tubbs Island, Sonoma Creek area, and along most major tidal sloughs that empty into the Napa River (Evens 2000*a*, 2000*b*; Collins and Evens 1992; U.S. Geological Survey unpubl. data). Clapper rails are present near the Bahia residential development in Novato. In 2006, at least four pairs of clapper rails were detected in tidal marsh along San Antonio Creek, just to the north of the Marin Audubon Society's tidal marsh restoration site near Neils Island (Marin County; Evens *in litt*. 2007). This observation was important since clapper rails have been patchily distributed in the upstream portions of the Petaluma River system.

Clapper rails also occur on Bull Island and, as documented in November 2010, north to the Napa Flood Control Marsh, upstream along the Napa River from the Highway 121 bridge (Stenzel *in litt*. 2010). Rails are sparse in the linear strip marsh between Highway 37 and San Pablo Bay, most likely due to the lack of dendritic tidal creeks and high tide refugia. The few clapper rails located in this marsh are associated with ditches or natural drainages (U.S. Fish and Wildlife Service unpubl. data).

Suisun Marsh Area. Clapper rails are present sporadically and in low numbers at various locations throughout the Suisun Marsh area. Areas where rails have been found recurrently since 1978 include the shoreline marshes from Martinez east to Concord Naval Station, marshes near the mouth of Goodyear slough (Bahia), Suisun and Hill sloughs, and the western reaches of Cutoff slough (Harvey 1980). Rails have even been detected in Suisun Marsh during the breeding season (Foin *et al*. 1997). Surveys in the late 1990s to 2000 indicated that clapper rails were present in marshes associated with Pacheco creek and Point Edith in Contra Costa County (U.S. Fish and Wildlife Service unpubl. data). Surveys in 2005 found no clapper rails in Suisun Marsh or Point Edith (Herzog *et al.* 2005) and, in 2006, only two clapper rails each were observed at Rush Ranch (Suisun Marsh) and Point Edith (Herzog *et al.* 2006). This survey also identified only two clapper rails at BSRA (Solano County) and at least two rails were detected during a survey of the same location in January 2011 (Evens *in litt*. 2011). Similar sporadic results were found during a multi-year survey by CDFW, in which they detected: no California clapper rails in 2002, eight in 2003, one in 2004, none in 2005, five in 2006, none in 2007, one in 2008, and none in 2009 (California Department of Fish and Game 2010).

Coastal Areas outside San Francisco Bay. Records of California clapper rails beyond San Francisco Bay are sparse, making population status in these areas difficult to track. Few records of clapper rails exist for Humboldt Bay; the last record is from 1947 (Wilbur and Tomlinson

1976). It is unknown whether clapper rails ever bred in Humboldt Bay, and clapper rails observed in that area are widely considered vagrants. Clapper rails had been presumed extirpated from Tomales Bay as of 1973, until sightings of single birds were reported there in 1998-2000 (Evens *in litt.* 2007). It is unknown whether clapper rails are currently breeding in Tomales Bay, but suitable habitat now exists and a Calfornia clapper rail was detected there in 2012 (Invasive Spartine Project *in litt.* 2012).

No records of clapper rails have been reported for Morro Bay, San Luis Obispo County, in over 20 years. Clapper rails have not been reported in Elkhorn Slough, Monterey County, since 1980 (Roberson 1993). These three populations (Humboldt Bay, Morro Bay, and Elkhorn Slough) are now considered extirpated, leaving San Francisco Bay as the last stronghold and breeding population of this subspecies.

4) Life History and Ecology

Behavior. In general, clapper rails are secretive and difficult to observe in dense vegetation, but once flushed can frequently be approached (U.S. Fish and Wildlife Service 1984). The U.S. Fish and Wildlife Service considers the California clapper rail sensitive to disturbance, and seeks to minimize human intrusion to occupied marshes, particularly during the breeding season.

When evading discovery, rails typically freeze, hide in small sloughs or under overhangs, or run rapidly through vegetation or along slough bottoms (U.S. Fish and Wildlife Service 1984). Rails prefer to walk or run over other forms of locomotion (Ripley 1977, Todd 1986). When flushed, they normally fly only a short distance before landing (Zucca 1954). Clapper rails swim well, although swimming is only used to cross sloughs or escape immediate threats at high tide (Sibley 1955, Todd 1986).

Clapper rails are diurnally active for 75 to more than 90 percent of the day. Activity peaks in the early morning and late evening (Zembal and Massey 1983, Zembal *et al.* 1989), when rails forage in marsh vegetation in and along creeks and mudflat edges. Rails often roost at high tide during the day (Zembal *et al.* 1989). During the non-breeding season, much of the day is spent roosting and preening.

Courtship. Clapper rails are at least seasonally monogamous, and defend overlapping year-round territories (Zembal *et al.* 1989, Albertson 1995, Garcia 1995). While both sexes advertise for mates, courtship is initiated by the male and involves the male approaching the female with an uplifted tail, pointing his bill to the ground, and swinging it from side to side (Meanley 1985, Albertson and Evens 2000). It is not known whether rails retain their mates between years. Extra-pair copulation is likely, since mated males actively seek unmated advertising females (Zembal and Massey 1985). Males perform most of nest building, and symbolic nest building, wherein males build a nest which is not to be used for actual nesting purposes, may also occur (Meanley 1985). Egg-laying often begins prior to completion of the nest (Eddleman and Conway 1998).

Nesting Phenology. The breeding period of the California clapper rail is prolonged. Pair bonding and nest building are generally initiated by mid-February. Nesting may begin as early as late February or early March (Evens and Page 1983), and extend through July in the South

Bay, and into August in the North Bay (DeGroot 1927, U.S. Fish and Wildlife Service unpubl. data). There appears to be a break in nesting between mid-May through late June in the North Bay, a period that corresponds to the highest summer tides (Evens and Page 1983). Two peaks in nesting activity occur, a greater peak between mid-April and early-May and a lesser peak between late-June and early-July (DeGroot 1927, Applegarth 1938, Gill 1972, Harvey 1988). The second nesting peak has been interpreted as attempts by late nesters (DeGroot 1927), second attempts after initial nesting failures (Gill 1972), or second broods (Wilbur and Tomlinson 1976).

Rails frequently build several nest platforms, but use only one for incubation (Applegarth 1938, Gill 1972, Wilbur and Tomlinson 1976). Both sexes share in incubation, which lasts from 18-29 days (Taylor 1996). Eggs are approximately 45 millimeters (1.77 inch) in length, and light tan or buff-colored with cinnamon-brown or dark lavender spotting concentrated at the broader end. Estimates of California clapper rail clutch size range from 5-14 eggs (DeGroot 1927, Gill 1972). Mean clutch sizes of 7.1 (U.S. Fish and Wildlife Service unpubl. data) to 7.5 (Foerster *et al.* 1990) have been reported. Hatching is generally synchronous, but occasionally eggs hatch one to several days apart (U.S. Fish and Wildlife Service unpubl. data). Defense of the nest site intensifies as hatching approaches (Applegarth 1938, U.S. Fish and Wildlife Service unpubl. data). Hatching requires approximately 48 hours to complete after breaking through of the shell (Johnston 1956*a*). Chicks soon depart the incubation nest, and one to three brood nests are typically constructed nearby (Applegarth 1938, Johnson 1973). Brood nests are high tide refuges for young rails, and consist of a platform of woven stems without a substantial canopy (Harvey 1980). These may also be used as gathering points and resting places for the young. Adults remain with the chicks to forage with them for up to 5 to 6 weeks (Applegarth 1938, Meanley 1985).

Nest Site. Rails require an intricate network of sloughs to provide abundant invertebrate populations (Grinnell *et al.* 1918, DeGroot 1927, Harvey 1988, Collins *et al.* 1994) and escape routes from predators, particularly for vulnerable flightless young (Taylor 1894, Adams 1900, DeGroot 1927, Evens and Page 1983, Foerster *et al.* 1990, Evens and Collins 1992). In addition, the small natural berms along tidal channels with relatively tall vegetation, such as *Grindelia stricta* (gumplant), provide elevated nesting substrate.

Nests must be built at an elevation that protects the bowl from complete inundation during high tides (Evens and Collins 1992, Collins *et al.* 1994). However, some nests are built directly on the ground. If a nest settles or gets wet, the adults may add additional materials such that a minimum elevation above the tides is maintained. Inundated nests result in abandonment and failure (U.S. Fish and Wildlife Service unpubl. data). Zucca (1954) proposed that late nesting attempts resulted from interruption of earlier attempts by high tides.

California clapper rails are relatively indiscriminate in their choice of nesting substrate, and prefer to use the tallest cover regardless of plant species (Garcia 1995). However, rails typically nest in the upper-middle tidal marsh plain or high tidal marsh zones, not upland habitat transition zones bordering tidal marsh. Vegetation must be 50 centimeters (19.7 inches) high or greater near mean high water to allow for nest concealment and prevent tidal inundation. Robust *Sarcocornia pacifica* (pickleweed) or *Grindelia* vegetation is usually selected for nest locations in San Francisco Bay. Shorter vegetation may be used at higher marsh elevations (Albertson and Evens 2000). Plant species used for nest construction includes *Spartina* spp. (cordgrass), *Sarcocornia*, *Grindelia*, *Distichlis spicata* (saltgrass), *Schoenoplectus* spp. (bulrushes), *Typha* (cattails), *Spartina* wrack, *Jaumea carnosa* (fleshy jaumea), lodged tumbleweeds, and other drift materials (DeGroot 1927, Zucca 1954, Gill 1972, Harvey 1980, Foerster *et al.* 1990, Garcia 1995).

Clapper rail nests consist of a platform surrounded by vegetation that has been pulled together to form a canopy. In the South Bay, most nests are located in *Grindelia* and *Sarcocornia*, with platforms constructed from *Spartina* and *Sarcocornia* (Harvey 1980, Foerster *et al.* 1990, U.S. Fish and Wildlife Service unpubl. data). Foerster *et al.* (1990) found evidence of preferential use of *Spartina* in nest platforms. In the brackish reaches of the northern San Francisco Bay Estuary, many clapper rail nests are located in *Schoenoplectus*. North Bay platforms typically consist of *Sarcocornia*, mixed *Distichlis* and *Sarcocornia*, or *Schoenoplectus* (Garcia 1995, Albertson and Evens 2000, U.S. Fish and Wildlife Service unpubl. data). Throughout the bay, variations in nest materials used by clapper rails have been reported (DeGroot 1927, Zucca 1954, Gill 1972, Harvey 1980, Foerster *et al.* 1990, Garcia 1995).

Nest Success and Productivity. Reproductive success of the California clapper rail is variable between marshes and years, and is reduced below the natural potential (Schwarzbach *et al*. 2006). Information on nest success and productivity is available from three studies conducted in the South Bay and one study in the North Bay (**Table II-2** and **Table II-3**).

In a 1980 study at Dumbarton, Ideal, and Mowry Marshes in the South Bay, Harvey (1988) reported a nest success (rate of nests having at least one egg hatch) of 56 percent and a hatching success (rate of eggs hatched per total eggs laid) of 38 percent. However, in a follow-up study in 1988 at Dumbarton and Mowry Marshes, Foerster *et al.* (1990) reported much lower numbers: a nest success of 32 percent and a hatching success of 19 percent. In both investigations, predation accounted for about one third of the lost eggs. Investigations undertaken in Faber Marsh in 1991 and in Faber, Mowry, Laumeister, and Greco Marshes in 1992 (in the South Bay), reported a nest success of 47 percent and hatching success of 41 percent (Schwarzbach *et al.* 2006). Predation in this study accounted for a loss of 38 percent of eggs. In the North Bay at Heerdt and Wildcat Marshes in 1998-1999, nest success was 39 percent and hatching success was 35 percent (Schwarzbach *et al.* 2006). Predation in this study accounted for a loss of 39 percent of eggs. Overall, these studies show a wide range in nest success for the California clapper rail of 32 to 56 percent, a wide range in hatching success of 19 to 41 percent, and a predation rate of 30 to 39 percent (**Table II-2**).

Hatchability (the number of eggs hatched per the number of eggs incubated to term) for clapper rails in San Francisco Bay varies with marsh (**Table II-3**). In the 1991-1992 South Bay investigations, hatchability ranged from 62.5 to 75.6 percent, with Laumeister having the lowest hatchability. Hatchability at North Bay marshes in 1998-99 was 60 percent and 69 percent for Wildcat and Heerdt, respectively.

Table II-2. Summary of California clapper rail reproductive success. South Bay data are from 1980, 1988, and 1991- 1992; North Bay data are from 1998-99.				
	1980[a]	1988[b]	1991-92[c]	1998-99[d]
Total number of nests found	50	29	Na[e]	Na[e]
Number of active nests monitored	26	24	71	18
Mean clutch size	7.3	7.5	7.0	6.7
Total number of eggs	189	155	431	98
Eggs hatched	71	29	177	34
Eggs lost to predators	63	51	164	38
Eggs unhatched[f]	34	36	71	25
Eggs disappeared	21	39	6	1
Nest success (percent in parentheses)	28 (56)	6 (32)	33 (47)	7 (39)
Nest failure (percent in parentheses)	16 (32)	11 (46)	38 (53)	11 (61)
Nest fate unknown	6	7	26	3

[a] Harvey 1980, study sites = Dumbarton (n=27), Mowry (n=18), Ideal (n=5)
[b] Foerster *et al.* 1990, study sites = Dumbarton and Mowry
[c] U.S. Fish and Wildlife Service unpubl. data, 1991 study site = Faber (n=16); 1992 study sites = Faber (n=4), Greco (n=20), Mowry (n=10), and Laumeister (n=20)
[d] U.S. Fish and Wildlife Service unpubl. data, study sites = Corte Madera (n=11), Wildcat (n=7), Petaluma (n=1)
[e] Not available
[f] Includes eggs lost to flooding and fail-to-hatch eggs

The 1992 South Bay study and the 1998-1999 North Bay study included investigations on nest productivity (number of young produced per nest attempt; Schwarzbach *et al*. 2006; **Table II-3**). The South Bay produced 1.9 young per nest and the North Bay produced 2.4. Currently, no data are available on fledge success for California clapper rails.

Normal hatching success and hatchability of clapper rail eggs is much higher (Zembal and Massey unpubl. data, Jorgensen 1975). A study of clapper rails in New Jersey indicated an 87.3 percent hatching success (Kozicky and Schmidt 1949). The hatching success and hatchability of the California clapper rail is clearly impaired. Reasons for low hatchability of eggs could include contamination, loss of genetic diversity, and reduced incubation of eggs due to disturbance. There is reason to believe that contamination may be the cause of some of the observed impairment in hatchability (**Appendix E**).

Table II-3. Clapper rail nest fate summary table. South Bay data are from 1992; North Bay data are from 1998-1999 (U.S. Fish and Wildlife Service unpubl. data).									
	Nests	**Total Young**	**Mean Clutch Size**	**Young/ Nest Attempt**	**% Hatch-ability[a]**	**% Hatch Success[b]**	**% Nest Predation (#)**	**% Nest Success (#)**	**% Nest Flooding (#)**
South Bay Total	***71***	***177***	***6.95***	***2.5***	***71.3***	***42.9***	***47.9***	***46.5***	***1.4***
Faber	14	41	6.75	2.9	71.9	46.6	21.4 (3)	50.0 (7)	7.1 (1)
Greco	20	61	6.75	3.1	75.6	45.2	50.0 (10)	60.0 (12)	0 (0)
Laumeister	26	33	6.73	1.3	62.5	25.1	61.5 (16)	30.8 (8)	0 (0)
Mowry	11	42	7.60	3.8	75.0	54.5	45.5 (5)	54.5 (6)	0 (0)
North Bay Total	***18***	***34***	***6.66***	***1.9***	***65.0***	***34.7***	***41.5***	***42.2***	***5.5***
Heerdt	11	18	6.90	1.6	69.0	26.9	54.5 (6)	27.3 (3)	9 (1)
Wildcat	7	16	6.25	2.2	60.0	51.6	28.6 (2)	57.1 (4)	0 (0)
Overall Total	**89**	**211**	**6.89**	**2.4**	**70.6**	**38.2**	**47.2**	**44.9**	**2.3**

[a] Hatchability is calculated as the number of eggs hatched / the number of eggs incubated to term (*i.e.* available to hatch).
[b] Hatch success is calculated as the number of eggs hatched per nest / clutch size.

Feeding Ecology. The clapper rail is an omnivore with a relatively broad feeding niche. Animal matter has been consistently emphasized as a major component of the diet (Moffitt 1941, Heard 1982, Zembal and Fancher 1988). Food items found in California clapper rails stomachs include introduced ribbed horse mussel (*Ischadium demissum*), spiders (*Lycosidae* spp.), clams (*Macoma balthica*), yellow shore crabs (*Hemigrapsus oregonensis*), amphipods (shrimp-like crustaceans), *Nereis vexillosa* (a polychaete worm), and striped shore crab (*Pachygrapsus crassipes*; Williams 1929, Applegarth 1938, Test and Test 1942, Varoujean 1972). Rails occasionally have been seen capturing and consuming rodents, particularly during higher tides; small birds are also occasionally taken (Spendelow and Spendelow 1980, Jorgenson and Ferguson 1982).

Territoriality/Site Fidelity. Clapper rails exhibit strong territorial defense, particularly during the late winter and early breeding seasons (Williams 1929, Albertson 1995, Garcia 1995). Territoriality weakens during extreme high tides when cover is limited, and during the post-breeding season. Rails have been observed in groups of 10 or more during winter high tide surveys (U.S. Fish and Wildlife Service unpubl. data). Little information is available on interspecies aggression in rails, though a California clapper rail has been observed successfully fending off a northern harrier (*Circus cyaneus*) from a brood and, on another occasion, itself at the Corte Madera Creek mouth, Marin County (Evens *in litt.* 2009).

Clapper rails generally exhibit strong site fidelity (Albertson 1995) although they do disperse. A banding study in the mid-1980s revealed the limited movement of rails in the South Bay, with 78 percent of resightings within 500 m (1,641 ft) of the original capture site (U.S. Fish and Wildlife Service unpubl. data).

Home Range. A 1991-1992 radiotelemetry study in south San Francisco Bay indicated an average home range of 4.7 hectares (11.6 acres) and an average core use area of 0.9 hectare (2.2 acres; Albertson 1995). Home ranges were maintained throughout the year, but varied among marshes and seasons. During the breeding season, average home ranges expanded from 2.9 hectares (7.1 acres) in January-February, to 3.7 hectares (9.1 acres) in May-July.

Home range size and site fidelity may be impacted by disturbance. Albertson (1995) documented a rail abandoning its territory shortly after a repair crew worked on a nearby transmission tower. The bird did not establish a stable territory within the duration of the breeding season, but eventually moved closer to its original home range several months after the disturbance. The reproductive success of this clapper rail is unknown.

Garcia (1995) evaluated the use of call count surveys for determining clapper rail territory size in Marin County, and found that territory size is underestimated using this approach. This is because rails call from core areas that are less than 35 percent of the total territory area used during the breeding season (Eddleman 1989, Conway *et al.* 1993). However, multiple call count surveys conducted between mid-January and mid-April significantly increase the accuracy of population estimates of clapper rails compared to single call count surveys (Garcia 1995).

Density. Density estimates are typically reported as the number of rails over the total acreage of the tidal marsh parcel. Because this method does not discount areas that are not suitable habitat, density estimates for clapper rails may underestimate the density of rails in appropriate habitat.

Numerous studies (Applegarth 1938, Gill 1979, Harvey 1988, Foerster *et al.* 1990, Collins *et al.* 1994) provide data on rail breeding densities in the South Bay (**Table II-4**). Estimates of clapper rail wintering (non-breeding) densities are variable and limited (Gill 1979, Moss 1980; Harvey 1980, 1981; Foerster 1989).

Dispersal. Post-breeding dispersal has been documented during the fall and early winter (Lindsdale 1936, Orr 1939, U.S. Fish and Wildlife Service unpubl. data, Albertson 1995). There is no clear evidence of migratory behavior in the California clapper rail. However, infrequent long distance dispersal does occur. Vagrant rails have been found in areas not known to support individuals throughout the year, such as the Farallon Islands (Bryant 1888), the rocky shores of Pacific Grove (Kimball 1922), and Pescadero Marsh (Orr 1942). These birds have been found primarily in late summer and fall, and are assumed to be dispersing subadults.

Table II-4. Estimates of California clapper rail breeding densities in San Francisco Bay.				
Site Name	Year	Density (rails/hectare)	Location[a]	Source
Dumbarton	1986 1988	1.47 0.64	South Bay	Harvey 1988 Foerster *et al.* 1990
Mowry	1986 1988	0.89 0.26	South Bay	Harvey 1988 Foerster *et al.* 1990
Audubon	1988	0.18	South Bay	Foerster *et al.* 1990
Ideal	1986	0.69	South Bay	Foerster *et al.* 1990
Central	1993	0.33	Central Bay[b]	Collins *et al.* 1994
Petaluma River	1993	0.26	North Bay[c]	Collins *et al.* 1994
Sonoma Creek	1993	0.18	North Bay[d]	Collins *et al.* 1994
Napa River	1993	0.23	North Bay[e]	Collins *et al.* 1994
Carquinez Strait	1993	0.03	North Bay[f]	Collins *et al.* 1994
Suisun Bay	1993	0.09	North Bay[g]	Collins *et al.* 1994
Grizzly Bay	1993	0.09	North Bay[h]	Collins *et al.* 1994

[a] South Bay density estimates used rope drags; North Bay density estimates used call counts.
[b] Central Bay included Richardson Bay, Muzzi, Corte Madera, Creekside, Gallinas, Hamilton, Point Pinole, and Wildcat marshes.
[c] Petaluma River included sites at the river mouth, Novato Creek, Black John Slough, Mira Monte Slough, Tule Slough, and Shultz Slough.
[d] Sonoma Creek included sites at the creek mouth, Second Napa Slough, Hudeman Slough, and Wingo.
[e] Napa River included sites at White Slough, Wilson Avenue, River Park, Boxer Marsh, Coon Island, Fagan Slough/Bull Island, Napa Town, and Mare Island Point.
[f] Carquinez Strait included BSRA/Benicia and Martinez.
[g] Suisun Bay included sites at Pacheco Creek, Point Edith, Port Chicago, and Antioch.
[h] Grizzly Bay included sites at Bahia, Goodyear Slough, the mouth of Suisun Slough, Cutoff Slough, Mallard Slough, Hill Slough/Union Creek, Navy Point, Boynton Slough, and Peytonia Slough.

Survivorship. The only estimates of annual adult California clapper rail survivorship are relatively low, ranging from 0.49 to 0.52 (Albertson 1995). These are similar to survival estimates reported for the Yuma subspecies (Eddleman 1989). Increased predation occurs during extreme winter high tides, probably due to increased movement of rails at this time when little cover is available (Albertson and Evens 2000). Adult survivorship has been suggested as the key demographic variable associated with survival of clapper rail populations (Foin *et al.* 1997).

Predators. Predators known to prey on clapper rails and their eggs include the native gopher snake (*Pituophis melanoleucus*), great blue heron (*Ardea herodias*), red-tailed hawk (*Buteo jamaicensis*), peregrine falcon (*Falco peregrinus*), northern harrier (*Circus cyaneus*), barn owl (*Tyto alba*), great horned owl (*Bubo virginianus*), short-eared owl (*Asio flammeus*), common raven (*Corvus corax*), raccoon (*Procyon lotor*), and California ground squirrel (*Spermophilus beechyii*) (Johnston 1956*b*).

Non-native predators identified to date include the Norway rat (*Rattus novegicus*), red fox (*Vulpes vulpes*), domestic cat (*Felis catus*) and feral pigs (*Sus scrofa*; Grewell *in litt.* 2006*b*). Adult clapper rails may be preyed upon by all of the above species except gopher snakes, ravens, raccoons, ground squirrels, and rats, which prey on eggs or chicks. Of these predators, raptors, Norway rats, and red fox are the most significant (DeGroot 1927, Foerster 1989, Albertson 1995, Harding *et al.* 1998). Studies in 1991-1992 found a negative correlation between red fox numbers and rail densities (Harding *et al.* 1998, Albertson 1995). The most severe rail population declines and highest fox numbers were found in the East Bay marshes (*e.g.*, Dumbarton, Mowry, Ideal, and Calaveras). Winter airboat surveys in 1992-1993 documented a clapper rail population increase in many South Bay marshes likely in response to the growth of invasive *Spartina*, and in response to predator control that began in 1991 (Harding *et al.* 1998).

The temporary decline in San Pablo Bay clapper rail populations in the early 1990s (Evens and Collins 1992, Collins *et al.* 1994, California Department of Fish and Game unpubl. data) may have occurred in response to invasion by red fox, wet winters that caused extreme flooding of tidal marshes and encouraged the growth of *Bolboshoenus maritimus* (alkali-bulrush) to the detriment of *Spartina foliosa* (Pacific cordgrass) habitat in the low marsh, or a combination of factors. The additional predation pressure from red fox invasion with a resulting increase in failed nests may have increased the importance of the second, mid-summer peak in nesting activity.

5) Habitat Characteristics/Ecosystem

Throughout their distribution, California clapper rails occur within a range of tidal and brackish marshes (Harvey *et al.* 1977). In south and central San Francisco Bay, and along the perimeter of San Pablo Bay, rails typically inhabit tidal marshes dominated by *Sarcocornia pacifica* and *Spartina foliosa,* especially where significant high tide refugia exist. *Spartina* dominates the lower marsh zone (marsh plain) throughout the south and Central Bay (DeGroot 1927, Hinde 1954, Harvey 1988). *Sarcocornia* dominates the middle and sometimes upper marsh zone throughout the South and Central Bay, with *Distichlis spicata*, *Jaumea carnosa*, *Frankenia salina* (alkali-heath), and others mixing with occasional *Sarcocornia* in the high marsh zone. *Grindelia stricta* var. *angustifolia* occurs along the upper edge of tidal sloughs throughout the entire San Francisco Bay Estuary. The marshes of Humboldt Bay, Morro Bay, and Elkhorn Slough historically have not supported *Spartina*. Vegetation at these locations has been dominated by *Sarcocornia pacifica* and *Distichlis spicata*.

Rail foraging and refugial habitat encompasses the lower, middle, and high marsh zones, as well as the adjacent transitional zone. Lower and middle marsh zones provide foraging habitat at low tide. Small tidal channels (*i.e.*, first- and second-order) with dense vegetation covering the banks are particularly important habitat features (Keldsen 1997, Garcia 1995). These provide important foraging habitat and hidden routes for travel in close proximity to nesting habitat. Within tidal marshes in portions of north San Francisco Bay, the abundance of California clapper rails is positively correlated with channel density or the total length of channel per unit area of marshland (Garcia 1995, Evens and Collins 1992, Collins *et al*. 1994, Foin *et al*. 1997). Keldsen (1997) found that rails prefer locations with a greater number of tidal creeks, *Grindelia* shrubs, and higher elevations. However, high tide conditions result in increased predator pressure on rails in a high marsh zone that has already been reduced by decades of development pressure.

In the North Bay, clapper rails also occur in tidal brackish marshes that vary significantly in vegetation structure and composition, ranging from salt-brackish marsh to fresh-brackish marsh transitions. *Bolboschoenus maritimus* (alkali bulrush), an indicator of salt-brackish marsh transitions, is sub-dominant to dominant in low marsh and lower middle marsh plains. *Schoenoplectus acutus* and *Schoenoplectus californicus* (tules), *Schoenoplectus americanus* (Olney's bulrush), and *Typha* spp. dominate the low marsh zone of fresh-brackish marsh transitions, while fresh-brackish marsh plain vegetation is a diverse, patchy mixture of dominant *Distichlis, Jaumea*, salt rush (*Juncus arcticus* ssp. *balticus, Juncus lesueurii*), and numerous native and non-native herbs, grasses, and sedges. *Grindelia stricta* var. *angustifolia* is the widespread dominant of high marsh vegetation in brackish marshes today, but it occurs with other tall, dense sub-shrubby or herbaceous native vegetation along marsh edges and creek banks, such as *Baccharis douglasii* (salt marsh baccharis), *Euthamia occidentalis* (goldenrod), *Achillea millefolium* (yarrow), *Scrophularia californica* (bee-plant), and asters (*Symphyotrichum lentum, Symphyotrichum chilensis*, and intermediates, *Symphyotrichum sublantus* var. *ligulatus*; now uncommon). The historically diverse high brackish marsh vegetation probably provided ample high tide flooding refuges for clapper rails.

Use of brackish marshes by clapper rails is largely restricted to major sloughs and rivers of San Pablo Bay and western Suisun Marsh, and along portions of Coyote Creek in south San Francisco Bay. In brackish marshes, other rail species such as Virginia rail and sora (*Porzana carolina*) are typically more common than clapper rails. Clapper rails were not reported from Suisun Marsh in the 19th and early 20th centuries. However, they have persisted in Suisun Marsh even after above-average rainfall and very low channel salinity in the 1990s, when tidal marshes there developed a fresh-brackish vegetation (Estrella *in litt.* 2007).

Clapper rails have rarely been recorded in nontidal marsh areas. Small numbers have been detected calling during the breeding season in a diked *Sarcocornia* habitat in Crittenden Marsh, Santa Clara County (Orton-Palmer and Takekawa 1992) and in Richardson Bay, Marin County (Evens *in litt.* 2009).

The quality of a marsh strongly influences the density of rail population it can support (Albertson 1995, Garcia 1995). Physical habitat characteristics critical to clapper rails include marsh size, location relative to other marshes, existence of functional high tide refugia, presence of buffers or transitional zones between marshes and upland areas, marsh elevation, and hydrology (Collins *et al.* 1994, Albertson 1995). Denser rail populations exist where the habitat patch size is greater than 100 hectares (247 acres; Collins *et al.* 1994). Currently, there are fewer than 15 such patches in the San Francisco Bay Estuary (Albertson and Evens 2000).

6) Critical Habitat

No critical habitat has been designated for the California clapper rail.

7) Reasons for Decline and Threats to Survival

Most species covered in this recovery plan are threatened by similar factors because they occupy the same tidal marsh ecosystem. These general threats, faced by all covered species, are discussed in greater detail in section I. Specific threats to California clapper rail are described below.

Factor A

Habitat Loss. Conversion of tidal marsh on a large scale began in the late 1800s. In the South Bay, tidal marsh was diked and drained primarily for urban and industrial development. In the North Bay (San Pablo and Suisun included), reclaimed land was used for grazing, agriculture, and duck clubs (Goals Project 1999). The loss of coastal wetland habitat to urban and industrial development has been extensive in California, with a 90 percent total loss of all wetlands since settlement of the region (Goals Project 1999). Though some development leads to total habitat loss, habitat loss has dramatically slowed since the rail was listed in 1970. Most development today leads to ongoing habitat disturbance and degradation which precludes or reduces occupation of much of the remaining potential habitat by California clapper rails.

Habitat Degradation. Other than outright habitat loss due to marsh reclamation, significant historic degradation to clapper rail habitat quality in remaining tidal marshes is caused by numerous human-caused physical and biological changes in the San Francisco Bay Estuary tidal marshes, including:

(1) Historic and current construction and maintenance of levees in tidal wetlands. Though construction of new levees has ceased, with the exception of restoration projects, remaining levees still fragment habitat and result, to varying degrees, in the following adverse effects:
   a. marsh fragmentation and reduction to small isolated marshes
   b. reduction in quality, distribution, and abundance of critical sub-habitats, such as high tide refugia
   c. reduction and simplification of natural tidal creek and levee networks by levees and flood control channels
   d. locally excessive sedimentation induced by diking of tidal creeks
   e. establishment of extensive non-tidal predator corridors, perches, and nest/den sites
   f. marsh subsidence and submergence due to groundwater overexploitation (mainly historical)

(2) Replacement of clapper rail tidal refugia along landward marsh edges with unbuffered urban edges.

(3) Conversion of tidal marsh to brackish-fresh marsh by urban fresh wastewater discharges.

(4) Structural habitat change caused by non-native plant invasions (particularly *Spartina alterniflora* hybrids in low marsh and *Lepidium latifolium* in high marsh).

(5) Increased predation by attracted avian and mammalian predators due to availability of man-made structures. Electrical towers and nearby buildings may be used for nesting and roosting of avian predators. Boardwalks may be used for roosting, in addition to serving as routes of access into the marsh interior for mammalian predators.

(6) Increased disturbance from recreational access, including humans and dogs.

(7) Reduced habitat quality and increased attraction of predators from litter and debris.

(8) Contamination of marsh sediments, which may impact clapper rails directly or indirectly. Potential direct effects include toxicity to adults, chicks, or embryos. Potential indirect effects include reduced prey quality, quantity, and availability, and altered vegetation structure/composition for nesting and sheltering (see **Appendix E**).

Few of these causes of habitat degradation are independent of one another; they interact and mutually amplify. For example, construction and subsequent maintenance of a levee restricts tidal circulation, concentrates impacts of any fresh wastewater discharges, provides predator corridors and nest/den sites, compresses tidal refugial vegetation to a narrow strip, and promotes ruderal (weedy) vegetation. It may also mobilize contaminants buried in marsh sediments. Further, the presence of a levee may provide recreational access for people and their pets, which results in increased disturbance and potential litter problems. Rodents attracted to the litter, and provided access and nest sites by levees, will result in added predation pressure on clapper rails.

Fragmentation. As described above in Existing threats to California tidal marsh ecosystems (section 1), levees have led to widespread degradation and loss of rail habitat. Many of the tidal marshes in the bay are relatively small fragments, and the presence of levees facilitates predator access across the entire site. This is particularly true for the linear/strip marshes prevalent in the South Bay. Levees allow predators to travel miles out into baylands that would otherwise be naturally isolated from terrestrial predators. Mammalian predators, especially red foxes, rats, and domestic cats (American Bird Conservancy 2006) use levees as movement corridors and denning/nesting sites, as described below under Predation. Any clapper rail nests located close to levees are therefore subject to higher predation pressures. The red fox is a highly efficient predator of rail eggs, chicks, and adults in the South Bay. We speculate that red foxes do not typically travel far from the levees, which may result in lower rates of fox predation in large marshes that have more nesting habitat away from levees than small marshes.

Other threats result indirectly from levees due to the breakdown of tidal marsh habitat into relatively small, discontinuous, narrow fragments too small to develop the complex tidal drainage networks needed for productive rail habitats. Generally, extinction rates increase as habitat size decreases and distance from neighboring populations increases (MacArthur and Wilson 1967). As remaining habitat units decrease in size, edge effects become increasingly important. Smaller units have less space available to buffer adverse impacts from small populations and outside influences, such as predation, human disturbance, or chemical contamination (see Factor E below). Catastrophic mortality from chance environmental events, such as flooding, is a severe threat to the long-term survival of small, isolated populations (Schonewald-Cox *et al.* 1983). Isolation of small local populations increases chances of inbreeding. The breeding of closely related individuals can cause genetic problems in small populations, particularly the expression of deleterious genes (inbreeding depression). Individuals and populations possessing deleterious genetic material are less able to cope with environmental conditions and adapt to environmental change. Furthermore, small populations are subject to the effects of genetic drift (random loss of genetic variability). Populations that undergo extreme declines and rebound from a small number of survivors are particularly vulnerable to inbreeding depression. Clapper rails in San Francisco Bay suffer from both risks. Loss of genetic variability may also limit the ability of individuals and populations to successfully respond to environmental stresses. Overall, these genetic factors affect population fitness and the likelihood of survival of the species.

Loss of buffer zones: Prior to settlement of the bay area by Europeans, tidal baylands graded into a transitional zone of low-lying moist grassland and vernal pool habitat, and then into upland areas (Goals Project 1999). A swath of undeveloped uplands then provided a sort of buffer zone between urban/industrial areas and tidal marshes and their associated habitats. Much of the historical development around the bay built upon not only the upland buffer zones, but the transition zone grassland and vernal pool habitats as well. Buffers provide two primary benefits to adjoining wetlands by (1) absorbing and deflecting disturbances originating in adjacent lands of incompatible land use, and (2) along with the transition/ecotone area, providing upland refugia during high tide and flood events, both of which ultimately influence habitat quality and carrying capacity of tidal marshes for clapper rails. Appropriately sized and structured buffer zones are a critical component of clapper rail habitats in urbanized settings.

Loss of upper marsh vegetation has greatly reduced available habitat throughout the range of the subspecies. Most marshes in south San Francisco Bay are adjacent to steep earthen levees that have all but eliminated upper marsh vegetation and reduced available cover for rails during winter flood tides. For example, reduction of upper marsh has been suffered at the south levees at Muzzi Marsh, Corte Madera, caused by routine mowing up to the wetland edge and in Suisun Marsh by diking and livestock grazing.

Wastewater discharges: Wastewater discharges that reduce natural salinity levels in tidal waters can adversely affect clapper rail populations and other species. Marsh conversion of tidal marsh to brackish marsh may lower the habitat quality and carrying capacity of tidal marshes to support clapper rails, as evidenced by lower population and nesting densities recorded in brackish marshes than tidal marshes (H.T. Harvey and Associates 1989). Since about 1970, the San Jose/Santa Clara Water Pollution Control Plant has been conducting freshwater discharges into saline marshes of South San Francisco Bay. Partly due to these freshwater discharges, between 1989 and 2007, there was a net conversion from tidal to brackish marsh at the southern end of San Francisco Bay along Coyote Creek and adjoining sloughs of the Santa Clara Valley (H.T. Harvey and Associates 2008). However, between 2006 and 2008, a decrease in freshwater outflow has resulted in a shift from brackish marsh to tidal marsh, in turn resulting in a net formation of 77 acres of tidal marsh since 1989 (H.T. Harvey and Associates 2008). No data concerning marsh conversion since 2008 was available at time of printing.

Non-native vegetation: Some introduced plants, particularly *Lepidium latifolium* (perennial pepperweed) and invasive *Spartina*, appear to pose threats, at least in the long-term, to habitat quality for clapper rails. Additionally, the *removal* of recently established invasive *Spartina* is a threat, the long-term effects being currently unclear and debated by species experts, as described above in Chapter I, Existing threats to California tidal marsh ecosystems. The rapid spread of *L. latifolium* throughout thousands of acres of brackish marshes and brackish high marsh edges in Suisun, San Pablo, and south San Francisco bays may interfere with seedling establishment of *Grindelia*, a tall native evergreen sub-shrub used by clapper rails for high tide cover and nesting substrate in high marsh. *Lepidium latifolium* establishes poor above-ground winter cover as it is leafless and provides little cover during high winter tides. Spreading rhizomatously and by seed, it may displace *Sarcocornia pacifica* and other plants in some locations. The extent to which this species may affect clapper rails and other native tidal marsh species needs further investigation.

As described under Existing threats to California tidal marsh ecosystems, invasive *Spartina* colonizes mudflats, pans, and slough channels. Once established it causes decreased water flow, increased sediment deposition, and infill. The net result is an increase in elevation of the area, exclusion of native *Spartina foliosa*, and replacement of diverse native vegetation with a monotypic stand that lacks vertical complexity. Infilling of habitat with invasive *Spartina* could result in loss of foraging habitat and movement corridors for clapper rails in future decades. However, the long-term effects of invasive *Spartina* are debateable, particularly when sea level rise is considered.

In the short term, the effects of tidal marsh invasion by *Spartina alterniflora* appear to be beneficial to rails. Because it is more fertile and can colonize elevations both higher and lower than the native *Spartina foliosa*, breeding and sheltering habitat are more rapidly provided for rails in restored marshes. However, the long-term impact of non-native *Spartina* invasion on California clapper rails is unknown. Along the Atlantic coast, vast *Spartina alterniflora* marshes provide the primary habitat for the east coast clapper rail (*Rallus longirostris crepitans*). However, the east and west coast environments are structurally quite different. If the structure of remaining and restored tidal marshes in California approach those of *Spartina*-dominated east coast tidal marshes (broad *Spartina* plains with infrequent large tidal creeks), the carrying capacity of California estuaries for the clapper rail may become permanently impaired.

As described under Tidal Marsh Conservation, Restoration, and Management in Chapter I, the ISP has reduced the coverage of invasive *Spartina* baywide by nearly 90 percent (from 324 net hectares [800 acres] to less than 40 net hectares [100 acres]) since its peak coverage in 2005-2006 (Olofson *in litt.* 2011). The impact of the eradication efforts has clearly been negative in the short-term, for the clapper rail. In fact, although some degree of short-term habitat loss was anticipated prior to invasive *Spartina* treatment, preliminary post-treatment rail surveys indicate that removal of the rail's habitat structure has resulted, after several years, in substantial declines in rail numbers, likely due to absence of native replacement vegetation and subsequent loss of breeding habitat and high tide refugia (Invasive Spartina Project 2010).

The introduced horse mussel may also cause some rail mortality by trapping the bills or feet of birds that have stepped on or probed into the shell (DeGroot 1927). Emaciated rails with mussels clamped onto toes or bills are occasionally observed (U.S. Fish and Wildlife Service unpubl. data).

Human Disturbance: Clapper rails vary in their sensitivity to human disturbance, both individually and between marshes. Clapper rails have been documented nesting in areas with high levels of disturbance, including areas adjacent to trails, levees, and roads heavily used by pedestrian and vehicular traffic (J. Didonato pers. comm., Baye *in litt*. 2008). In contrast, direct human-caused disturbance to the California clapper rail is known to occur in some locations of the Bay Trail (Albertson *in litt*. 2009*b*).

Also, Albertson (1995) documented a rail abandoning its territory in Laumeister marsh, shortly after a repair crew worked on a nearby transmission tower.

Data on reproductive success of nests near heavily trafficked areas are lacking. Clapper rails nesting next to regularly disturbed areas are likely to be subject to higher rates of predation due to easy access provided by trails, levees, and roads. Disturbance of incubating or brooding adults may translate into reduced hatch or fledge success of young through increased nest predation if the adult vacates the nest, or through temperature stress (heat or cold) due to lack of thermoregulation by the adult. Reduced reproductive success results in reduced recruitment to an already unstable endangered population. In addition, continued disturbance may stress the adults and reduce survival through disruption of normal activities, such as reduced foraging or resting time or increased susceptibility to predators. Reduced survival of adult clapper rails, which has been identified as the most critical life stage in population models (M. Johnson unpubl. data; Foin *et al.* 1997), may also impact the long-term viability of the population.

The ramifications of disturbance related to human traffic during breeding season primarily include effects on eggs and chicks or the season's reproductive effort. In addition, anthropogenic noise may also impact survival of adults. Adults may be more responsive to noise during the breeding season, as their mating system is based primarily on auditory signals. Loud noises may elicit calling or prevent advertising calls from being heard, which could disrupt pair bonding and mating efforts. Studies of noise criteria suggest that noise levels above 80 to 85 decibels (dB) are disruptive to normal behavioral patterns in birds (Transportation Noise Control Center 1997). Clapper rails may be sensitive to noise throughout the year, as rails were heard calling in response to a nearby jackhammer in September (Evens *in litt*. 2009).

Clapper rail reactions to disturbance may vary with season; however, both breeding and non-breeding seasons are critical times. Disturbance during the nonbreeding season may primarily affect survival of adult and subadult rails. Adult clapper rail mortality is greatest during the winter (Eddleman 1989, Albertson 1995), primarily due to predation (Albertson 1995). Human-related disturbance of clapper rails in the winter, particularly during high tide and storm events, may increase vulnerability to predators. The presence of people and their pets in the high marsh plain or near upland areas during winter high tides may prevent rails from leaving the lower marsh plain (Evens and Page 1983). Rails that remain in the marsh plain during inundation are vulnerable to predation due to minimal vegetative cover available (Evens and Page 1986). This situation is exacerbated in small diked marshes with little to no high tide refugia or high marsh plain.

Although clapper rails may occur in areas with high levels of human-related disturbance, the effects of the disturbance on the rails is unknown and potentially significant. Many marshes only support very small clapper rail populations (*e.g.* only two rails detected at BSRA in 2005; Herzog *et. al*. 2005), which suggests that even minor incursions could disrupt and potentially extirpate vulnerable small populations or subpopulations. Because most clapper rail marshes are subjected to a variety of uses, the cumulative detrimental effects may be appreciable. Numerous routine human activities have the potential to adversely affect individual rails and overall population viability, for example, flood control; levee, dredge lock, pipeline, and powerline maintenance; recreational uses including bird watching and water sports; human and domestic animal incursion from adjoining developments; mosquito control ditching, spraying; use of ATVs/Argos in baylands; etc.

Litter: Refuse also affects habitat quality. Although clapper rails often seek refuge on flotsam, during flood tides litter of various kinds also supports populations of predators such as Norway rats. In some cases the accumulation of litter may kill marsh vegetation or be a threat to clapper rail nests. In other cases woody flood debris may provide a structure upon and around which native vegetation may grow (*e.g.,* trellis for *Sarcocornia*), ultimately providing potential nesting opportunities as well as high tide refugia. Thus, it is important to distinguish between natural debris and human litter and refuse. Some forms of litter, such as plastic and balloon strings, directly impact clapper rails, as evidenced a dead clapper rail found tangled in the string of a rubber balloon (Albertson 1995).

Factor B

Coupled with the unprecedented habitat loss of the mid-1800s was equally unprecedented hunting pressure. Kennerly (1859) indicated that clapper rails were one of the most numerous birds sold in San Francisco markets during the mid-1800s. Until 1889, bagging up to 200 clapper rails per hunting trip was not uncommon (Grinnell *et al.* 1918) and thousands of rails were reported killed in a single day in 1859 (Wilbur and Tomlinson 1976). Up to 5,000 rails of several species were reported killed during a one-week period in 1897 in south San Francisco Bay (Gill 1979). By 1894, clapper rail populations had noticeably declined (Taylor 1894), and some people in the South Bay were advocating a temporary closure of the rail hunting season (Cohen 1899). By 1902, clapper rail numbers had dropped precipitously due to simultaneous habitat loss and hunting pressure. The annual closed summer season remained in effect, but was insufficient protection. Tidal marsh conversion concentrated the birds in smaller areas, greatly facilitating fall hunting (Grinnell *et al.* 1918). The Federal Migratory Bird Law, passed in 1913, was designed to stop illegal shipment of migratory birds across state lines. After the enactment of the Migratory Bird Treaty Act in 1918 brought about the cessation of hunting, rails increased in abundance in the remaining San Francisco Bay marshes (Bryant 1915, Grinnell and Miller 1944). The implementation of this Act has effectively ameliorated this threat.

Factor C

***Predation*—**Throughout the bay, the remaining clapper rail population is besieged by a suite of mammalian and avian predators. Mammalian species, such as red fox, Norway rats, raccoons, skunks, and cats, are common terrestrial predators. They are also likely to impact salt marsh harvest mice and other native species, such as black rails and endemic tidal marsh song sparrows. Other species, such as gray fox and opossums, are also considered potential predators due to their foraging habits, but their impacts to tidal marsh species are less well documented.

Precipitous declines in South Bay rail populations during the mid to late 1980s are attributed largely to intensive predation by the red fox (Foerster *et al.* 1990, Albertson 1995) which was introduced to San Francisco Bay in 1980 (Harding *et al.* 1998). Rail carcasses and egg remains have been found outside of active red fox dens (Foerster and Takekawa 1991). Between 1991 and 1996, a significant negative correlation existed between breeding densities of rails and average fox abundance, such that sites with the highest densities of foxes had no rails. In addition, there was a significant positive relationship between the growth rate of clapper rail populations and red fox trapping success in the preceding year. Albertson (1995) suggested that in the South Bay, predation by red foxes posed the most serious threat to adult clapper rails at that time.

Red foxes are present in the North Bay as well as the South Bay (California Department of Fish and Game unpubl. data). Recent preliminary evidence suggests that red foxes in the North Bay (Petaluma, Santa Rosa, and Sebastopol) are non-native; however, red foxes from the Montezuma Hills area near the Suisun Bay are genetically more similar to the native Sierra Nevada red fox (*Vulpes vulpes necator*) (Sacks *in litt.* 2009). To date, no quantitative data are available on rail mortality due to non-native red fox in the North Bay or near Suisun. Non-native red fox have been observed since 1988, however, and anecdotal evidence suggests that foxes have been a factor in declines in rail detections at the mouth of Sonoma Creek (Evens 2000*a*).

Predation consistently takes a high toll on both nest success and hatching success although the impact of predators on clapper rails varies with marsh. Chicks and eggs are vulnerable to predation by the entire suite of predators. Norway rats appear to take the majority of eggs lost to predators (Harvey 1988, Foerster *et al.* 1990, Striplen 1992). Foerster *et al.* (1990) found the majority of documented nest losses were due to rats and raccoons. Of 54 active clapper rail nests that contained 348 eggs, predators were responsible for the loss of 115, rodents destroyed 108, foxes destroyed 4, and snakes destroyed 3 (Striplen 1992). An additional 43 eggs failed to hatch due to nest abandonment or inundation, and 38 disappeared during incubation. Estimates of nest predation may be underestimated, however, because certain predators, particularly red fox, are known to carry eggs away from nests prior to consumption. Red fox-depredated rail eggs ($n = 4$) were recovered an average of 5.8 meters (6.3 yds) from the nest in the South Bay (Striplen 1992). Such displaced eggs may be overlooked by observers, and nest failure mistakenly attributed to other causes, such as adult abandonment or nest inundation. Gopher snakes (*Pituophis melaoleucus*) have taken several clapper rail nests at Laumeister Marsh, and it is possible that ground squirrels and long-tailed weasels (*Mustela frenata*) may take clapper rail nests while foraging in marshes (Albertson *in litt.* 2006).

Avian species are also important predators of tidal marsh birds and mammals, including clapper rails. Populations of many native avian species (common ravens, American crows, California gulls) are artificially increased above historical population levels due to the increased availability of food resources and nesting opportunities associated with human activities. Clapper rail predation from these species has correspondingly been elevated above historical levels. Other species, such as the northern harrier, have been pushed from much of their nearby upland habitat by urban development, and their foraging activities are locally concentrated in the wetland areas. Common ravens and red-tailed hawks are known to nest in electrical towers, boardwalks, and buildings and forage in various nearby marshes of South San Francisco Bay which have otherwise limited hunting perches (Albertson *in litt.* 2009*a*). The peregrine falcon is also a likely predator of the clapper rail, and the population of this species has increased locally in recent years as a result of peregrine falcon recovery actions.

Landfills and urban areas provide food resources that would otherwise not be available, while buildings, towers, and other human-made structures provide nesting and roosting opportunities. There are three landfills directly adjacent to the Don Edwards San Francisco Bay National

Wildlife Refuge (Refuge): Palo Alto, Newby Island, and Tri City. Known or potential predators of California clapper rail eggs, such as California gulls and common ravens are attracted by these facilities. In a study by Ackerman *et al*. (2009) of gull movement in relation to landfills, it was determined that California gulls from a breeding colony at pond A6 in the Alviso area of the South Bay arrived at landfills at 6:00 in the morning and left at 6:00 in the evening when the landfills were closed and the exposed refuse was covered. California gull populations in the South Bay have increased from fewer than 200 breeding birds in 1982 to over 46,800 in 2008, due to the availability of food resources, largely from landfills, coupled with the availability of nesting habitat on dry salt ponds and levees (Ackerman *et al.* 2009). Ackerman *et al.* (2006) determined that in 2005 and 2006, California gulls depredated at least 61 percent of avocet chicks (*Recurvirostra americana*) and 23 percent of stilt chicks (*Himantopus mexicanus*) in the South Bay and it is suspected that similar predation pressures exist for Forster's terns (*Sterna forsteri*) and snowy plovers (*Charadrius alexandrinus nivosus*; Robinson *et al.* 2007). Little is known about the effect of gulls on California clapper rail chicks or eggs, but given their effect on other marsh birds, it is reasonable to suspect that gull species may present a threat to the rail.

Landfills have also been identified as a major source of feral and otherwise free-roaming cats on the Refuge, and steps are currently being taken to limit the numbers of cats entering the Refuge from these sites (Albertson *in litt.* 2006). In addition, the numerous Bay Area levees and trails allow cats easy access to clapper rails, as well as other rare tidal marsh species (American Bird Conservancy 2006). For instance, many sections of the Bay Trail and other public trails have large populations of cats, many of which are fed daily by well-meaning members of the public or organized cat advocate groups. Five general areas within the scope of this recovery plan were identified as sites where cat predation is considered a threat to sensitive bird species: Don Edwards San Francisco Bay National Wildlife Refuge, San Pablo Bay wetlands, BSRA, Eastshore wetlands (Alameda County), and Elkhorn Slough (Monterey County) (American Bird Conservancy 2006).

Factor E

Following the initial development of the San Francisco Bay, the single most significant remaining long-term threat to California clapper rail is rising sea level resulting from global climate change. A 2009 Pacific Institute study revealed that sea level may rise by as much as 1.4 meters (1.09 to 1.53 yds) by the year 2100, flooding approximately 388 square kilometers (150 square mi) of land immediately adjacent to current wetlands, including current California clapper rail habitat, with accompanying accelerated erosion resulting in a loss of an additional 106.2 square kilometers (41 square mi) of California's coast (Heberger *et al.* 2009). As a significant threat to habitats ecosystem-wide, sea level rise is discussed in further detail under Existing threats to California tidal marsh ecosystems (Factor A) in the Introduction. In summary, according to a 2009 study conducted by Pacific Institute, under medium to medium-high emissions scenarios, mean sea level along the California coast will rise from 1.0 to 1.4 meters (1.09 to 1.53 yds) by the year 2100 (**Figure I-6**). Other key findings of the study report that a 1.4 meter (1.53 yds) sea level rise would flood approximately 388 square kilometers (150 square miles) of land immediately adjacent to current wetlands and would result in accelerated erosion resulting in a loss of an additional 106 square kilometers (41 square miles) of California's coast by 2100 (Heberger *et al.* 2009). The effects of past subsidence of marsh plain relative to mean tidal level, particularly in the South Bay (Atwater *et al.* 1979), are likely to be amplified by rising tidal levels.

Contaminants. Environmental contaminants may affect the health and vigor of clapper rails directly through toxic effects to individuals, or indirectly through effects to organisms upon which the rail depends. Acute poisoning associated with oil or toxic material spills could result in rail mortalities within affected habitat. A large oil spill in South Bay marshes could be catastrophic for the rail population. To date, most direct contaminant impacts to the rail have likely been due to lifetime exposures at chronic, sub-lethal concentrations that alter individual fitness. Known contaminants of concern for rail recovery in the San Francisco Bay Estuary include mercury, selenium, PCBs, and petroleum hydrocarbons. The potential toxicological effects of long term chronic contaminant exposures can include reproductive impairment, compromised immune function, reduced growth, deformity, and altered behavior (Schwarzbach *et al*. 2006). While few adult clapper rail mortalities have been directly attributed to contaminants, elevated mercury levels have been found in the tissues of some dead adults. Reproduction in clapper rails has been documented as poor, and contaminants, particularly mercury and perhaps PCBs, are the most likely contributors (Schwarzbach *et al*. 2006).

Contaminants could also indirectly impact rails by altering habitat features such as benthic prey density or nesting cover. Petroleum hydrocarbons and trace elements, such as arsenic, copper, silver, cadmium, and lead, may be an indirect hazard through toxicity to benthic prey. Although benthic organism densities and species composition are known to be altered within the bay by contaminants at some locations (San Francisco Estuary Institute 1999), the effect within rail habitat has not been systematically assessed.

Also of potential concern are newer environmental contaminants that are rarely monitored and poorly understood. Unmonitored contaminants in San Francisco Bay include such chemicals as pharmaceuticals, plasticizers, flame retardants, and detergent additives (San Francisco Estuary Institute 2000). Toxic effects of many of these chemicals to rails and other estuary biota are not known. In other species, some of these chemicals have caused endocrine disruption and altered gender development through in ovo exposures (Colburn and Clement 1992).

With the exception of the largest deepwater discharges of industry and some municipalities, much of the ongoing contamination of the bay enters at the margins, often through tidal marsh habitat. Many, if not most, tidal marsh sediments are more contaminated than open bay sediments (Collins and May 1997). As an omnivore inhabiting the margins of the bay, the clapper rail is exposed to sediment-born contamination of baylands, and may be particularly at risk of exposure to those chemicals that bioaccumulate in benthic prey. When comparing diving ducks with other species, the higher concentrations of selenium were found in benthic foragers (Ohlendorf *et al.* 1986). Contaminants that are toxic to vertebrates, persist in sediments, and transfer and accumulate in clapper rail prey, present the greatest contaminant hazards to clapper rail recovery.

For the past 75 years or more the greatest densities of breeding rails have been found in marshes of the South Bay (DeGroot 1927, Gill 1979, Harvey 1988). Freshwater inflows to the South Bay are substantially more limited than in the North Bay, which receives inflow from the Sacramento and San Joaquin rivers. As a consequence, the residence time for water and also waterborne contaminants is substantially longer in the South Bay. Previous investigators have found a variety of contaminant problems in the South Bay, with silver, mercury, and selenium found to be elevated in bay biota (Luoma and Cloern 1982, Thomson *et al.* 1984, Ohlendorf *et al.* 1986, Smith *et al.* 1986, Luoma and Phillips 1988, Ohlendorf and Fleming 1988, Ohlendorf *et al.* 1991, Lonzarich *et al.* 1992). Mercury and selenium are of particular concern because they are known to accumulate in avian eggs in proportion to the maternal dose, and to adversely impact birds by directly reducing the hatchability of eggs, as well as reducing growth and post-hatch survival of juveniles exposed in the egg.

The following is a brief synopsis of recent contaminant investigations in the San Francisco Bay Estuary. The focus is on contaminants that have been identified as potential hazards to California clapper rails. Mercury, selenium, organochlorine pesticides, polychlorinated biphenyls (PCBs), and petroleum hydrocarbons are discussed. It is important to note that this list in not all-inclusive, and that there are many other compounds being released into the environment that may also adversely affect clapper rails and other tidal marsh organisms. Additional details on environmental contaminants in San Francisco Bay are presented in **Appendix E**.

Mercury: Mercury accumulation in eggs is perhaps the most significant contaminant problem affecting clapper rails in San Francisco Bay. California is geologically enriched with mercury, and anthropogenic activities, such as mining for mercury and gold, have released large amounts of mercury in northern California and San Francisco Bay (Schwarzbach *et al*. 2006). Mercury *bioaccumulation* and toxicity to clapper rails are not simple functions of mercury concentration in sediments, but depend on rates of methylation that are mediated by bacterial activity and other abiotic factors. Methylmercury concentrations in tidal marsh sediments appear to be more variable than total mercury concentrations (U.S. Fish and Wildlife Service unpubl. data). Preliminary results suggest that sediment methylmercury concentrations are related to slough order, with higher concentrations of methylmercury occurring in higher order channels (San Francisco Estuary Institute 2008). In a study by Schwarzbach, methylmercury was, on average, 95 percent of the total mercury concentration found in eggs with a 95 percent confidence interval between 89 and 100 percent (Schwarzbach *et al*. 2006).

Mercury is extremely toxic to embryos and has a long biological half-life. Toxic effects of mercury in bird eggs have been documented by many investigators in both laboratory and field studies (*e.g.*, Wolfe *et al.* 1998). Fimreite (1971) observed hatchability declines in ring-necked pheasants (*Phasianus colchicus*) when egg concentrations of methylmercury were between 0.5 and 1.5 µg/g, fresh wet weight (fww). In 1992, fifty percent of all the fail-to-hatch California clapper rail eggs from the South Bay were above 0.5 µg/g concentration (fww) and 20 percent from the North Bay were above this concentration (Schwarzbach *et al*. 2006). Twenty-five percent of all the 1992 fail-to-hatch rail eggs were above the 0.86 µg/g (fww) effects threshold estimated for mallards (Heinz 1979). Mean mercury concentrations among marshes ranged between 0.27 and 0.79 µg/g (Schwarzbach *et al*. 2006).

In 1998 and 1999, a similar study was conducted in the North Bay (U.S. Fish and Wildlife Service unpubl. data). Mercury concentrations in 22 fail-to-hatch eggs ranged from 0.20 to 3.5 µg/g (fww). Concentrations in half of these eggs were above 1.00 µg/g (fww). Mercury concentrations in five failed eggs from Hayward Marsh in 1998-99 ranged from 1.28 to 2.12 µg/g (fww). Maximum methylmercury concentrations in marsh sediment were positively correlated with mean mercury concentrations in failed eggs. In 1998, three embryos from Wildcat Marsh (Contra Costa County) exhibited *polydactyly* and reduced digits and limbs. Schwarzbach *et al.* (2006) concluded that elevated chromium and barium were among the most likely candidate trace elements responsible for abnormalities; but they could not rule out the possibility that mercury also contributed to the occurrence of deformities.

In summary, three conclusions may be drawn: 1) mercury is accumulated in California clapper rail eggs at potentially embryo toxic concentrations within both the North and South Bay; 2) methylmercury in bay sediments is predictive of the mercury hazard to rail reproduction; and 3) the mercury hazard of North Bay marshes is not less than the South Bay, as suggested by the 1992 collected eggs (Schwarzbach *et al*. 2006).

Comparison of marsh hatchability and egg mercury results is complicated by the fact that only fail-to-hatch rail eggs have been tested, a limitation of working with an endangered species. Therefore, mercury concentrations in successfully hatched eggs could not be determined. However, recent work by Heinz (2002) using carefully developed techniques for injection of methylmercury into eggs of many different wild species suggest that avian species vary greatly in the sensitivity of their embryos to methylmercury and that the California clapper rail embryos may be among the more sensitive of avian species to methylmercury. Therefore, based on egg injection work on mallards (*Anas platyrhynchos*) and assessments of the rail's current reproductive status, it has been estimated that observed adverse effects, in the form of developmental abnormalities and reproductive harm could be seen above 0.2 µg/g fresh wet weight (fww) methylmercury in rail eggs (U.S. Fish and Wildlife Service 2003). Davis *et al.* (2003) states that, "mercury toxicity to clapper rail embryos appears to be one of the primary causes of mortality in the population of this endangered species."

Selenium: The two major potential sources of selenium to the San Francisco Bay Estuary are irrigation drainwater from the San Joaquin River and discharges from the six major oil refineries. Both sources enter the estuary in the northern reaches of the bay. Mean selenium levels in the San Francisco Estuary are below the current aquatic life water quality criteria of 5 µg/L (EPA 2009). The Regional Monitoring Program for 1997 (San Francisco Estuary Institute 1999) reported total selenium concentrations throughout the bay from 0.03 to 2.20 µg/L, with highest concentrations detected in the South Bay. Inflows diverted to the Central Valley Project and State Water Project canals usually average about 1 µg/L selenium. However, this single criterion is insufficient to protect aquatic birds from bioaccumulative effects of selenium in aquatic food chains (Stewart *et al*. 2004). San Francisco Bay is considered a selenium-impaired waterbody due to bioaccumulation of selenium in biota including subtidal clams, sturgeon, and diving ducks (Ohlendorf *et al.* 1986) and has been officially listed by the San Francisco Bay Regional Water Quality Control Board as such under section 303(d) of the Federal Clean Water Act.

Selenium has been considered a contaminant of concern for wildlife in the bay since Ohlendorf *et al.* (1986) documented that selenium concentrations in diving duck livers collected in the South Bay were comparable to concentrations in ducks at Kesterson, where selenium caused embryo deformities in aquatic birds and greatly reduced hatchability of avian eggs. However, the few rail abnormalities found within the bay (Schwarzbach *et al*. 2006) thus far have not been linked to elevated selenium concentrations in eggs.

The *in ovo* threshold for selenium exposure that causes toxic effects on embryos of California clapper rails is unknown. The *in ovo* embryo toxicity threshold for selenium in black-necked stilts (*Himantopus mexicanus*), another benthic forager, is 6 µg/g (dry weight; dw) (Skorupa 1998). Clapper rail eggs collected from the North Bay in 1987 contained up to 7.4 µg/g selenium (dw) (Lonzarich *et al.* 1992). Selenium concentrations found in North Bay eggs in 1987 were two to three times higher than selenium concentrations in the South Bay. This pattern is consistent with the fact that major selenium inputs to the estuary enter via the North Bay and delta. Investigations of fail-to-hatch clapper rail eggs in the South Bay in 1992 and in the North Bay in 1998 (Schwarzbach *et al*. 2006), have not duplicated the elevated selenium results of Lonzarich *et al.* (1992). Maximum egg selenium concentrations in more than 60 eggs were less than 3.2 µg/g (dw). It seems unlikely that current selenium concentrations in the bay are having a significant impact on clapper rail reproduction, but that could change if selenium loadings to the estuary increase.

Organochlorines: San Francisco Bay has a history of organochlorine contamination from the use of chlorinated hydrocarbon pesticides and polychlorinated biphenyls (PCBs) from the 1950s through 1975 (Venkatesan 1999). Organochlorines are persistent in the environment and are still commonly detected in sediment samples throughout the bay (San Francisco Estuary Institute 2000). As a benthic forager, rails are exposed to these compounds in sediment and through benthic organisms. Lonzarich *et al.* (1992) noted a substantial decline in rail egg organochlorines between 1975 and 1986-87 random egg collections. In a follow-up study in 1992, 22 fail-to-hatch clapper rail eggs from the South Bay were analyzed for organochlorines (Schwarzbach *et al.* 2001). Results from these eggs showed a continuing trend of decline in organochlorine concentration. Neither the 1986-87 random egg collections nor the 1992 failed egg collections found a reduction in clapper rail eggshell thickness. Organochlorine concentrations in failed clapper rail eggs collected in 1998-1999 from two Central Bay marshes were similar to those from the South Bay in 1992 (Schwarzbach *et al.* 2006). These studies concluded that organochlorine pesticide concentrations were not likely to cause adverse effects on clapper rail reproduction (Lonzarich *et al.* 1992, Schwarzbach *et al.* 2001, Schwarzbach *et al.* 2006).

Trends in PCB concentrations in eggs differed from those of organochlorine pesticides. PCB concentrations declined from an average of 2.86 µg/g (fww) in 1975 to 0.82 µg/g (fww) in 1986-1987 (Lonzarich *et al.* 1992). In contrast, PCB concentrations in rail eggs collected from the South Bay in 1992 averaged 1.30 µg/g (Schwarzbach *et al.* 2001). The general trend of decreasing PCB concentrations continued in eggs collected in 1998-1999 from the Central Bay (Schwarzbach *et al.* 2006), with an average of 0.56 µg/g (fww). It is interesting to note that in each year during which clapper rail eggs were collected, PCB concentrations were greater than concentrations of any other organochlorine pesticide quantified, however, only one collected had PCBs high enough to have impacted hatchability (Schwarzbach *et al.* 2006).

Decreased hatching success in white leghorn chickens (*Gallus domesticus*), the most sensitive avian species tested, was associated with PCB egg residues of 0.87 µg/g (ww) in a feeding study with Aroclor 1242 (Britton and Huston 1973, Schwarzbach *et al.* 2006). Of the 1992 rail eggs, 18 of 22 contained PCB concentrations above this threshold. If rails are as sensitive to PCB toxicity as chickens, they may be at risk from PCBs.

Petroleum hydrocarbons: San Francisco Bay Estuary has many potential sources of petroleum hydrocarbon release, as it is highly urbanized, with six oil refineries, substantial ship and oil tanker traffic, and a large number of gas-powered vehicles. As a result, petroleum hydrocarbons are commonly detected in bay waters and sediment. Polycyclic aromatic hydrocarbons (PAHs) are among the most toxic hydrocarbons; many are carcinogenic or mutagenic (Eisler 1987). Rails may be exposed to petroleum hydrocarbons both internally through normal foraging and externally from an oil spill.

There have been several major oil spills within San Francisco Bay in the last decades, including long-term leaks from the SS *Jacob Luckenbach* along the northern California coast since 1953; the Martinez Manufacturing Complex of Shell Oil Company, Peyton Slough, California, 1988; Tosco Corporation Avon Refinery spill, Martinez, California 1980; the Cape Mohican oil spill, San Francisco, 1996; chronic releases by Chevron from Castro Cove near Richmond, Contra Costa County; the Kinder-Morgan Suisun Marsh oil spill of 70,000 gallons from a pipeline rupture in April 2004; major spill of 58,000 gallons of oil from the *Cosco Busan* in San Francisco Bay, November 2007; and a 400-800 gallon spill of bunker fuel from the Dubai Star tanker vessel in 2009 (U.S. Fish and Wildlife Service 1997*b*, California Department of Fish and Game 2009). These spills were due to a number of causes including shipping accidents, a pipeline rupture and an open valve at a refinery, leaks from a sunken ship, etc. Many of the spills affected the interior shoreline of the bay, with impacts to the Central Bay and Carquinez Strait. Numerous marshes in both areas support clapper rails. Although no clapper rails were identified in salvage or cleanup operations, rails may have been oiled and escaped detection due to their normally secretive behavior. The effects of an oil spill depend on the degree of oiling and the nature and weathering of the oil. A large oil spill in the South Bay, where clapper rail populations are more densely concentrated, could have serious ramifications for the long-term survival of the species.

e. Salt marsh harvest mouse *(Reithrodontomys raviventris)*

1) Brief Overview

The salt marsh harvest mouse *(Reithrodontomys raviventris)* was listed as a Federal Endangered Species (U.S. Fish and Wildlife Service 1970) on October 13, 1970, and a California State Endangered Species in 1971 (California Department of Fish and Game 2005). It has a recovery priority number of 2C, based on a high degree of threat, a high potential of recovery, and its taxonomic standing as a species. The additional “C” ranking indicates some degree of conflict between the conservation needs of the species and economic development (U.S. Fish and Wildlife Service 1983). A previous recovery plan was written for the species in 1984 (U.S. Fish and Wildlife Service 1984). There are two subspecies: the northern salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*) lives in the marshes of the San Pablo and Suisun bays, and the southern salt marsh harvest mouse (*Reithrodontomys raviventris raviventris*) is found in the marshes of Corte Madera, Richmond, and South San Francisco Bay.

The salt marsh harvest mouse was previously considered to be restricted to saline or subsaline marsh habitats around the San Francisco Bay Estuary. It is now known that mice have been found in high numbers in brackish diked marshes in the Suisun Bay, primarily in mature stands of *Schoenoplectus americanus* with deep masses of thatch within them (Sustaita *et al*., in press) and also in mature and heavily thatch-filled alkali bulrush (*Bolboschoenus maritimus*) in the South San Francisco Bay (H.T. Harvey 2007). Habitat loss due to human actions is the greatest threat to the salt marsh harvest mouse. Habitat loss that threatens salt marsh harvest mouse is due to filling, diking, subsidence, changes in water salinity, non-native species invasions, sea level rise associated with global climate change and pollution. In addition, habitat suitability of many marshes is further limited by small size, fragmentation, and lack of other vital features such as sufficient escape habitat. Larger tracts of high quality habitat are needed to maintain stable populations over time.

2) Description and Taxonomy

Description. The salt marsh harvest mouse is a rodent (Order Rodentia) in the family Muridae (subfamily Sigmodontinae; **Figure II-11**). The scientific name *Reithrodontomys raviventris* means "grooved-toothed mouse with a red belly." Both subspecies of salt marsh harvest mouse have grooved upper front teeth, but only a few populations of the southern subspecies have animals with a cinnamon- or rufous-colored belly. Both subspecies have rich dorsal brown hair and a unicolored to moderately bicolored tail. The combined head and body length is approximately 7.6 centimeters (3 inches) with an average weight of less than 10 grams (0.353 ounce).

The salt marsh harvest mouse is morphologically similar to the more widespread western harvest mouse (*Reithrodontomys megalotis*), which co-occurs in some habitats. The underside of the western harvest mouse, including its tail, ranges from white to dark gray (Shellhammer 1984). Accurate field identification of mice in tidal marsh habitats requires special expertise as some populations of the salt marsh harvest mouse may exhibit morphological characteristics similar to those of the western harvest mouse, especially in the northern reaches of the estuary. Comprehensive morphological comparisons of harvest mouse populations in the region are given by Fisler (1965; see **Table II-5**); modifications of those traits for use in field identification are found in Shellhammer (1984). Villablanca and Brown prepared an interim report on the use of molecular and morphological tools to determine if salt marsh harvest mice and western harvest mice are hybridizing as well as to distinguish them by morphological traits (Villablanca and Brown *in litt*. 2004). Results of the study indicate that the two species are not hybridizing and that, in Suisun, tail length is the most distinguishing character between salt marsh harvest mice (tail lengths of 77.5 mm and greater) and western harvest mice (tail length of 77.4 mm and less).

Taxonomy. The two subspecies of salt marsh harvest mouse were originally described as two distinct species. The type is the salt marsh harvest mouse of San Francisco Bay, *Reithrodontomys raviventris raviventris*, described by Dixon (1908) from Redwood City, San Mateo County, California. Some individuals of the southern subspecies may have a rusty or cinnamon brown belly, although there is variation in this trait among populations and many populations of the southern subspecies have few to no individuals with red bellies. The northern subspecies of San Pablo Bay and the Suisun Marsh area, *Reithrodontomys raviventris halicoetes*, was described from specimens taken in the Petaluma Marsh, Sonoma County, by Dixon (1909). It has a whitish belly, and is overall more similar in appearance to the western harvest mouse. Artificial breeding experiments that attempted to hybridize the two subspecies resulted in low mating success and one litter that was destroyed by the mother (Fisler 1965). This suggests that the subspecies boundary is based on reproductive, as well as geographic, isolating mechanisms.

Figure II-11. Salt marsh harvest mouse (Kendal Morris/USFWS)

Despite similarities that led Hooper (1944), Fisler (1965), and others to infer that the salt marsh harvest mouse was derived from an ancestor of the western harvest mouse, genetic analysis does not support a close ancestral relationship between the two (Hood *et al*. 1984, Nelson *et al*. 1984, Bell *et al*. 2001). Instead, genetic data suggest that the salt marsh harvest mouse is most closely related to the plains harvest mouse (*Reithrodontomys montanus*), a western interior species that does not occur near the central California coast today.

Table II-5. Key Field characters distinguishing the salt marsh harvest mouse from the western harvest mouse *(adapted from Fisler 1965, Shellhammer 1984,* Quickert *in litt. 2010).*

Trait	**Southern salt marsh harvest mouse (*R. r.* *raviventris*)**	**Northern salt marsh harvest mouse (*R. r.* *halicoetes*)**	**Western harvest mouse (*R. r.* *megalotis*)**
tail thickness (20 millimeters (0.79 in) from body)	2.1 to 3.0 mm (0.083 to 0.118 in)	Suisun: 1.8 to 2.8 mm (0.07 to 0.11 in), Outside Suisun: 2.1 to 3.0 mm (0.083 to 0.118 in)	1.9 to 2.0 mm (0.075 to 0.079 in)
venter (belly) hair color	rusty-cinnamon	Suisun: light gray, Outside Suisun: white	white
tail hair color	unicolor or indistinctly bicolor (typical)	unicolor or indistinctly bicolor (typical)	distinctly bicolor (typically white hairs below)
tail:body ratio	94.7 to 105.3	Suisun: 100-143, Outside Suisun: 107.0 to 116.8	Suisun: 81-121, Outside Suisun: 103.1 to 110.8
tail tip	heavy, relatively blunt	Suisun: intermediate, Outside Suisun: heavy, relatively blunt	relatively pointed
pelage (coat)	relatively thick; long hairs	relatively thick; long hairs	relatively thin; short hairs
activity (during trap, release observation)	relatively placid; infrequent aggressive behavior	relatively placid; infrequent aggressive behavior	relatively active, typical, frequent aggressive behavior
early morning activity	becomes torpid when cold	Show torpidity in Suisun, no torpidity outside Suisun	no torpidity

3) Population Trends and Distribution

Historical Distribution. By the time the salt marsh harvest mouse was distinguished as a species in 1908, extensive tidal marshes throughout its range had already been reclaimed for agriculture, salt ponds, and urban development. Therefore, there are no historical records of its abundance or distribution in the estuary to use as a baseline.

The salt marsh harvest mouse probably occupied most of the middle tidal, or *Sarcocornia*-dominated, marsh plains and high marsh zones of San Francisco Bay, San Pablo Bay, and the Suisun Marsh prior to the significant marsh reclamation of the 1840s. Although estimates of historic tidal marsh area in the San Francisco Bay Estuary are not precise enough to distinguish between suitable and unsuitable habitats for the salt marsh harvest mouse, most of the mature tidal marshes in the region had extensive middle marsh plains and even more extensive high marshes. It is likely that most suitable habitat supported salt marsh harvest mice, since the species can colonize rapidly under favorable conditions (Geissel *et al.* 1988, Bias and Morrison 1999), and habitats were naturally contiguous and extensive. Thus, the area inhabited by the salt marsh harvest mouse prior to tidal marsh reclamation could have approached 77,000 hectares (190,000 acres), the total tidal marsh area (Dedrick 1989, Goals Project 1999).

Current Distribution. The current distribution of the salt marsh harvest mouse can be found in **Figure II-12**. Distribution can be estimated from the remaining suitable diked and tidal marsh habitat, and the review of live-trapping surveys, although trapping data are limited (Shellhammer 1984, Zetterquist 1976, Larkin 1984, Bias and Morrison 1993). Much of the data on local abundance and distribution of the salt marsh harvest mouse have been derived from local short-term studies, usually conducted on privately owned diked baylands proposed for land use changes (H. Shellhammer pers. comm. 2005). These data must be interpreted with caution as most are neither extensive nor long term.

The divide between the northern and southern subspecies occurs in San Pablo Bay near China Camp State Park. The southern subspecies, *Reithrodontomys raviventris raviventris*, occurs south of the break in habitat near San Pedro Point and the northern subspecies, *Reithrodontomys raviventris halicoetes* occurs to the north. The *raviventris* subspecies has a disjunct distribution. It is found from south of Point Pinole at the southeastern edge of San Pablo Bay, south around the eastern side of Central and South San Francisco Bay and the western side of the San Francisco Penninsula north to about San Mateo. It is also found in the Larkspur-Corte Madera area on the Marin Penninsula. The *halicoetes* subspecies form is found on the east side of the Bay northward essentially from San Pedro Point, around San Pablo Bay and throughout the Suisun Bay. It too, has a disjunct distribution, in that it is also found on the Contra Costa County coast from the Pittsburg area to the Carquinez Straits.

Southern subspecies population status

The population status of the southern subspecies is more precarious than that of the northern subspecies. Few major, resilient, or secure populations persist (Roberts Landing, Hayward Marsh, Eden Landing, Mayhews Landing, Calaveras Point Marsh, New Chicago Marsh, Renzel/ITT Marsh, Redwood Shores, in addition to likely populations at Bair Island, Greco Island, Mowry Slough, and other sites). These were very small and isolated compared with the probable historical pattern of distribution and abundance of the subspecies. All major population centers of the southern subspecies are remote from one another based on dispersal distances known for the species. The small populations and higher degree of isolation of the southern subspecies in Marin County indicate a high probability of local extirpation due to inability to recolonize following local extinction.

Although salt marsh harvest mouse abundance does not appear to correspond with the distribution of its native tidal marsh due to the relatively common occurrence of the species in areas of nontidal or microtidal *Sarcocornia pacifica* (pickleweed) marsh, this appears to be an artifact of surveying effort. A fairly small fraction of large pure tidal marsh has been surveyed for the species, while a large fraction of diked marshes have been surveyed. The few large tidal marshes that have been surveyed have yielded very high densities of the mouse (Duke pers. comm. 2005).

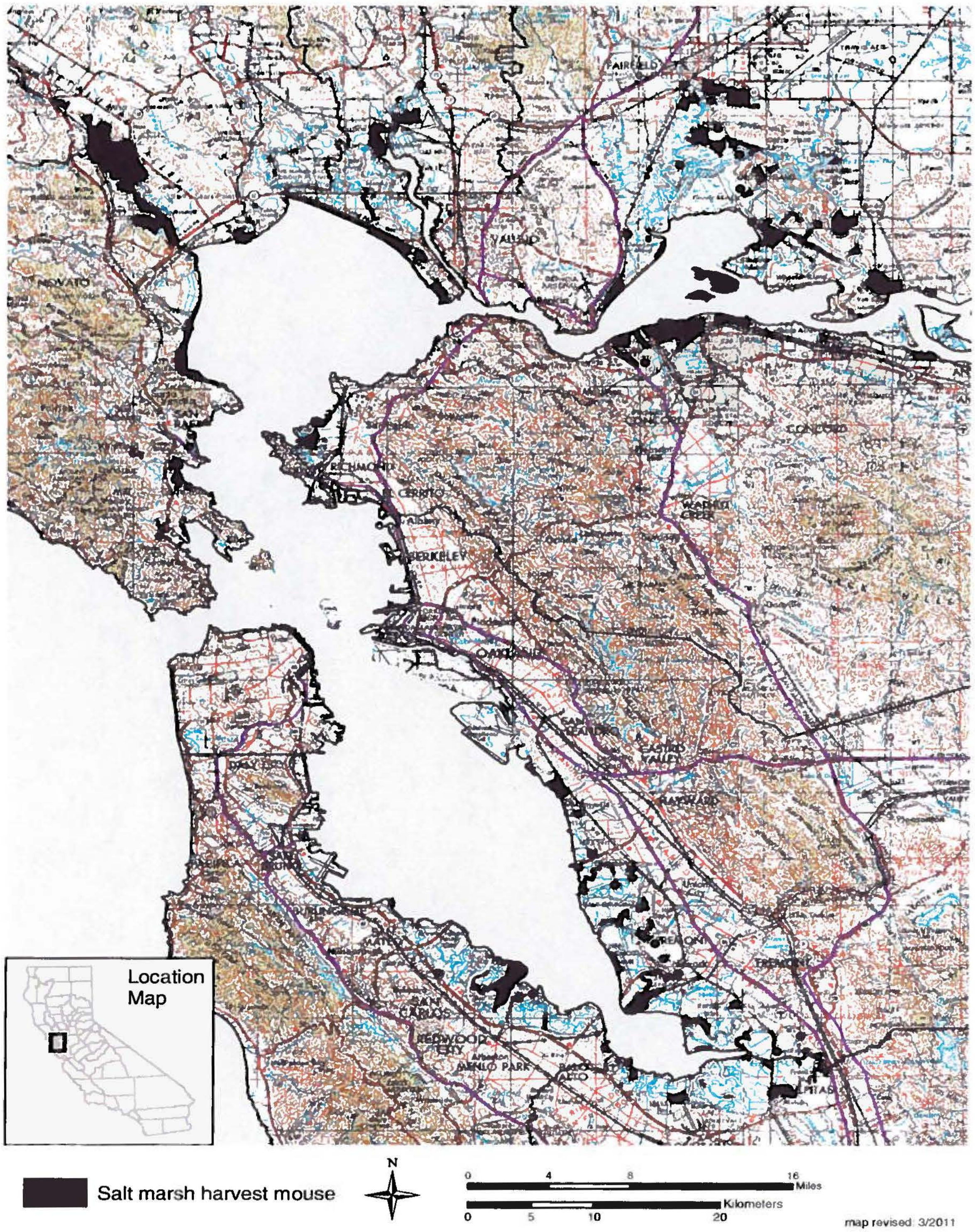


Figure II-12. Distribution of salt marsh harvest mouse

Studies by Shellhammer (unpubl. data) indicate that population size is generally correlated with the depth of the *Sarcocornia* plain (*i.e.*, the middle zone of tidal marshes) and the presence and depth of the high marsh zone where animals can find refuge during highest tides. There are indications that deep (from shore to bay) *Sarcocornia* marshes, especially if they have islands of *Grindelia* within them, may provide enough habitat for the mice such that they can compensate for extremely narrow high marshes at their upper edges. Corridors (sometimes referred to as strip marshes) tend to have narrower *Sarcocornia* zones (as well as extremely narrow high marsh zones) and support few to no mice. In fact, the narrower the strip marsh, the more frequently and intensely it floods (Albertson *in litt.* 2009*a*). Most of the marshes of the South San Francisco Bay are strip-like marshes and, as such, support few mice. In strip-like marshes identified as marsh corridors to connect habitat areas, the relative value of the width and complexity of the high marsh zone increases as the width of the middle marsh, or *Sarcocornia* zone, diminishes (Shellhammer unpubl. research).

Northern subspecies population status

The fringing tidal marshes along northern San Pablo Bay (Petaluma River to Mare Island Strait) support the largest population of the northern subspecies of salt marsh harvest mice in San Pablo Bay. Outside of the Highway 37/Mare Island Marsh there are other major centers of stable or large populations. These include the tidal/microtidal marshes around Gallinas Creek, Coon Island, Fagan Marsh, and Point Edith to Middle Point. Patchy and unstable, though sometimes sizable populations of salt marsh harvest mouse occupy tidal marshes of Suisun Marsh. In the diked marshes of Suisun Marsh, especially those that are designated and managed as Mouse Conservation Areas, there are relatively stable populations of fairly high densities (Shellhammer *in litt*. 2010*a*).

The northern subspecies is more widespread and patchy in distribution in both diked and tidal marshes than the southern subspecies, although densities may be very low outside of the Highway 37/Mare Island and Suisun Marshes and marshes of the Contra Costa County shoreline. Like the southern subspecies, many northern subspecies populations have been displaced from tidal marshes to unstable diked Sarcocornia marshes. Salt marsh harvest mice may become abundant in portions of diked brackish marshes, especially in Mouse Conservation Areas where extensive tall dense cover of *Sarcocornia* vegetation and various species of brackish vegetation develop (Sustaita *et al*., in press) because of effective and consistent water management. Management of tidal areas such that thatch-filled *Schoenoplectus americanus* (threesquare bulrush) and mature, dense *Sarcocornia* plains develop with deep high marsh and adjacent grassland for refugia during annual flooding and that resulting from continued sea level rise is ideal (Shellhammer *in litt.* 2010*a*). Such management would result in longer-term sustainability of populations than in diked marshes. Unmanaged or poorly managed diked *Sarcocornia* marshes, however, can be unstable and highly vulnerable to catastrophic flooding and local extirpation. Salt marsh harvest mice are sometimes also found in significant numbers in grasslands at the upper edge of diked marshes around San Francisco Bay (Zetterquist 1976, Shellhammer *et al.* 1982, Johnson and Shellhammer 1988, Shellhammer *et al.* 1988, Thompson *in litt.* 2009), as described below under Habitat Characteristics/Ecosystem. The extent to which this habitat is utilized is not clear.

Less population survey information is available for the northern subspecies, despite its larger range, than for the southern subspecies.

4) Life History and Ecology

Reproduction. Salt marsh harvest mice are generally sexually active from May through November for the northern subspecies, and March through November for the southern subspecies (Fisler 1965). Bias and Morrison (1993) suggest that the breeding season of the Mare Island population (northern subspecies) extends from August through November; more than 30 percent of the females trapped were pregnant during September and October. Compared with environmentally determined mortality factors, reproduction does not appear to be a limiting factor for the species.

Home range. Telemetry studies of the northern salt marsh harvest mouse at Mare Island Marshes found a mean home range size of 0.21 hectare (0.52 acre), and a mean linear distance moved of 11.9 meters (13 yds) in 2 hours (Bias and Morrison 1999). Most movements occurred in June, and least in November. Mare Island mean home ranges were much larger than those estimated by Geissel *et al.* (1988) for the southern subspecies, which were no greater than 0.15 hectare (0.37 acre). Movements through open habitats were not restricted to rare or extraordinary events (Kovach and Pomeroy 1989; Geissel *et al.* 1988; Bias and Morrison 1993, 1999).

Competition. Population dynamics based on interactions between harvest mice and other small mammals are not well understood (Blaustein 1980, Geissel *et al.* 1988, Bias and Morrison 1993, Bias 1994, Wertz-Koerner 1997, Hulst 2000). Hypotheses of *competitive exclusion* in salt marsh harvest mouse populations, based on analogy with studies on voles (*Microtus californicus*) and western harvest mice, should be applied with caution to salt marsh harvest mice (Blaustein 1980, 1981; Heske *et al.* 1984).

Predation. Very little is known about predation impacts to the species, although predation related to flooding has been viewed as an important factor (Johnston 1957, Fisler 1965). During high winter tides it is common to see great blue herons, great egrets, snowy egrets, ring-billed gulls, California gulls, and American kestrels all taking small mammals from the upper edges and flooded areas of marshes. Protection from predators depends on the dense vegetation cover of typical salt marsh harvest mouse habitat. Mice that leave this cover, or those forced out by flooding, are exposed to predation by hawks and gulls by day, and short-eared owls (*Asio flammeus*) at night (Fisler 1965). Abundant white-tailed kites (*Elanus caeruleus*) and northern harriers (*Circus cyaneus*) frequently forage over thickly vegetated diked and tidal *Sarcocornia* marshes in San Pablo Bay during all tidal stages (P. Baye pers. observ.), but their impact on salt marsh harvest mice is unknown. California clapper rails and herons also occasionally take small mammals (Terres 1980, Josselyn 1983, Meanley 1985). The impact of terrestrial predators on salt marsh harvest mice has not been studied. Potential terrestrial predators include red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), feral or otherwise free-roaming cats (*Felix domestica*), skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*). Other than predation of exposed mice during marsh flooding events, predation is presumably greatest in habitats with incomplete or sparse cover, such as diked baylands with patchy vegetation and high proportions of annual grasses. These habitats also are usually closer to urban edges where terrestrial predators, such as cats, occur. The overall impact of non-flood predation on the recovery of salt marsh harvest mice is less significant than other factors such as habitat quality and size.

5) Habitat Characteristics/Ecosystem

The basic habitat of the salt marsh harvest mouse is *Sarcocornia*-dominated vegetation (Dixon 1908, Fisler 1965). Other highly important habitat considerations include high tide/flood refugia of emergent *Grindelia* (gumplant; both at the upper edge of the marsh and within mature marshes, even at the highest high tides), seasonal use of terrestrial grassland, exploitation of suboptimal habitats, and habitat selection in brackish marsh vegetation where *Sarcocornia* is a relatively minor component next to *Bolboplectus maritimus paludosus*, as often is the case in Suisun and South Bay marshes (HT Harvey and Associates 2007).

Salt marsh harvest mice are typically associated with tall, dense, continuous stands of *Sarcocornia pacifica* in saline soil. These stands remain mostly unsubmerged during periods of flooding, or are mixed with other unsubmerged sources of cover, such as taller vegetation (*Grindelia* or debris; Fisler 1965, Rice 1974, Johnson and Shellhammer 1988, Shellhammer *et al.* 1988, Bias and Morrison 1993, Hulst 2000). Within *Sarcocornia* marshes the taller, denser stands tend to support the most salt marsh harvest mice, although they may also be abundant in tidal marshes with relatively short *Sarcocornia* canopies. A *Sarcocornia* canopy height of approximately 15 centimeters (6 inches) appears to be the lowest commonly used by salt marsh harvest mice (Shellhammer *et al.* 1982, Fisler 1965). The relationship between *Sarcocornia* height and salt marsh harvest mice abundance may depend on degree of canopy submergence rather than height alone.

The ecological basis for the salt marsh harvest mouse affinity for *Sarcocornia* habitat is probably due to several factors, including year-round cover from predators, use of *Sarcocornia* as a food source, competition with other small mammals, and escape from flooding (Fisler 1965; Shellhammer *et al.* 1982, 1988; Geissel *et al.* 1988, Bias and Morrison 1993). These factors are not uniquely associated with *Sarcocornia*, however, and there is significant variation in vegetation types used by salt marsh harvest mice. Saline to subsaline marsh that lacks *Sarcocornia*, or supports it as a minor component, may be used as habitat by significant numbers of salt marsh harvest mice; this is especially the case in many parts of the Suisun Bay (Botti *et al.* 1986, California Department of Water Resources *in litt*. 2007). Though it was originally thought that *Spartina foliosa* (Pacific cordgrass), some *Schoenoplectus spp.* (bulrush, tule), and *Typha* (cattail) vegetation provided only marginal and incidental habitat for the salt marsh harvest mouse (Fisler 1965, Shellhammer *et al.* 1982), recent studies (2000-2005) in the Grizzly Island and Hill Slough areas within the Suisun Marsh indicate a much greater use of various *Schoenoplectus* species, especially *Schoenoplectus americanus*, than found in other portions of the range (California Department of Water Resources *in litt*. 2007). In fact, Sustaita *et al*. (in press) found that *Schoenoplectus americanus* may be important in providing unsubmerged habitat. Surveys in tidal and diked wetlands have confirmed that salt marsh harvest mice can be found using pure stands over 80 meters (87 yds) deep. Traps set at over one meter (1.09 yds) high continuously captured salt marsh harvest mice at the same rate as mixed *Sarcocornia* wetland vegetation.

Also, Shellhammer *et al.* (1982) concluded that mixed stands of native tidal marsh vegetation dominated by *Sarcocornia* have higher habitat value than pure stands. Tidal marsh plants suggested as beneficial in mixed stands include *Frankenia salina* (alkali-heath), *Atriplex prostrata* (spearscale), and possibly small amounts of *Distichlis spicata* (saltgrass). On the other hand, the Mare Island *Sarcocornia* marshes are very low in vascular plant species diversity other than *Sarcocornia* and *Cuscuta salina* (parasitic dodder), but support exceptionally tall, dense *Sarcocornia* vegetation and an abundance of salt marsh harvest mice (Bias and Morrison 1993). Although salt marsh harvest mice have a high affinity for the annual tidal marsh forb *Atriplex prostrata*, due to the inherent winter dieback of this species it has no significant winter habitat value (Rice 1974, Botti *et al.* 1986).

Salt marsh harvest mice commonly occur in the upper portions of tidal marshes where terrestrial grasses are absent or remote, while western harvest mice tend to be dependent on proximity to terrestrial grass vegetation (Fisler 1965). However, salt marsh harvest mice frequently utilize terrestrial grassland habitats adjacent to tidal marsh and grass-*Sarcocornia* ecotones (Zetterquist 1976, Shellhammer *et al.* 1982, Johnson and Shellhammer 1988, Shellhammer *et al.* 1988), and this use is highest in the late spring and early summer. Salt marsh harvest mice in eastern San Pablo Bay and Suisun Marsh (northern subspecies) appear to be widespread in terrestrial grasslands and grassland-brackish marsh ecotones. The South Bay has relatively little grassland for mice to occupy, aside from the edges of the Alameda Flood Control Channel north of Coyote Hills (Shellhammer *in litt.* 2010*a*). Persistent low numbers of salt marsh harvest mice were found in predominantly grassland vegetation at Cullinan Ranch, which is adjacent to Mare Island Marsh, one of the most densely populated habitats of the species (Wertz-Koerner 1997, Hulst 2000). Studies conducted jointly by CDFW and CDWR have shown that salt marsh harvest mice move at least 100 meters (109 yds) from tidal wetland edges (Sustaita *et. al,* in press). Johnson and Shellhammer (1988) speculated that dispersal to grasslands may be driven by competition from California meadow voles, but this has not been consistently shown (Bias and Morrison 1993, Hulst 2000). The use of grasslands by salt marsh harvest mice in the spring has been interpreted as an opportunistic exploitation of a seasonally available resource, rather than use of an essential habitat (Fisler 1965, Johnson and Shellhammer 1988).

The extent to which salt marsh harvest mice used, or would use, native grasslands has not been investigated (Baye *et al.* 2000, Holstein 2000). Native grasses occur infrequently, but in local abundance, along the edges of tidal and brackish marshes in San Pablo Bay and the Suisun Marsh area. Cover is a limiting factor for the northern subspecies (Fisler 1965), and native *Leymus triticoides* (wildrye) stands, which provide tall dense cover at all times of the year (P. Baye pers. observ.), may form a better marginal grassland habitat than annual European grasses.

Lepidium latifolium (perennial pepperweed) readily invades brackish middle marsh plains that support significant proportions of *Sarcocornia* vegetation and associated native tidal marsh plants. It can overtop and shade a *Sarcocornia* understory, and displace all other tidal brackish marsh vegetation (P. Baye pers. observ. 1990-2000). *Lepidium latifolium* can form dense, often monotypic stands in high tidal marsh zones and terrestrial ecotones. It is not known whether or how salt marsh harvest mice use perennial *L. latifolium.* Despite the great and increasing extent of *L. latifolium* in brackish tidal marshes historically occupied by salt marsh harvest mice, there have been no quantitative investigations of this relationship.

Studies have documented ecologically significant numbers of salt marsh harvest mice in what have been historically termed marginal, atypical, and suboptimal habitats (Botti *et al*. 1986, Geissel *et al* 1988, Wertz-Koerner 1997, Hulst 2000). In fact, Sustaita *et al*. (in press) found salt marsh harvest mice equally supported by *Sarcocornia* and mixed-halophyte microhabitats. For that reason, it is important to avoid sampling bias caused by locating survey lines only in stands of vegetation determined to be optimum habitat or those thought most likely to produce trap success. This practice ensures failure to identify atypical or suboptimal stands of vegetation that support ecologically significant populations of salt marsh harvest mice (Baye 2000, Baye *et al.* 2000). Very few studies have been conducted on the marsh plain in broad tidal marshes. This makes it difficult to comparatively assess population densities, and thereby the importance, of these tidal marshes. The few examples that exist (Calaveras Point, Highway 37 marshes) yield significantly high numbers of captures (Duke pers. comm. 2005). Though salt marsh harvest mice are found in both saline marshes dominated by *Sarcocornia* and in brackish marshes dominated by *Schoenoplectus* spp., the common factor is depth of marsh, density of vegetation, as well as size and continuity of cover. Immature *Schoenoplectus* spp. with little to no thatch does not support mice.

Flood and tidal refugia. Flooding, as a factor in habitat quality for salt marsh harvest mice, is closely related to vegetation and marsh structure. Flooding that submerges vegetation of the middle marsh plain may occur from very high tides near the summer and winter solstices, storm surges, and extreme river outflows into the estuary. Fisler (1965) concluded that the January and December tides were critical high tides that could endanger whole populations of salt marsh harvest mice. Prolonged flooding exposes salt marsh harvest mice to predators, and increases the risk of mortality due to exposure or drowning. Although salt marsh harvest mice float and swim well (Fisler 1965), and cross open water without being forced by flooding (Geissel *et al.* 1988, Bias and Morrison 1999), they do not swim as well as other small tidal marsh mammals, nor do they dive (Johnston 1957). Mice move locally from flooded tidal marsh to emergent high ground or vegetation. Salt marsh harvest mice likely remain in their home ranges during high tide immersion of marsh vegetation, and swim or cling to taller emergent portions of vegetation or floating debris (Johnston 1957, Hadaway and Newman 1971).

The relative importance of landward marsh edges as flood refugia for salt marsh harvest mice probably differs between narrow and deep tidal marshes. Flood refugia at landward marsh edges appear more important in narrow marshes where mice are concentrated during high tide and slightly less important in deeper marshes, given their intramarsh refugia. Even in deep marsh plains, the only available refugia are *Grindelia* vegetation, natural *berms* and levees, and trapped floating woody debris along marsh edges at creek banks (Johnston 1957; Hadaway and Newman 1971; Bias and Morrison 1993, 1999).

Salinity. Salinity may influence salt marsh harvest mouse habitat independent of its correlation with *Sarcocornia*. Zetterquist (1978) found that salt marsh harvest mice were most abundant in portions of diked tidal marshes where salinity was extremely high. A high physiological tolerance for salt in food and water (Fisler 1965, Coulombe 1970) may confer a competitive advantage to salt marsh harvest mouse in harshly saline marsh habitats, particularly where competition with the more aggressive, but less salt-tolerant, California vole occurs (Geissel *et al.* 1988; Blaustein 1980, 1981). This suggests that otherwise suboptimal hypersaline tidal marsh vegetation and salt pans may provide important habitat exploited intermittently by salt marsh harvest mice to cope with interspecific competition. However, this conclusion is uncertain. The wide high tidal marsh plain at Mare Island Marsh consists of nearly pure stands of extremely tall, dense *Sarcocornia* with few local pans that are brackish for most of the year (P. Baye pers. observ.), yet this marsh supports consistently high populations of salt marsh harvest mice that coexist with California voles (Kovach and Pomeroy 1989; Bias and Morrison 1993, 1999). Similarly, many tall, dense stands of *Sarcocornia* non-tidal seasonal wetlands grow in non-saline to subsaline soils (Kovach and Pomeroy 1989, P. Baye pers. observ.).

6) Critical Habitat

No critical habitat has been designated for the salt marsh harvest mouse.

7) Reasons for Decline and Threats to Survival

Most species covered in this recovery plan are threatened by similar factors because they occupy the same tidal marsh ecosystem. These general threats, faced by all covered species, are discussed in greater detail in section I. Specific threats to salt marsh harvest mouse are described below.

Factor A

The most fundamental reason for the decline of the salt marsh harvest mouse is loss of habitat through filling (*i.e.,* destruction), subsidence, and vegetation change (U.S. Fish and Wildlife Service 1984, Bias and Morrison 1993, Shellhammer 2000). The high and middle, or *Sarcocornia*, zones, of tidal marshes have been the most affected. Shellhammer (unpubl. research) has found that the high marsh zone, once kilometers deep (from shore to bay) throughout the South San Francisco Bay, is now an interrupted band approximately 2 meters (2.19 yds) deep. The same study found that the adjacent upland edge (*i.e.*, the ecotone between marsh and upland) exists today in only 2.5 percent of the South Bay's edge. Habitat losses include areas associated primarily with historical diking and reclamation of tidal marshes, urban development of diked tidal marshes, and adverse water management in diked brackish marshes of Suisun Marsh (Suisun Ecological Workgroup 2001). Other large net losses of nontidal occupied habitat have occurred since the publication of the first recovery plan including: 1) grading and development of saline seasonal marsh adjacent to Mayhews Landing along old Jarvis Avenue in Newark; 2) re-emergent Sarcocornia in subsided, filled diked baylands at the residential Redwood Shores development; 3) replacement of *Sarcocornia* with annual seasonal wetland forbs at the Gentry-Pierce site in Fairfield; and 4) conversion of *Sarcocornia* to seasonal waterfowl habitat through improvements in Suisun Marsh duck clubs.

Significant habitat degradation has continued in some portions of the salt marsh harvest mouse range. Ongoing high-magnitude wastewater discharges from sewage treatment operations and channelized urban runoff into tidal sloughs from San Jose to Milpitas (Guadalupe, Alviso, Artesian/Mallard Sloughs, Coyote Creek) have concentrated impacts on fringing tidal marshes. The perennial depression of channel water salinity during high freshwater flows has caused conversion of middle tidal marsh plains from tidal marsh to brackish marsh with reduced marsh salinity and resulted in domination by pure stand of species (*Bolboschoenus maritimus* [alkali bulrush], *Lepidium latifolium*) that have very low or negative habitat value to the salt marsh harvest mouse (H.T. Harvey and Associates 1997). During years of high rainfall, cumulative brackish marsh conversion problems are most severe, although high background freshwater outflows may mask the impact of wastewater discharges on brackish marsh conversion. As human population size and water use increases in the Santa Clara Valley, this problem may worsen.

Extirpated populations may fail to re-establish despite regeneration of suitable habitat conditions, possibly because of constraints on dispersal from source populations. Where few widely spaced source populations are separated by significant geographic or ecological barriers, there is little chance for recolonization by vagrant founders. Many narrow strip-like marshes are the only potential corridors between existing larger marshes. Narrow marshes (*i.e.*, those with shallow *Sarcocornia* marsh plains and very narrow high marsh zones) are highly unlikely to be functional corridors. In addition, narrow marshes are at great risk of disappearing completely with sea level rise, making the areas they formerly occupied barriers instead of corridors (Shellhammer and Duke *in litt*. 2010). Current preliminary evidence suggests that 14 percent of the edge of the South Bay with narrow marshes (less than 50 meters [55 yds] wide) has no or poor quality upper marsh habitat. These areas are of very limited value for mouse movement, effectively functioning as filters to movement at best. The very narrow marshes (less than 25 meters [27 yds] wide) have no escape cover whatsoever and may well be barriers to movement (Shellhammer *in litt*. 2010*a*).

The non-native invasive species *Carpobrotus edulis* (iceplant, Hottentot fig) has expanded within Napa marshes to the point of covering entire small islands. The salt marsh harvest mouse is not known to use *C. edulis* and, more importantly, the invasion crowds out appropriate mouse habitat (Shellhammer *in litt*. 2010*b*).

Flooding of salt marsh harvest mouse habitat in diked baylands is influenced by (1) the degree of subsidence below sea level, (2) the efficiency of tidegate drains and drainage ditches operating at low tide, and (3) the magnitude of flooding. Average rainfall seldom causes complete or widespread submergence of *Sarcocornia* canopies. Extremely high rainfall, managed intake of bay water, overtopping, and levee breaching all can completely submerge *Sarcocornia* canopies, and cause mass mortality and dispersal of salt marsh harvest mice. The greater the degree of subsidence, the greater the potential for catastrophic flooding of long duration. The 1983 flooding of the New Chicago Marsh in Alviso is an example of such potential flooding in a deeply subsided marsh. Coyote Creek overtopped, flooding all of Alviso, the New Chicago Marsh, and all the adjoining salt ponds. The marsh remained flooded for weeks, and levee tops surrounding the marsh (potential escape cover) were also underwater. Routine flooding and draining associated with conventional methods of waterfowl marsh management in Suisun Marsh also causes widespread, prolonged submergence of salt marsh harvest mouse habitat. Overtopping of levees by storm tides is a common phenomenon in San Francisco Bay during extreme high tides that will probably increase with rising sea level, and may be exacerbated by increased storm intensity predicted by global climate change, as discussed in section I. Therefore, even diked tidal marshes actively managed for long-term recovery of the salt marsh harvest mouse (Shellhammer 1989) may be at risk of catastrophic flooding.

One response of salt marsh harvest mice to flooding is movement to high ground, such as old levees (Dixon 1908, Fisler 1965). During extreme flooding of the marsh, there is increased dispersal of salt marsh harvest mice from Mare Island strip marshes across Highway 37, which can result in mortality from road kill (Wertz-Koerner 1997). Less extreme tides or floods that do not fully submerge marsh vegetation may not induce detectible dispersal (Hulst 2000). Movements across Hwy 37 are the exception. The more common threat to salt marsh harvest mice is that they are forced to the top of *Sarcocornia* as the highest high tides of the year rise and the animals are taken by predators. In marshes with a small total area of *Sarcocornia* it is surmised (Shellhammer pers. comm. 2005) that the death rate to predation and drowning exceeds the birth and immigration rate, and that these narrow marshes usually lose any salt marsh harvest mice.

Factor C

Predation—Avian species are important predators of tidal marsh mammals, likely including salt marsh harvest mice. Populations of many native avian species (common ravens, American crows, California gulls) are artificially increased above historical population levels due to the increased availability of food resources and nesting opportunities associated with human activities (Albertson *in litt.* 2009*a)*. Other species, such as the northern harrier, have been pushed from much of their nearby upland habitat by urban development, and their foraging activities are locally concentrated in the wetland areas. Common ravens and red-tailed hawks are known to nest in electrical towers, boardwalks, and buildings and forage in various nearby marshes of South San Francisco Bay that otherwise have limited hunting perches (Albertson *in litt.* 2009*a*). It is not known if peregrine falcons also predate the salt marsh harvest mouse but it is reasonable to believe they would, and the population of this species has increased locally in recent years as a result of peregrine falcon recovery actions.

Landfills and urban areas provide food resources that would otherwise not be available, while buildings, towers, and other human-made structures provide nesting and roosting opportunities. There are three landfills directly adjacent to the Don Edwards San Francisco Bay National Wildlife Refuge (Refuge): Palo Alto, Newby Island, and Tri City. Known or potential predators of salt marsh harvest mice, such as California gulls and common ravens are attracted by these facilities. As mentioned in the section above on California clapper rails, California gull populations in the South Bay have increased immensely since 1982 (Ackerman *et al.* 2009), due to the availability of food resources, largely from landfills, coupled with the availability of nesting habitat on dry salt ponds and levees and it is estimated that they spend at least 20 percent of their foraging time at landfills in the South Bay. Little is known about the effect of gulls on salt marsh harvest mice, however, gulls have been directly observed predating small mammals in the marsh at high tide and it is reasonable to suspect, given their elevated numbers, that gull species may present a threat to the salt marsh harvest mouse.

Also, as mentioned in the section above on California clapper rails, landfills are known to support and trails and levees are known to provide easy access to feral and otherwise free-roaming cats into the marsh (Albertson *in litt.* 2006; American Bird Conservancy 2006). As with gulls, little is known of the effect of cats on salt marsh harvest mice, however, it is reasonable to suspect that cats may present a threat to the species.

Factor E

Contaminants— The degree to which chemical contaminants, such as heavy metals, organochlorines, and PCBs (**Appendix E**) affect the quality of salt marsh harvest mouse habitat is not known. Initial studies in San Francisco Bay and San Pablo Bay that analyzed small mammal tissue samples for selected contaminants were inconclusive for salt marsh harvest mice (Clark *et al.* 1992). The presence of relatively high concentrations of contaminants (*e.g.*, mercury, lead, cadmium, selenium) at tidal marsh sites with some of the largest or most dense populations of salt marsh harvest mice, such as Mare Island, Castro Creek Marsh, and Calaveras Point, suggests that contaminants may not be an overriding factor in habitat quality or reproductive success of this species.

Salt marsh harvest mouse habitat is also at risk of contamination due to oil spills, particularly along major gas and oil pipelines alongside Highway 680.

B. Non-Focal Listed Species - *Chloropyron maritimum* ssp. *maritimum* (salt marsh bird's-beak)

Although *Chloropyron maritimum* ssp. *maritimum* occurs in the tidal marsh ecosystem, it is not a focal species of this recovery plan because the species range is larger than the geographic area covered by this plan. This recovery plan includes recovery strategies and actions for the Morro Bay population of *C. maritimum* ssp. *maritimum*. However, recovery criteria are not provided and the species should not be considered a focal species of this recovery plan. See the paragraph below for information on the recovery plan for this species.

1) Brief Summary

Chloropyron maritimum Benth. ssp. *maritimum* (salt marsh bird's-beak) of the south-central California coast was federally listed as endangered in 1978 (U.S. Fish and Wildlife Service 1978), and listed as endangered by the State of California in 1979 (California Department of Fish and Game 2005). Its northern range limit is Morro Bay, which is included in the geographic scope of this plan. *Chloropyron maritimum* ssp. *maritimum* has been assigned a recovery priority number of 6, according to the 2007 Recovery Datacall for the Carlsbad field office of the U.S. Fish and Wildlife Service, based on its high degree of threat, low potential for recovery, and status as a subspecies (U.S. Fish and Wildlife Service 1983). A final recovery plan was prepared in 1985 (U.S. Fish and Wildlife Service 1985*a*). An isolated, and presumed extirpated, population at Morro Bay, San Luis Obispo County, California, was considered *Chloropyron maritimum* ssp. *palustre* (Point Reyes bird's-beak), at the time of listing, and thus was not treated in the 1985 recovery plan. Living populations rediscovered at Morro Bay in 1986, prompted taxonomic reinterpretation of the Morro Bay population which was subsequently classified as *C. maritimum* ssp. *maritimum* (Chuang and Heckard 1986). Because this population occurs with the endangered *Suaeda californica* (California sea-blite) in Morro Bay, it is included in this recovery plan. While adequate data are not available to assess long-term decline of *C. maritimum* ssp. *maritimum* in Morro Bay, existing populations do face serious threats.

2) Description and Taxonomy

Description. *Chloropyron maritimum* ssp. *maritimum* is an annual hemiparasitic plant in the Orobanchaceae (broom-rape family; **Figure II-13**). The popular name "bird's-beak" refers to the curved, somewhat tubular flowers and bracts. The flowers of some *C. maritimum* taxa have showy pale pink pouches with darker purple lips on purplish-green plants. Other taxa have pale grayish-green foliage and less conspicuous white flowers with dark brownish-purple lips. The flowers of *C. maritimum* ssp. *maritimum* develop in loose to dense spikes 2 to 9 centimeters (0.8 to 3.5 inches) long. The hairiness of the foliage and stems is variable, and most plants have visible salt-encrusted glandular hairs. *Chloropyron maritimum* ssp. *maritimum* may occur as short, erect, scarcely branched plants, or as plants with a profusion of spreading or ascending branches. The seeds are borne in capsules that mature from mid-summer through fall.

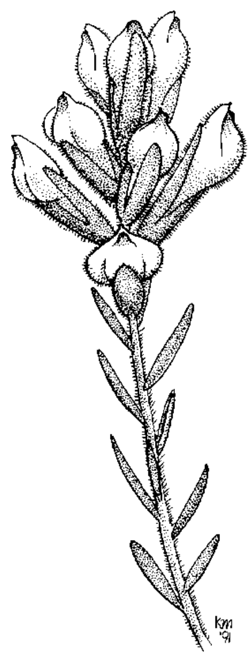


FIGURE II-13. *Chloropyron maritimum* ssp. *maritimum* (Kendal Morris/USFWS)

Taxonomy. At the time *Chloropyron maritimum* ssp. *maritimum* was listed (as *Cordylanthus maritimus* ssp. *maritimus*), the genus *Cordylanthus* was placed in the Scrophulariaceae (figwort family). However, based on molecular systematic studies using DNA sequences of three plastid genes, Olmstead *et al.* (2001) transferred the hemiparasitic group Castillejiinae, including *Cordylanthus,* to the Orobanchaceae. This systematic treatment will be followed in the upcoming revision of the Jepson Manual.

Additional molecular phylogenetic analysis, initiated as part of the above cited studies, indicates that *Chloropyron* is not a monophyletic genus (Tank and Olmstead 2008). In accordance with these findings Tank *et al*. (2009) recognize the genus *Chloropyron* and a previously published name *Chloropyron maritimum* (Nutt. ex Benth.) A. Heller subsp. *maritimum* for salt-marsh bird's-beak. This combination will also be recognized in the upcoming revision of the Jepson Manual. Though the taxon continues to be called *Cordylanthus maritimus* ssp. *maritimus* on the Federal List of Threatened and Endangered Wildlife and Plants (List) pursuant to the Endangered Species Act (Act) (16 U.S.C. 1531 et seq.), here we use the currently accepted name, *Chloropyron maritimum* ssp. *maritimum*.

The species is divided into northern and southern coastal subspecies, and an inland subspecies. *Chloropyron maritimum* ssp. *maritimum*, the southern California coastal subspecies, is distinguished from the northern ssp. *palustris*, mainly by geographic distribution in that it occurs from Morro Bay south through southern California. It is also distinguished by branching patterns, growth habit, narrower and more acute leaves, and variations in seed size and floral traits (Chuang and Heckard 1973, 1993). Though the population of *C. maritimum* ssp. *maritimum* at Morro Bay is addressed in this recovery plan for reasons stated above, all other populations of the subspecies are addressed in the *Salt Marsh Bird's-Beak Recovery Plan* (U.S. Fish and Wildlife Service 1985*a*). The Morro Bay plants were not considered *C. maritimum* ssp. *maritimum* when the 1985 Salt Marsh Bird's-Beak Recovery Plan was written.

The three intergrading subspecies have distinct ecological and geographical distributions. *Chloropyron maritimus* ssp. *canescens* (hoary salt marsh bird's-beak) is a widely distributed, but uncommon, plant of inland saline/alkaline wetlands of the Great Basin; *Chloropyron maritimum* ssp. *maritimum (*salt marsh bird's-beak), an endangered tidal marsh plant limited to few populations in southern California and Baja California, Mexico; and *Chloropyron maritimum* ssp. *palustre* (Point Reyes bird's-beak), a similar rare tidal marsh plant from San Francisco Bay to Oregon.

Although Chuang and Heckard (1973) concluded that the morphological differences are sufficient to warrant taxonomic distinction below the species rank, they noted that specimens morphologically intermediate between *Chloropyron maritimum* ssp. *canescens* and ssp. *maritimum* occur in saline inland soils of southern California near the coast. Chuang and Heckard (1973) further observed that specimens of putative ssp. *maritimum* at the northern end of its range (south of Morro Bay) resemble ssp. *palustris* (Chuang and Heckard 1973), and Chuang and Heckard (1986) later reclassified the Morro Bay population from ssp. *palustris* to ssp. *maritimum*, realigning the subspecies range limits. Chuang and Heckard (1973) cautioned that ssp. *maritimum* is a variable group, and is itself intermediate between ssp. *canescens* and ssp. *palustris*.

3) Population Trends and Distribution

Historical Distribution. Historically, *C. maritimum* ssp. *maritimum* was widespread near the upper edges of coastal tidal marshes from Morro Bay in San Luis Obispo County to San Diego County and northern Baja California. Presently, it occurs only in scattered sites at fewer than 10 remnant tidal marshes. Half of the known occurrences at time of listing are now considered extirpated.

Current Distribution. The Morro Bay population of *C. maritimum* ssp. *maritimum* was not detected between 1912 and at least 1970 (Hoover 1970, Chuang and Heckard 1973), but has been reported since the 1980s (L. Heckard pers. comm. 1986). The Morro Bay population consists mostly of small subpopulations (hundreds to thousands of plants) in very localized fluctuating colonies in two major local populations (P. Baye pers. obs. 1998-1999; **Figure II-14**). One is found between Sweet Springs Nature Preserve and Shark's Inlet, the second is southeast of the terminal widening of the sandspit (Walgren *in litt.* 2006). In the 1990s there was a population southwest of Cuesta Inlet near a public access point where the habitat is subject to trampling. This population has since disappeared; the exact cause of the disappearance is unknown (Walgren *in litt.* 2006). In 2004, the population near Sweet Springs Nature Preserve consisted of 2 subpopulations, with more found in some years. The sandspit supports no subpopulations in some years. It is unclear if the population is in decline or simply has variable success from year to year (Walgren *in litt.* 2006). In 2004, the *C. maritimum* ssp. *maritimum* population at Morro Bay totaled roughly 1,300 plants, about 1,000 of which were in the sandspit locality (Walgren *in litt.* 2006). Populations of *C. maritimus* typically fluctuate by orders of magnitude among years (Parsons and Zedler 1997). Population fluctuations in *C. maritimum* ssp. *palustre* may relate to rainfall and vegetation structure, but the relationship is neither simple nor well understood. High rainfall appears to correspond with large population size in ssp. *maritimum* in more arid southern California (Parsons and Zedler 1997, B. Grewell pers. comm. 2000).

4) Life History/Ecology

Reproduction. Factors considered important to the reproductive status of *C. maritimum* ssp. *maritimum* include the numbers of individuals, the isolation of individual plants, pollination, herbivory, seed production, seed dispersal, seed dormancy, seed germination, and seedling habitat.

Chloropyron species were once thought to be self-incompatible (Chuang and Heckard 1973); however, later work by Parsons and Zedler (1997) indicates that there is some degree of self-compatibility and that both cross- and self-pollination may increase with flower manipulation by insect visitors. Whether self-pollination alters the viability of the seeds needs further investigation.

Specific pollinators of *C. maritimum* ssp. *maritimum* at Morro Bay are unknown (Walgren *in litt.* 2006). Bees are thought to be the principal pollinators of ssp. *maritimum* at other locations (Parsons and Zedler 1997). The flower structure suggests that only bees would be effective pollinators; bumblebees (*Bombus* spp.) may be the most efficient and effective (Proctor *et al.* 1996, Faegri and van der Pijl 1979). Small native halictine bees have been observed visiting ssp. *maritimum* flowers at Ormond Beach, Ventura County. At Point Mugu, Ventura County, four species of bees and two species of flies appear to pollinate the flowers (U.S. Fish and Wildlife Service 1985*a*). Upland habitats near tidal marsh occupied by *C. maritimum* are likely needed to support pollinating insects that do not nest in tidal marsh, such as most bees (Callaway and Zedler 2004).

Figure II-14. Distribution of Chloropyron maritimum ssp. maritimum

map revised: 11/2013

The flowering period for *C. maritimum* ssp. *maritimum* is May to October. Seed output averages between 15 to 20 seeds per capsule (Chuang and Heckard 1973). Many factors may reduce seed set. Pre-dispersal seed predation in *C. maritimum* ssp. *maritimum* can be caused by *lepidopteran* larvae and locusts (U.S. Fish and Wildlife Service 1985*a*). The salt marsh snout moth, *Liphographus fenestrella* (Parsons and Zedler 1997) and leaf roller moth larvae (*Platynota stultana*; U.S. Fish and Wildlife Service 1985*a*) are known seed predators. Nothing is known of post-dispersal seed predation in *C. maritimum*.

Unlike perennial plants, the annual population of *C.m. maritimum* depends entirely on yearly seed germination and seedling establishment. Physical factors such as currents, tides, wave action, and sheet erosion are among the ways seeds are moved around within and between marshes. The seeds of *C. maritimum* ssp. *maritimum* have a honeycombed surface that traps air bubbles and makes them highly buoyant. They have been shown to float for up to 50 days and floatation may be the primary local dispersal mechanism for *C. maritimum* ssp. *maritimum* (Newman 1981). Animals, especially birds, may carry the seeds on their feet, or in their fur, feathers, or digestive systems (U.S. Fish and Wildlife Service 1985*a*).

Chloropyron maritimum ssp. *maritimum* persists through unfavorable years as a dormant seed bank (Parsons and Zedler 1997) because high densities and abundance of standing plants may follow years of extremely low seed production. The longevity of the marsh soil seed bank of this species is not known, but artificially stored seed of ssp. *maritimum* have remained viable for over 11 years (Parsons and Zedler 1997). Dry storage of seeds for two years enhanced germination by 230 percent over germination of fresh seeds (U.S. Fish and Wildlife Service 1985*a*). Germination also increased with *scarification* or *vernalization* (Newman 1981).

Availability and abundance of seedling habitat may be an important factor limiting reproduction in ssp. *maritimum*. The range of salinity associated with growth of ssp. *maritimum* is 5 to 33 parts per thousand, but pulses of freshwater from flooding or rainfall are probably necessary for germination (Parsons and Zedler 1997). Salinity at the time of germination usually cannot exceed 12 parts per thousand (Newman 1981).

5) Habitat Characteristics/Ecosystem

Chloropyron maritimum ssp. *maritimum* occurs in variable habitats throughout its range. It appears to favor the middle to high marsh zone, but may range toward upper and lower extremes in some cases. In Morro Bay it occupies a narrow margin of estuary edge at the high tide line (Walgren *in litt.* 2006), with one population found in brackish to tidal marsh and one in relatively recently formed tidal marsh at the north end of the sandspit (P. Baye pers. obs. 1998-1999). Populations generally occur in areas with low salinity in the spring and low vegetative cover (Newman 1981, Dunn 1981). *Chloropyron maritimum* ssp. *maritimum* is found on sandy marsh substrates with relatively sparse, short tidal marsh vegetation, and is usually absent or declining in dense, tall tidal marsh vegetation (Newman 1981, Kelly and Fletcher 1984, Parsons and Zedler 1997). Dense vegetation may inhibit growth due to shading or reduced water availability. *Chloropyron maritimum* ssp. *maritimum* may increase in abundance in response to disturbances that reduce vegetation cover (Vanderweir and Newman 1984, Parsons and Zedler 1997). However, it is vulnerable to crushing and trampling, as it is easily broken off and tends to occur at higher, less muddy marsh elevations where foot traffic is concentrated (Zedler 1982, Zedler 1984, Walgren *in litt.* 2006).

Plant associations. In Morro Bay, *Chloropyron* is found in typical estuary edge vegetation (Walgren *in litt.* 2006). It is associated with *Sarcocornia pacifica* (pickleweed), *Distichlis spicata* (salt grass), *Frankenia salina* (alkali-heath), *Limonium californicum* (sea-lavender) and occasionally *Cuscuta salina* (saltmarsh dodder; Walgren *in litt.* 2006) and *Lasthenia glabrata* ssp. *coulteri* (Coulter goldfields) (Baye *in litt*. 2010).

Members of the genus *Chloropyron* are hemiparasitic. Their roots form haustoria to obtain water and nutrients through the roots of other host plants. It is not known to what degree individuals of this subspecies are dependent on their hosts. *Chloropyron maritimum* ssp. *maritimum* can grow without host plants (Chuang and Heckard 1971), but hemiparasitism may permit them to flourish in the hot, dry, higher soil-salinity conditions of summer (Vanderwier and Newman 1984). Under experimental conditions, *Chloropyron* exhibits variation in biomass depending on host species (Fink and Zedler 1990). The host plants of *C. maritimum* ssp. *maritimum* are unknown (Walgren *in litt.* 2006).

Dense vegetation may inhibit growth of *C. maritimum* ssp. *maritimum* due to shading or reduced water availability. For a period of time following germination, seedlings live independently. Experimental work on *C. maritimum* ssp. *maritimum* indicates that soil nitrogen limits reproductive capacity of individual plants (Parsons and Zedler 1997). The largest populations of ssp. *palustris*, however, are on sandy marsh substrates (Russell 1973) with sparse and low vegetation cover, suggesting that unproductive environments, rather than productive nitrogen-rich environments, favor abundance in the field.

6) Critical Habitat

Critical habitat has not been designated for *Chloropyron maritimum* ssp. *maritimum*.

7) Reasons for Decline and Threats to Survival

Most species covered in this recovery plan are threatened by similar factors because they occupy the same tidal marsh ecosystem. These general threats, faced by all covered species, are discussed in greater detail in the Introduction section of this recovery plan (section I.D.). Specific threats to *C. maritimum* ssp. *maritimum* are described below.

Factor A
All the *C. maritimum* ssp. *maritimum* known localities, as well as potential habitat around Morro Bay, are at risk from impacts of non-native plants, including *Carpobrotus edulis* (iceplant) and trees and shrubs such as *Eucalyptus globulus* (eucalyptus), *Myoporum laetum* (myoporum), and *Cupressus macrocarpa* (Monterey cypress). Non-native plants may crowd out the subspecies or degrade its habitat through shading, litter fall, or freshwater drawdown.

The largest subpopulation of *Chloropyron maritimum* ssp. *maritimum* at Morro Bay is on the bay side of the barrier sand spit, close to a large expanse of mobile sand and at risk of being buried by a high wind event (P. Baye pers. observ. 1997-2000). While dune movement is a natural process, this area has been affected by past deposits of dredged sand. The low numbers and small area currently occupied by the subspecies at Morro Bay increase the risk of a substantial portion of the local population being destroyed by a natural process involving an unnatural resource (dredged sand).

Two of the localities of the subspecies at Morro Bay occur in marshes adjacent to residential locations in the Los Osos area. These habitats are narrow, sandy high tidal marsh fringes, potentially subject to disturbance impacts such as trampling by humans, horseback riding, and boat haul-outs. Currently, dozens of small boats are routinely left hauled out on the high tidal marsh zone in several areas around the bay. Although recent disturbance levels have been low in many areas, continued increase in residential population and recreational pressures may adversely affect this subspecies. Demand for flood control or shoreline stabilization near residential areas—particularly in light of rising sea level and higher extremes of storm and wave energy—could exert pressure to harden shorelines or build berms in habitat areas.

While there has been some loss of potential habitat for *Chloropyron maritimum* ssp. *maritimum* in areas of shoreline hardening, such as around developed portions of the City of Morro Bay, the great majority of this occurred prior to the recognition of the Morro Bay plants as ssp. *maritimum*. Since at that time, the plants were thought to be the more common *C. maritimus* ssp. *palustris*, impacts to the plants were not assessed with the same degree of scrutiny as impacts to the more rare subspecies would have been; therefore, the degree of impact is not known. Ongoing development for housing and other purposes in upland habitats near tidal marsh is likely to reduce native pollinators of the subspecies.

Factor E

Nearly all the threats faced by *Chloropyron maritimum* ssp. *maritimum* at Morro Bay are heightened by the low numbers and small area of distribution of the subspecies there. Small populations have increased vulnerability to extinction due to catastrophic events like severe droughts, storms, fires, pollution spills, non-native species invasion, or epidemics (Schonewald-Cox *et al.* 1983). Another factor is natural variability in birth and death rates: a chance cluster of years of high death rates or low birth rates is likely to result in the extirpation of small populations. At low population sizes, genetic and evolutionary effects become important, including loss of genetic diversity due to founder effects, genetic drift, inbreeding, and inbreeding depression. In December, 2003, Morro Bay experienced an earthquake (centered near Paso Robles) that uplifted portions of potential habitat. The uplift was patchy but in some areas amounted to a foot or more, enough to make formerly suitable habitat uninhabitable by the subspecies.

III. RECOVERY STRATEGIES

A. RECOVERY GOALS, OBJECTIVES, AND CRITERIA

1. Recovery Goals and Objectives

The ultimate goal of this recovery plan is to recover all listed species so they can be delisted (removed from listing under the Endangered Species Act). The interim goal is to recover all endangered species to the point that they can be downlisted from endangered to threatened status. The goal for *Chloropyron maritimum* ssp. *maritimum* (salt marsh bird's-beak) is to support recovery strategies detailed in the Salt Marsh Bird's-beak Recovery Plan (U.S. Fish and Wildlife Service 1985*a*). For species covered by this recovery plan that are not federally listed as threatened or endangered, the goal is to conserve them so as to avoid the need for protection provided by listing.

To achieve these goals, the following objectives have been developed:

1. Secure self-sustaining wild populations of each covered species throughout their full ecological, geographical, and genetic range.

2. Ameliorate or eliminate, to the extent possible, the threats that caused the species to be listed or of concern and any future threats.

3. Restore and conserve a healthy ecosystem function supportive of tidal marsh species.

If these objectives are met for the covered species, the recovery and conservation goals will be reached.

2. Recovery Units

For most species covered in this recovery plan, recovery units have been designated. A recovery unit is a special unit of a listed species' range that is geographically or otherwise identifiable and is important to the recovery of the listed species. Recovery units are individually important to conservation of unique biotic and abiotic factors (such as genetic robustness, demographic robustness, important life history stages, or other features) necessary for the long-term sustainability of species within the recovery unit. Although recovery units are not designated for non-listed species, the establishment of recovery units for the listed species will assist in meeting the conservation objectives for the non-listed species in this recovery plan as well.

Each recovery unit designated for a species must be recovered before a species can be delisted (**Table III-1** lists the recovery units designated for each species). Recovery of each listed species discussed in this recovery plan depends upon satisfying the recovery criteria within each recovery unit for the given species. Recovery units do not represent distinct population segments nor do they reflect designated critical habitat for any of the species covered in this recovery plan. The respective status of each species in each recovery unit varies, as does their potential to contribute to each species' recovery.

Lands bayward of the recovery unit boundary are considered within the recovery unit. The recovery unit boundary in the San Francisco Estuary has been delineated to follow the extent of sea levels predicted by year 2050, under the medium to medium-high emissions scenario described in the 2009 Pacific Institute Study (Heberger *et al.* 2009). Therefore, these lands incorporate not only historic tidal marsh, but also adjacent lands which could play important roles in recovery of the tidal marsh ecosystem, in light of anticipated sea level rise. We recognize that not all lands within the recovery unit boundary will be necessary for recovery of the covered species and that participation by private landowners in recovery plan implementation is entirely voluntary.

Table III-1 Recovery Units Included in this Recovery Plan and Listed Species Known to Occupy each Recovery Unit

Listed Species	**Recovery Unit**				
	Suisun Bay Area	San Pablo Bay	Central/ South San Francisco Bay	Central Coast	Morro Bay
Cirsium hydrophilum var. *hydrophilum* (Suisun thistle)	X				
Chloropyron molle ssp. *molle* (soft bird's-beak)	X	X			
Suaeda californica (California seablite)			X		X
California clapper rail (*Rallus longirostris obsoletus*)	X	X	X	X	
Salt marsh harvest mouse (*Reithrodontomys raviventris*)	X	X	X		

Maintaining representation of each species throughout their respective ranges is necessary for the long-term recovery and conservation of the listed species covered in this recovery plan. Protecting populations distributed throughout a species range conserves the natural range of morphological, physiological, genetic and environmental variation of the species. This helps ameliorate the vulnerability of a species to environmental fluctuations and catastrophes as well as protects evolutionary potential. To ensure that each taxon in this recovery plan can persist despite weather variations, climate change, or catastrophic events, the suite of populations in recovery areas should occur throughout the full range of environmental conditions in which the taxon occurred historically. The range of genetic variation must be represented to allow for evolution and response to environmental change. Genetic diversity has not been investigated for most taxa covered in this recovery plan; therefore, well-distributed populations across the species' range and across ecological conditions are recommended as a surrogate for preserving genetic diversity.

The recovery units established in this recovery plan were based upon the natural division of the plan area into discrete sub-areas, which also correspond to ecologically distinct zones or areas somewhat isolated from each other biologically. Many of the species share the same recovery units. **Figure III-1** gives an overview of tidal marsh ecosystem recovery units. **Figures III-2** through **III-6** depict the five individual recovery units, with map segments and criteria-based regional planning units (marsh complexes) identified.

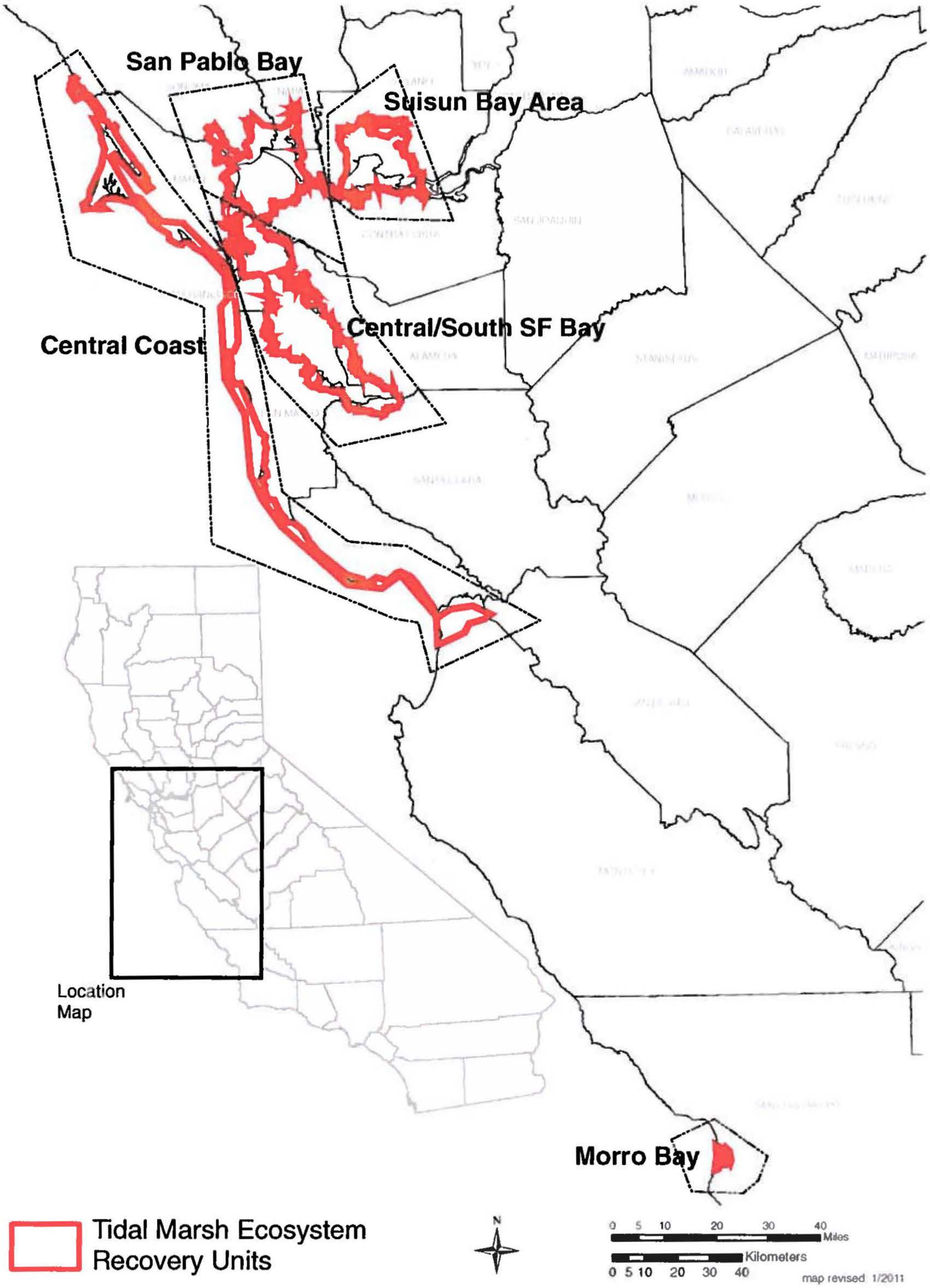


Figure III-1. Overview of tidal marsh ecosystem recovery units.

Each recovery unit described below is necessary because each (1) protects one or more populations of the covered species found in it, (2) contributes to protection of populations throughout the geographic ranges of the covered species found in it, and (3) protects geographically distinct populations and thereby the natural range of morphological, physiological, environmental and/or genetic variation.

SUISUN BAY AREA RECOVERY UNIT

The Suisun Bay Area Recovery Unit (**Figure III-2**) includes suitable or restorable tideland habitats in the Suisun Bay area from Carquinez Strait to the edge of the Delta (legal Delta boundary), representing the eastern extent of the range of the covered species. It is separated from the San Pablo Bay recovery unit by gaps in habitat in the Carquinez Strait and intervening hills. Limited populations of *Cirsium hydrophilum* ssp. *hydrophilum* and *Chloropyron molle ssp. molle* and moderate numbers of salt marsh harvest mouse exist within the Suisun Bay Area Recovery Unit. Populations of California clapper rail in this recovery unit are sparser and more tenuous than in other recovery units, but are expected to strengthen with habitat restoration. Impacts of rising sea level are expected to result in increased salinity and will benefit clapper rails in Suisun, however, loss of high marsh refugia will outweigh the benefits of increased low marsh foraging habitat. In addition to being necessary for the reasons described above, this unit is necessary because it provides a suitable pathway for the species' habitat to shift up the estuary as anticipated climate change and sea level rise produce increasing salinities toward the east.

SAN PABLO BAY RECOVERY UNIT

The San Pablo Bay recovery unit (**Figure III-3**) encompasses San Pablo Bay populations and is separated from adjacent recovery units by gaps in populations and habitat for most covered species. The unit includes tideland habitats from Point San Pablo on the Contra Costa coast and Point San Pedro, Marin County, to the Carquinez Strait at the Carquinez (I-80) Bridge. Population dynamics of covered species in this unit are likely decoupled from adjacent units because of low dispersal relative to local recruitment. Limited populations of *Chloropyron molle ssp. molle*, California clapper rail, and salt marsh harvest mouse exist within the San Pablo Bay recovery unit. This recovery unit is less altered by development at higher elevations than the Central/South San Francisco Bay recovery unit and in many places has high sediment concentrations, so accommodation of rising sea level can be more readily achieved here. Accompanying increased salinity may enhance habitat conditions for the covered species. Although the Carquinez Strait presents a natural barrier to habitat connectivity between the San Pablo Bay and Suisun Bay Area Recovery Units, there may exist some degree of habitat and population connectivity between the San Pablo Bay and Central/South San Francisco Bay recovery units.

CENTRAL/SOUTH SAN FRANCISCO BAY RECOVERY UNIT

The Central/South San Francisco Bay recovery unit (**Figure III-4**) encompasses suitable or restorable tidelands from Point San Pablo on the Contra Costa coast and Point San Pedro, Marin County, to the extreme southern extent of the Bay. Limited populations of *Suaeda californica* and salt marsh harvest mouse exist within the Central/South San Francisco Bay recovery unit.

This recovery unit supports the majority of California clapper rail populations. Populations in this unit are widely separated from northern ones, but there may be occasional dispersal between the areas. Impacts of rising sea level are expected to be variable in this area, given variable sediment concentrations and erosion/deposition patterns. Covered species in this recovery unit face unique management issues that vary substantially from other recovery units (*i.e.*, invasive *Spartina* control, current planning and implementation of extensive tidal marsh restoration, and high human density and recreational pressure).

CENTRAL COAST RECOVERY UNIT

Habitats of the Central Coast recovery unit (**Figure III-5**) possess California's distinct maritime climate (cool with little temperature variation), as opposed to the more continentally influenced climates in the San Francisco Bay Estuary. This unit includes suitable or restorable tidelands along the California coast from Bodega Head south to the mouth of the Salinas River. The California clapper rail is the only listed species covered in this recovery plan that occurs in the Central Coast recovery unit. The Central Coast recovery unit includes the southern range of the California clapper rail to Elkhorn Slough, and its population in Tomales Bay, Marin County. Isolated from the San Francisco Bay California clapper rails by wide gaps in habitat, population dynamics of the California clapper rails in the Central Coast recovery unit may be demographically distinct. The Central Coast recovery unit is necessary for recovery of this species in the coastal portion of its range, which will also provide additional protection for the species in an unpredictable ecosystem. This recovery unit also is needed to provide habitat diversity and capacity for habitat shifts and to hedge against progressive adverse environmental or ecological impacts in other parts of the range, such as non-native species invasions or climate alteration due to changes in atmospheric or ocean conditions (*e.g.*, climate warming or "El Niño"-like conditions).

MORRO BAY RECOVERY UNIT

The Morro Bay recovery unit (**Figure III-6**) encompasses suitable or restorable tidelands within Morro Bay, including extensive tidal mudflats, sandflats, tidal marsh plains, and brackish marsh ecotones, patterned over the convergent deltas and distributary channels of the Chorro Creek and Los Osos Creek drainages. The recovery unit also includes a large barrier spit and dune system. Until the early 2000s, the Morro Bay recovery unit supported the only remaining natural population of *Suaeda californica*. *Suaeda californica* in this recovery unit faces management issues primarily related to recreational use.

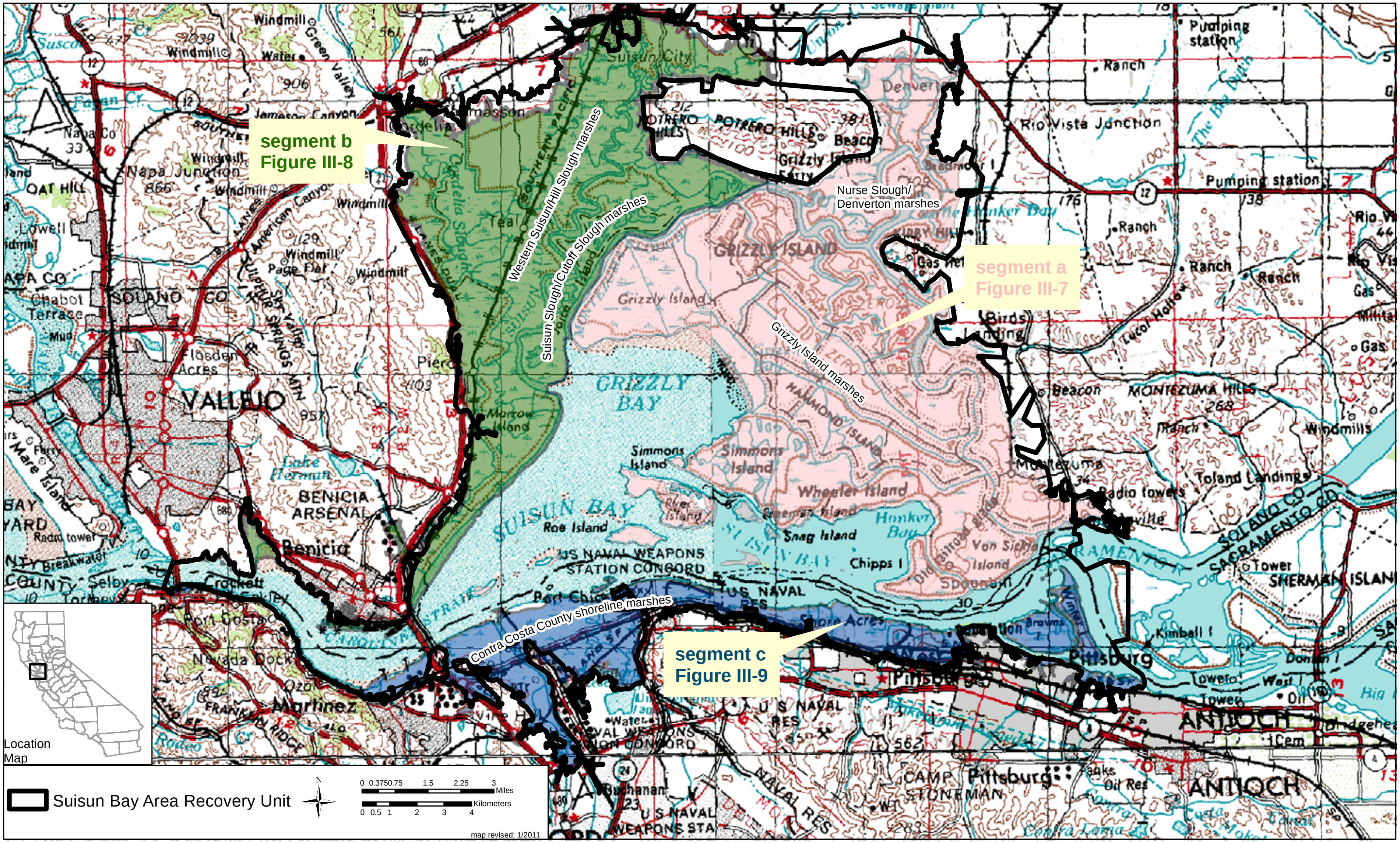


Figure III-2. Suisun Bay Area Recovery Unit

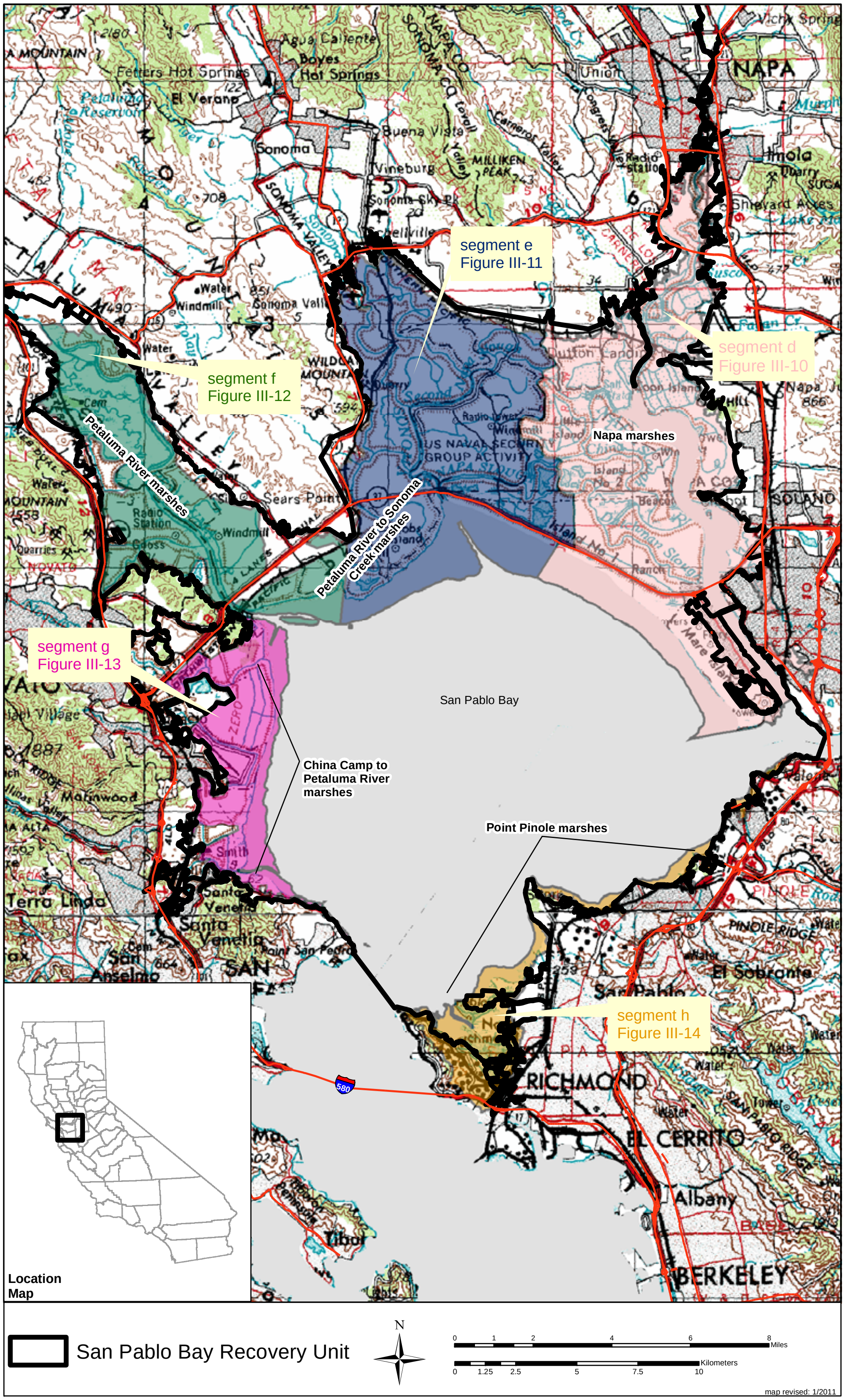


Figure III-3. San Pablo Bay Recovery Unit.

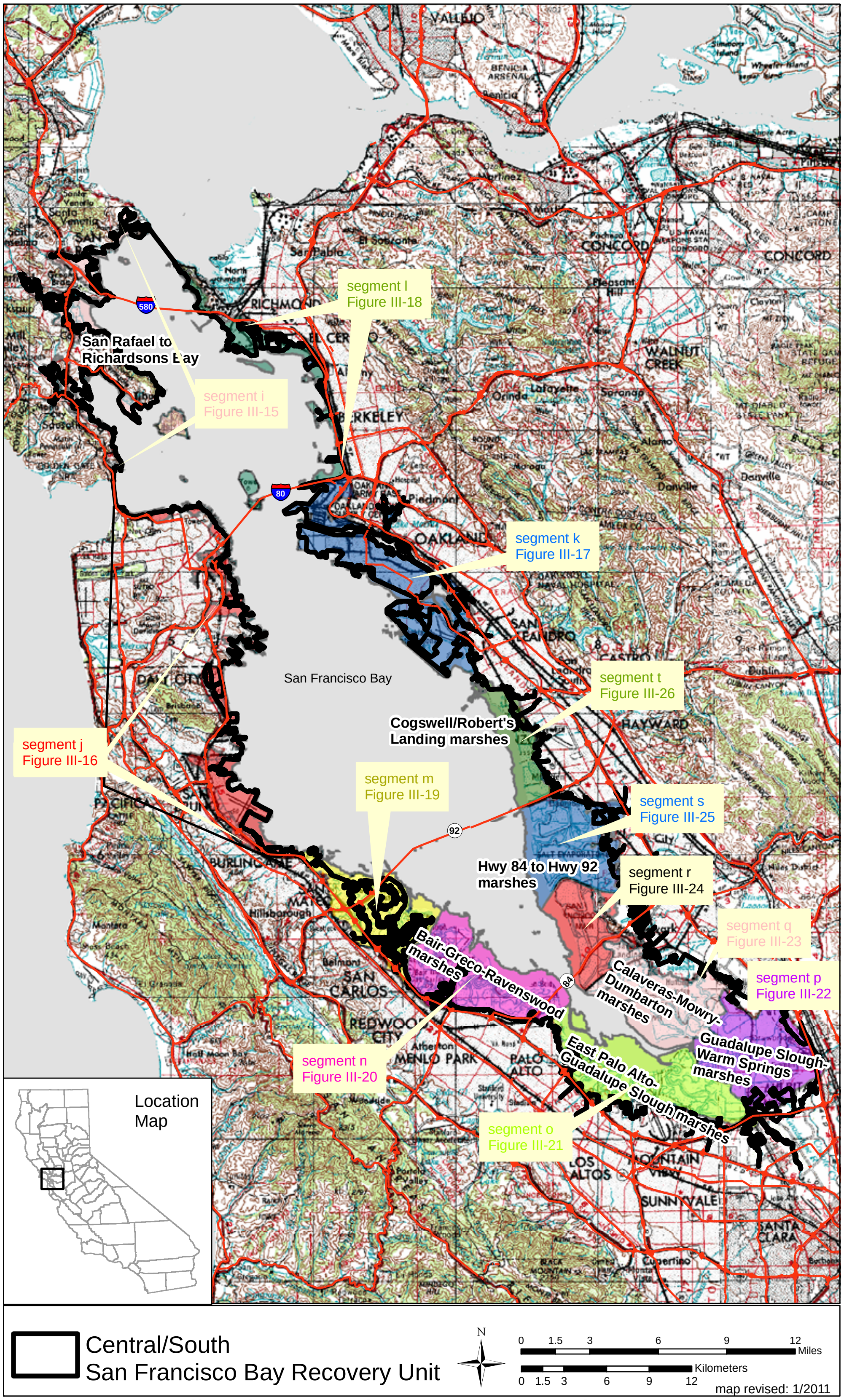


Figure III-4. Central/South San Francisco Bay Recovery Unit.

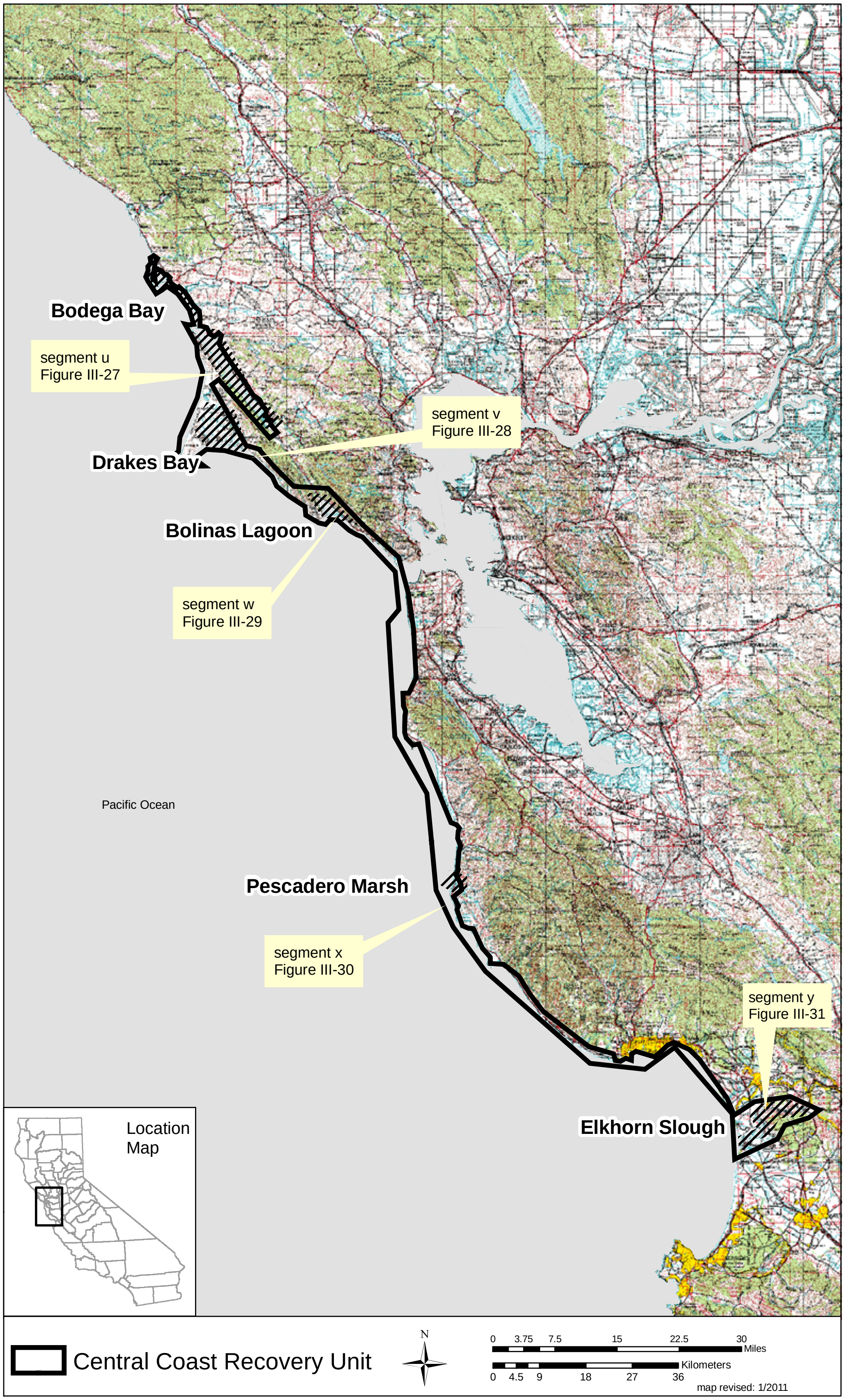


Figure III-5. Central Coast Recovery Unit.

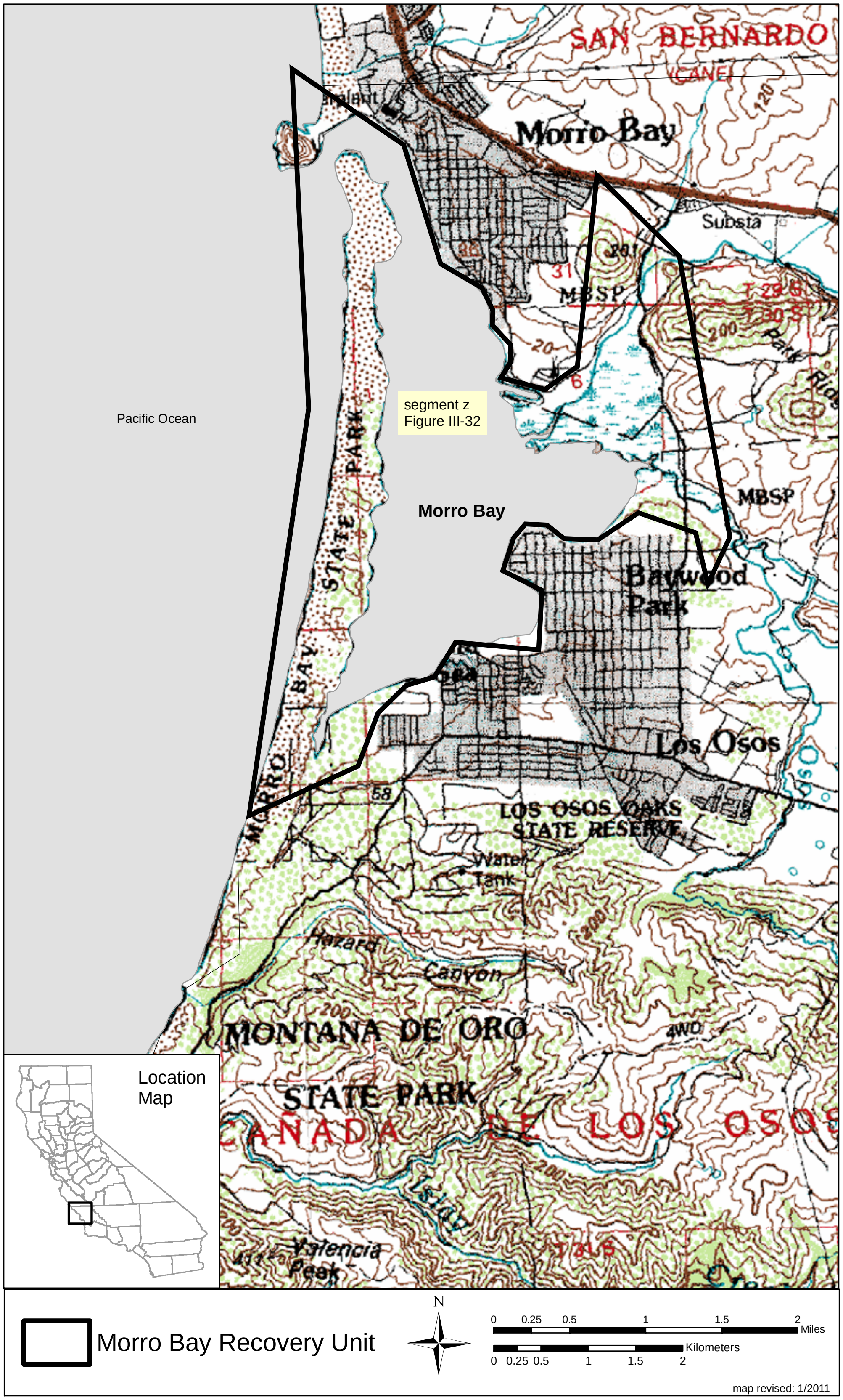


Figure III-6. Morro Bay Recovery Unit.

3. Recovery Criteria

An endangered species is defined in the Endangered Species Act as a species that is in danger of extinction throughout all or a significant portion of its range. A threatened species is one that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range. When we evaluate whether or not a species warrants downlisting or delisting, we consider whether the species meets either of these definitions. A recovered species is one that no longer meets the Act's definitions of threatened and endangered. Determining whether a species should be downlisted or delisted requires consideration of the of the same five categories of threats (*i.e.*, the five threat factors, A-E) which were considered when the species was listed and which are specified in section 4(a)(1) of the Endangered Species Act.

Recovery criteria are conditions that, when met, would result in a determination that a species may warrant downlisting or delisting. Thus, recovery criteria are mileposts that measure progress toward recovery. Recovery criteria are provided below for each listed species covered in this recovery plan. Because the appropriateness of downlisting or delisting is assessed by evaluating the five threat factors identified in the Endangered Species Act, the recovery criteria below pertain to and are organized by these factors. Recovery criteria were developed in coordination with species experts, using best available science. In some cases, information is lacking, such as historic population levels and distributions constituting healthy rangewide statuses. This complicated the process of determining appropriate target acreage and population levels necessary to reach recovery. However, taking into consideration life history traits, known historic population trends, and current threats to the species enabled us to develop defensible recovery criteria which were vetted through species experts during the development process. These recovery criteria are our best assessment at this time of what needs to be completed so that the species may be downlisted or delisted (*i.e.*, meeting the definition of threatened but not the definition of endangered or meeting neither the definition of threatened nor the definition of endangered, respectively). Because we cannot envision the exact course that recovery may take and because our understanding of the vulnerability of a species to threats is very likely to change as more is learned about the species (*e.g.* habitat, demography, genetics) and its threats, it is possible that a status review may indicate that downlisting or delisting is warranted although not all recovery criteria are met. Conversely, it is possible that the recovery criteria could be met and a status review may indicate that downlisting or delisting is not warranted (*e.g.* a new threat may emerge that is not addressed by the recovery criteria below and that causes the species to remain threatened or endangered).

Recovery criteria do not apply to non-listed species. For the species of concern covered under this recovery plan, we assume that conservation efforts will be a success if viable, self-sustaining wild populations of these species are conserved in perpetuity and they do not need to be listed under the Endangered Species Act.

Table III-2 summarizes recovery criteria for the covered listed plant species. **Table III-3** summarizes recovery criteria for the California clapper rail and salt marsh harvest mouse.

a. *Cirsium hydrophilum* var. *hydrophilum*

Downlisting Criteria- Cirsium hydrophilum var. *hydrophilum*

Factor A: The present destruction, modification or curtailment of its habitat or range. To reclassify *Cirsium hydrophilum* var. *hydrophilum* to threatened status, threats to the species habitat must be reduced. This species has only one recovery unit, the Suisun Bay Area Recovery Unit, therefore, all criteria apply to this one recovery unit. This will have been accomplished if the following have occurred:

A/1. *Area inhabited:* The minimum area inhabited annually by the species must be **2,000 acres** over a period of **five years**. The area inhabited by the species shall be the sum of land areas of convex polygons enclosing individuals of each separate population. If not divisible into separate populations, this area criterion may be met by a minimum area inhabited annually by the species of **3,000 acres** over a period of **five years**.

A/2. *Area preserved* – A minimum of **4,000 acres** must be permanently preserved and under protective management. This must include existing or successfully restored tidal marsh areas with suitable habitat for the species and encompass a mimimum of **80 percent** of the extant occurrences of the species.

A/3. Reduction in extant *Lepidium latifolium* populations in tidal areas of Suisun Marsh (in and down-gradient of the high marsh-upland ecotone) to less than **ten percent** cover for **five years**.

A/4. Natural tidal range[2] must be restored at Hill Slough and the ponded area at Rush Ranch to return periodic tidal flooding.

Factor B: Overutilization for commercial, scientific or educational purposes. Overutilization currently is not known to be a factor for this species. Therefore, no recovery criteria have been developed for this factor.

Factor C: Disease or predation. Disease is not known to present a major threat at this time. Though seed predation threatens *Cirsium hydrophilum* var. *hydrophilum*, we do not believe amelioration of this threat is required to downlist the species; therefore, though delisting criteria have been developed, downlisting criteria have not.

Factor D: Inadequacy of existing regulatory mechanisms. Since we have not identified existing regulatory mechanisms for *C. hydrophilum* var. *hydrophilum* as being inadequate, we have not developed recovery criteria under this factor.

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[2] Tidal range approximating those measured at Rush Ranch's First and Second Mallard Branches, Suisun Slough and Cutoff Slough.

Factor E: Other natural or manmade factors affecting its continued existence. To reclassify *Cirsium hydrophilum* var. *hydrophilum* to threatened status, the species must be protected from other natural or manmade factors known to affect its continued existence. This will have been accomplished if the following have occurred:

E/1. To provide sufficient resilience to stochastic events, downlisting criteria under criteria A/1 and A/2 have been met and have resulted in at least the following:

Number of populations:
At least **three** separate populations or one large population must occur within Suisun Marsh. Required target number of individuals is dependent on whether separate populations are easily identifiable, as described below. A population shall be any concentration of plants with closest individuals to other populations greater than 1 kilometer (0.6 mile) apart over a period of five years.

Number of plants:
Mean – Over **five years** of monitoring, a mean of at least **3,000 individuals** must occur annually over the entire range of the species. The third-largest separate population over the same period must have a mean of at least **300 individuals**. If there are fewer than three separate populations, a mean of at least **5,000 individuals** must occur annually throughout the entire range of the species over a period of **five years**.

Minimum – The entire species must not fall below **800 individuals** for **two consecutive years** over a period of **five years**.

Delisting criteria- Cirsium hydrophilum var. *hydrophilum*

Factor A: The present destruction, modification or curtailment of its habitat or range. To delist *Cirsium hydrophilum* var. *hydrophilum*, threats to the species habitat must be reduced or removed. This will have been accomplished if the following have occurred:

A/1. *Area inhabited* – The minimum area inhabited annually by the species must be **3,000 acres** over a period of **eight years**. The area inhabited by the species shall be the sum of land areas of convex polygons enclosing individuals of each separate population. If not divisible into separate populations, this area criterion may be met by a minimum area inhabited annually by the species of **4,000 acres** over a period of **eight years**.

A/2. *Area preserved* – A minimum of **6,000 acres** of suitable habitat must be permanently preserved and under protective management. This must include existing or successfully restored tidal marsh areas with suitable habitat for the species and encompass a minimum of **80 percent** of the species, as well as habitat supporting adequate self-sustaining populations of pollinators.

A/3. All conditions under *downlisting* criterion A/3 have been met. In addition, a plan must be developed and implemented for early detection and control of *Lepidium latifolium* following any future increase beyond **ten percent** cover in tidal areas of Suisun Marsh (in and down-gradient of the high marsh-upland ecotone). Also, a funding source must be secured to fund such actions in perpetuity.

A/4. All conditions under *downlisting* criterion A/4 have been met.

A/5. Reliable propagation and reintroduction methods must be developed and available.

A/6. Trampling and rooting damage to *Cirsium hydrophilum* var. *hydrophilum* by feral pigs must have been eliminated at all populations for **five years**.

Factor B: Overutilization for commercial, scientific or educational purposes. Overutilization currently is not known to be a factor for this species. Therefore, no recovery criteria have been developed for this factor.

Factor C: Disease or predation. Disease is not known to present a major threat to *Cirsium hydrophilum* var. *hydrophilum* at this time. However, to delist *C. hydrophilum* var. *hydrophilum*, seed predation pressures need to be reduced or removed. This will have been accomplished if the following has occurred:

C/1. Unnaturally high seed predator pressures on *C. hydrophilum* var. *hydrophilum* from thistle weevil (*Rhinocyllus conicus*) must fall below a level at which it negatively affects long-term population persistence. This level will be determined through future research.

Factor D: Inadequacy of existing regulatory mechanisms. Since we have not identified existing regulatory mechanisms for *C. hydrophilum* var. *hydrophilum* as being inadequate, we have not developed recovery criteria under this factor.

Factor E: Other natural or manmade factors affecting its continued existence. To delist *Cirsium hydrophilum* var. *hydrophilum*, the species must be protected from other natural or manmade factors known to affect its continued existence. This will have been accomplished if the following have occurred:

E/1. To provide sufficient resilience to stochastic events, all conditions under *delisting* criteria A/1 and A/2 have been met and have resulted in at least the following:

Number of populations:
At least **four separate populations** must occur within Suisun Marsh. If the species' population is large and not divisible into separate populations, see *Number of plants,* below.

Number of plants:
Mean **–** Over **eight years** of monitoring, a mean of at least **4,000** individuals must occur annually, spread across at least **four populations** and the fourth-largest population over the same period must have a mean of at least **500 individuals**. If not divisible into separate populations, a mean of at least **7,000 individuals** must occur annually throughout the entire range of the species over a period of **eight years**.

Minimum **–** The entire species must not fall below **1,000 individuals** for **two consecutive years** over a period of **eight years**.

E/2. *Seed banking* of all extant populations and representative genetic diversity (per commonly accepted seed banking protocols) must be complete.

E/3. Research must be conducted to determine if hybridization is occurring between *Cirsium hydrophilum* var. *hydrophilum* and *Cirsium vulgare*. If research shows that hybridization is occurring, extant *C. vulgare* populations must be eliminated in Suisun Marsh and a monitoring plan must be in place to detect and eliminate future infestations of *C. vulgare.*

E/4. To minimize impacts sustained after oil spills occurring at or near populations, the San Francisco Bay and Delta Area section of the Sector San Francisco-Area Contingency Plan must be revised to place high priority on the emergency protection of *Cirsium hydrophilum* var. *hydrophilum*.

E/5. High marsh/upland transition lands must be preserved or created as part of new marsh restoration efforts and managed to provide opportunity for landward migration of species in response to sea level rise.

This criterion will be met when sea level rise modeling shows sufficient uplands have been protected to accommodate landward migration while still allowing for acreage criteria to be met (see delisting criteria A/1 and A/2).

b. *Chloropyron molle* ssp. *molle*

Downlisting criteria- Chloropyron molle ssp. molle

Factor A: The present destruction, modification or curtailment of its habitat or range. To reclassify *Chloropyron molle ssp. molle* to threatened status, threats to the species habitat must be reduced. This species has two recovery units: the Suisun Bay Area Recovery Unit and the San Pablo Bay Recovery Unit. Criteria for individual recovery units are specified as appropriate. This will have been accomplished if the following have occurred:

A/1. *Area inhabited:* The minimum area inhabited annually by the species in the Suisun Bay Area Recovery Unit must be **3,000 acres** and the minimum area inhabited annually by the species around San Pablo Bay Recovery Unit must be **1,000 acres**, over a period of **five years**. The area inhabited by the species shall be the sum of land areas of convex polygons enclosing individuals of each population.

A/2. *Area preserved* – A minimum of **5,000 acres** of suitable habitat in the Suisun Bay Area and San Pablo Bay Recovery Units must be permanently preserved and under protective management. This must include existing or successfully restored tidal marsh areas with suitable habitat for the species and encompass a minimum of **80 percent** of the species.

A/3. Reduction in extant *Lepidium latifolium* populations in tidal areas (in and down-gradient of the high marsh-upland ecotone) to less than **ten percent** cover for five years.

A/4. There must be less than **ten percent** total cover of other non-native, invasive perennial or non-native winter annual grass species (other than *Lepidium latifolium)*, including, but not limited to, *Apium graveolens* (celery), *Cotula coronipfolia* (brass-buttons), *Juncus gerardi* (black-grass rush), *Spartina patens* (salt-meadow cordgrass), *Polypogon monspeliensis* (annual beard grass), *Hainardia cylindrical* (barbgrass), *Parapholis incurva* (sicklegrass), *Crypsis schoenoides* (swamp grass), and *Lepidium latifolium* within 50 feet of extant *C. molle ssp. molle* populations.

A/5. Natural tidal range must be restored at Hill Slough and the ponded area at Rush Ranch to return periodic tidal flooding.

Factor B: Overutilization for commercial, scientific or educational purposes. Overutilization currently is not known to be a factor for this species. Therefore, no recovery criteria have been developed for this factor.

Factor C: Disease or predation. Disease is not known to present a major threat to *C. molle ssp. molle* at this time. Though seed predation threatens *C. molle ssp. molle*, we do not believe amelioration of this threat is required to downlist the species; therefore, though delisting criteria have been developed, downlisting criteria have not.

Factor D: Inadequacy of existing regulatory mechanisms. Since we have not identified existing regulatory mechanisms for *C. molle* ssp. *molle* as being inadequate, we have not developed recovery criteria under this factor.

Factor E: Other natural or manmade factors affecting its continued existence. To reclassify *C. molle ssp. molle* to threatened status, the species must be protected from other natural or manmade factors known to affect its continued existence. This will have been accomplished if the following have occurred:

E/1. To provide sufficient resilience to stochastic events, all conditions under downlisting criteria A/1 and A/2 have been met and have resulted in at least the following:

Number of populations:
At least **nine populations** must occur in the Suisun Bay Area Recovery Unit and at least **four populations** must occur around San Pablo Bay Recovery Unit. A population shall be any concentration of plants separated by greater than one kilometer (0.6 mile) from other such concentrations of plants, with no intervening locations observed over a five year period.

Number of plants:
Mean– Over five years of monitoring, each population must have a mean of at least **3,000 individuals**.

Minimum – The entire species must not fall below **500 individuals** for **two consecutive years** over a period of **five years**.

Seed production:
There must be an average of more than **10 seed capsules** produced per plant, resulting in an average of more than **15 mature seeds** per plant.

Delisting criteria- Chloropyron molle ssp. molle

Factor A: The present destruction, modification or curtailment of its habitat or range. To delist *Chloropyron molle ssp. molle*, threats to the species habitat must be reduced or removed. This will have been accomplished if the following have occurred:

A/1. *Area inhabited* –The minimum area inhabited annually by the species in the Suisun Bay Area Recovery Unit must be **6,000 acres** and the minimum area inhabited annually by the species around San Pablo Bay Recovery Unit must be **2,500 acres** over a period of **eight years**. The area inhabited by the species shall be the sum of land areas of convex polygons enclosing individuals of each population.

A/2. *Area preserved* – A minimum of **9,000 acres** in the Suisun Bay Area Recovery Unit or around San Pablo Bay Recovery Unit must be permanently preserved and under protective management. This must include existing or successfully restored tidal marsh areas with suitable habitat for the species and encompass a minimum of **80 percent** of the species population.

A/3. All conditions under *downlisting* criterion A/3 have been met. In addition, a plan must be developed and implemented for early detection and control of *Lepidium latifolium* following any future increase beyond **ten percent** cover in tidal areas (in and down-gradient of the high marsh-upland ecotone). Also, a funding source must be secured to fund such actions in perpetuity.

A/4. All conditions under *downlisting* criterion A/4 must have been met.

A/5. All conditions under *downlisting* criterion A/5 must have been met.

A/6. Trampling damage by grazed cattle and feral pigs to *C. molle ssp. molle* and its haustorial connections to host plants must have been eliminated at all populations for **eight years**.

A/7. Reliable propagation and reintroduction methods must be developed and available.

Factor B: Overutilization for commercial, scientific or educational purposes. Overutilization currently is not known to be a factor for this species. Therefore, no recovery criteria have been developed for this factor.

Factor C: Disease or predation. Disease is not known to present a major threat to *C. molle ssp. molle* at this time. However, to delist *C. molle ssp. molle*, seed predation pressures need to be reduced or removed. This will have been accomplished if the following has occurred:

C/1. Pre-dispersal seed predation on *C. molle ssp. molle* from moth larvae (*Saphenista* spp., Tortricidae and salt marsh snout moth, *Lipographis fenestrella*, Pyralidae) must, on average, fall below 15 percent.

Factor D: Inadequacy of existing regulatory mechanisms. Since we have not identified existing regulatory mechanisms for *C. molle* ssp. *molle* as being inadequate, we have not developed recovery criteria under this factor.

Factor E: Other natural or manmade factors affecting its continued existence. To delist *C. molle ssp. molle*, the species must be protected from other natural or manmade factors known to affect its continued existence. This will have been accomplished if the following have occurred:

E/1. To provide sufficient resilience to stochastic events, all conditions under *delisting* criteria A/1 and A/2 have been met and have resulted in at least the following:

Number of populations:
At least **ten separate populations** must occur in the Suisun Bay Area Recovery Unit and at least **eight separate populations** must occur around San Pablo Bay Recovery Unit. A population shall be any concentration of plants with closest individuals to other populations greater than 1 kilometer (0.6 mile) apart over a period of five years. If the species' population is large and not divisible into separate populations, see *Number of plants,* below.

Number of plants:
Mean **–** Over **eight** years of monitoring, each population must have a mean of at least **3,000 individuals**; or if the species is widespread and abundant and is not divisible into separate populations, there must be a mean of at least **300,000 individuals** in the Suisun Bay Area Recovery Unit and at least **300,000 individuals** around San Pablo Bay Recovery Unit over a period of **eight years.**

Minimum **–** The entire species must not fall below **1,000 individuals** for **two consecutive years** over a period of **eight years**.

Seed production:
There must be an average of more than **10 seed capsules** produced per plant, resulting in an average of more than **15 mature seeds** per plant.

E/2. Seed banking of all extant populations and representative genetic diversity (per commonly accepted seed banking protocols) must be complete.

E/3. To minimize impacts sustained after oil spills occurring at or near populations, the San Francisco Bay and Delta Area section of the Sector San Francisco-Area Contingency Plan must be revised to place high priority on the emergency protection of *C. molle ssp. molle*.

E/4. High marsh/upland transition lands must be preserved or created as part of new marsh restoration efforts and managed to provide opportunity for landward migration of species in response to sea level rise.

This criterion will be met when sea level rise modeling shows sufficient uplands have been protected to accommodate landward migration while still allowing for acreage criteria to be met (see delisting criteria A/1 and A/2).

c. *Suaeda californica*

Downlisting criteria- Suaeda californica

Factor A: The present destruction, modification or curtailment of its habitat or range. To downlist *Suaeda californica* to threatened status, threats to the species habitat must be reduced. This species has two recovery units: the Central/South San Francisco Bay Recovery Unit and the Morro Bay Recovery Unit. Criteria for individual recovery units are specified as appropriate. This will have been accomplished if the following have occurred:

A/1. Within the Morro Bay Recovery Unit, dunes are revegetated with native species to achieve natural shoreline stability consistent with that which existed in historic dune systems.

A/2. Eradication of *Carpobrotus edulis* (iceplant) is conducted throughout habitat for *S. californica* at the Morro Bay Recovery Unit.

A/3. Habitat supporting at least **three populations** in the Central/South San Francisco Bay Recovery Unit must exist on land in conservation ownership or under conservation management.

Factor B: Overutilization for commercial, scientific or educational purposes. Overutilization is not known to be a threat to *S. californica* at this time. Therefore, no recovery criteria have been developed for this factor.

Factor C: Disease or predation. Neither disease nor predation is known to be a major threat to *S. californica* at this time. Therefore, no recovery criteria have been developed for this factor.

Factor D: Inadequacy of existing regulatory mechanisms. Since we have not identified existing regulatory mechanisms for *S. californica* as being inadequate, we have not developed recovery criteria under this factor.

Factor E: Other natural or manmade factors affecting its continued existence. To downlist *S. californica* to threatened status, the species must be protected from other natural or manmade factors known to affect its continued existence. This will have been accomplished if the following have occurred:

E/1. To provide sufficient resilience to stochastic events, all conditions under downlisting criteria A/1, A/2, and A/3 have been met and have resulted in at least the following:

Number of populations:
A minimum of **three populations** must occur in the Morro Bay Recovery Unit and a minimum of **three populations** must occur in the Central/South San Francisco Bay Recovery Unit. A population shall be any concentration of plants separated by greater than 1.9 km (1.2 miles) from other such concentrations of plants, with no intervening locations observed over a period of five years.

Number of plants:
Minimum – For **five consecutive years** of monitoring, the **three populations** in the Morro Bay Recovery Unit must total a minimum of **3,000 individuals**.

For **five consecutive years** of monitoring, the **three populations** around San Francisco Bay must total a minimum of **1,500 individuals**.

Delisting criteria- Suaeda californica

Factor A: The present destruction, modification or curtailment of its habitat or range. To delist *Suaeda californica*, threats to the species habitat must be reduced or removed. This will have been accomplished if the following have occurred:

A/1. All conditions under *downlisting* criterion A/1 have been met.

A/2. All conditions under *downlisting* criterion A/2 have been met. In addition, monitoring must indicate no presence of *C. edulis* for eight consecutive years.

A/3. Habitat supporting at least **three populations** in San Francisco Bay must exist on land in conservation ownership or under conservation management for ten generations.

A/4. Service-approved management plans are implemented at Montaña de Oro State Park, Sweet Springs Marsh in Baywood Park, and Morro Bay State Marina to prevent trampling of *Suaeda californica* in those areas.

Factor B: Overutilization for commercial, scientific or educational purposes. Overutilization is not known to be a threat to *S. californica* at this time. Therefore, no recovery criteria have been developed for this factor.

Factor C: Disease or predation. Neither disease nor predation is known to be a major threat to *S. californica* at this time. Therefore, no recovery criteria have been developed for this factor.

Factor D: Inadequacy of existing regulatory mechanisms. Since we have not identified existing regulatory mechanisms for *S. californica* as being inadequate, we have not developed recovery criteria under this factor.

Factor E: Other natural or manmade factors affecting its continued existence. To delist *S. californica*, the species must be protected from other natural or manmade factors known to affect its continued existence. This will have been accomplished if the following have occurred:

E/1. To provide sufficient resilience to stochastic events, delisting criteria under criteria A have been met and have resulted in at least the following:

Number of populations:
A minimum of **three populations** must occur in the Morro Bay Recovery Unit and a minimum of **three populations** must occur around San Francisco Bay. A population shall be any concentration of plants separated by greater than 1.9 km (1.2 miles) from other such concentrations of plants, with no intervening locations observed over a ten year period.

Number of plants:
Minimum – For **ten consecutive years** of monitoring, the **three populations** in the Morro Bay Recovery Unit must total a minimum of **5,000 individuals**.

For **ten consecutive years** of monitoring, the **three populations** around San Francisco Bay must each support at least **500 individuals**. Also, the cumulative total of all San Francisco Bay populations must total a minimum of **8,000 individuals**.

E/2. To minimize impacts sustained after oil spills occurring at or near *S.californica* populations, the San Francisco Bay and Delta Area and Central Coast Area sections of the Sector San Francisco-Area Contingency Plan must be revised to place high priority on the emergency protection of *S. californica*.

E/3. High marsh/upland transition lands must be preserved or created as part of new marsh restoration efforts and managed to provide opportunity for landward migration of species in response to sea level rise.

This criterion will be met when sea level rise modeling shows sufficient uplands have been protected to accommodate landward migration while still allowing for acreage criteria to be met (see delisting criteria A/1 and A/2).

Table III-2

Summary of *Cirsium hydrophilum* var. *hydrophilum, Chloropyron molle ssp. molle,* and *Suaeda californica* Recovery Criteria

Criteria	*C. h.* var. *hydrophilum* Downlist	*C. h.* var. *hydrophilum* Delist	*C. m.* ssp. *molle* Downlist	*C. m.* ssp. *molle* Delist	*S. californica* Downlist	*S. californica* Delist
Factor A						
Minimum inhabited area (ac)	2,000 over 5 years (if not separate populations then 3,000)	3,000 over 8 years (if not separate populations then 4,000)	3,000 in Suisun Bay Area Recovery Unit (RU) and 1,000 in San Pablo Bay RU over 5 years	6,000 in Suisun Bay Area RU and 2,500 in San Pablo RU over eight years	-	-
Minimum preserved (ac)	4,000	6,000	5,000	9,000	3 locations in San Francisco Bay must be on preserved lands (no minimum acreage)	3 locations in San Francisco Bay must be on preserved lands (no minimum acreage)
Reduction in *Lepidium latifolium* in tidal areas to less than 10 percent cover for five years	X	X, plus a plan to must be developed and implemented to maintain future infestations below 10 percent cover	X	X, plus a plan to must be developed and implemented maintain future infestations below 10 percent cover	-	-
Seed production	-	-	X, average of 10 seed capsules resulting in 15 mature seeds per plant	X (same as downlist)	-	-
Restoration of natural tidal range at Hill Slough and ponded area at Rush Ranch	X	X	X	X	-	-
Reliable restoration and reintroduction	-	X	-	X	-	-

Criteria	***C. h.* var. *hydrophilum* Downlist**	***C. h.* var. *hydrophilum* Delist**	***C. m.* ssp. *molle* Downlist**	***C. m.* ssp. *molle* Delist**	***S. californica* Downlist**	***S. californica* Delist**
methods						
Eradication of *Carpobrotus edulis* (iceplant) conducted throughout habitat for *S. californica* at Morro Bay	-	-	-	-	X (*C. edulis* control within Morro Bay RU)	X (*C. edulis* control within Morro Bay RU. Must be 0% *C. edulis* for 8 consecutive years)
Other non-native plant control	-	-	X (less than 10% cover of other non-native, invasive perennial or non-native winter annual grass species)	X (same as downlist)	-	-
Elimination of trampling/rooting	-	X	-	X	-	X (via management plans at 3 sites in Morro Bay RU[1])
Partial dune revegetation in Morro Bay[1]	-	-	-	-	X	X
Natural recruitment	-	-	-	-	Recruitment at 3 localities resulting from San Francisco Bay reintroduced populations, for 10 generations each	Recruitment at 5 localities resulting from San Francisco Bay reintroduced populations, for 10 generations each
Factor C						
Predator management	-	X (seed predation must fall below a level at which it negatively	-	X (seed predation must fall below 15%)	-	-

Criteria	*C. h.* var. *hydrophilum* Downlist	*C. h.* var. *hydrophilum* Delist	*C. m.* ssp. *molle* Downlist	*C. m.* ssp. *molle* Delist	*S. californica* Downlist	*S. californica* Delist
		affects long-term population persistence)				
Factor E						
Minimum # populations	3	4	9 in Suisun Bay Area RU; 4 in San Pablo Bay RU	10 in Suisun Bay Area RU; 8 in San Pablo Bay RU	3 in Morro Bay RU; 3 in Central/South San Francisco Bay RU	3 in Morro Bay RU; 3 in Central/South San Francisco Bay RU
# of plants	Minimum of 3,000 over 5 years (if not separate populations, then 5,000). Third largest population must have minimum of 300 individuals	Minimum of 4,000 over 8 years (if not separate populations, then 7,000)	3,000 *in each* population over 5 years	3,000 *in each population* over 8 years (if not separate populations, then 300,000 around Suisun Bay Area RU; 300,000 around San Pablo Bay RU)	3,000 *total* over 5 consecutive years in Morro Bay RU; 1,500 total over 5 consecutive years in San Francisco Bay	5,000 *total* over 10 consecutive years in Morro Bay RU; 500 in each population, with a total of 8,000 in San Francisco Bay
Minimum species population	May not fall below 800 for two consecutive years	May not fall below 1,000 for two consecutive years	May not fall below 500 for two consecutive years	May not fall below 1,000 for two consecutive years	-	-
Seed banking accomplished	-	X	-	X	-	-
Research into hybridization, plus possible control of *Cirsium vulgare*	-	X	-	-	-	-
Oil spill response plans prepared to protect populations	-	X	-	X	-	X
High marsh/upland transition lands preserved or created and managed	-	X	-	X	-	X

"X" indicates that criterion applies.
"-" indicates that criterion does not apply.

d. *California clapper rail*

Downlisting criteria- California clapper rail

Factor A: The present destruction, modification or curtailment of its habitat or range. To downlist California clapper rail to threatened status, threats to the species habitat must be reduced. This species has four recovery units: the Suisun Bay Area Recovery Unit, the San Pablo Bay Recovery Unit, the Central/South San Francisco Bay Recovery Unit, and the Central Coast Recovery Unit. Criteria for individual recovery units are specified as appropriate. This will have been accomplished if the following have occurred:

A/1. **Protection and management of habitat at each of the following marsh complexes sufficient to support a population of 500 rails (except at San Rafael Creek-Richardsons Bay, including Corte Madera Creek, which could support 180 rails):**

Central/Southern San Francisco Bay Recovery Unit (**Figure III-4**):

- San Rafael Creek-Richardsons Bay, including Corte Madera Creek,
- Bair-Greco-Ravenswood,
- East Palo Alto-Guadalupe Slough,
- Guadalupe Slough-Warm Springs,
- Mowry-Dumbarton,
- Hwy 84 to Hwy 92 (Coyote Hills/Eden Landing), and
- Hwy 92-Arrowhead Marsh

Habitat Area: The habitat for each population within the Central/South San Francisco Bay Recovery Unit (except San Rafael Creek to Richardsons Bay) must have a minimum area of 1,111 acres[3] (450 ha) of contiguous high-quality tidal marsh habitat with well-developed channel systems and high-tide refugia/escape cover, at the high marsh/upland transition zone and/or inner-marsh. Due to constraints on restorable land, habitat in the San Rafael Creek to Richardsons Bay complex must be a minimum of 400 acres (162 ha), and have the same critical characteristics, as stated previously.

A/2. **Protection and management of habitat at each of the following marsh complexes sufficient to support a population of 500 rails (except at Point Pinole Marsh which could support 80 rails):**

San Pablo Bay Recovery Unit (**Figure III-3**):

- China Camp to Petaluma River,
- Petaluma River marshes,
- Petaluma River to Sonoma Creek,

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[3] The requirement for population habitat area and characteristics is based on a calculated carrying capacity of more than 500 birds, assuming 0.45 bird/acre (1.1 birds/ha, the 90th percentile of observed South Bay winter population density). A carrying capacity of 500 rails was determined to be the minimum population size that might ensure population persistence (assuming low year-to-year variability in population size and a stable or increasing population). For more information on the calculation of carrying capacity, see **Appendix F**.

- Napa marshes (Sonoma Creek to southern tip of Mare Island), and
- Point Pinole marsh

Habitat Area: The habitat area for each population within the San Pablo Bay Recovery Unit, except that at Point Pinole marsh, must have a minimum of 2,500 acres[4] (1,012 ha) of contiguous high-quality tidal marsh habitat with well-developed channel systems and high-tide refugia/escape cover, at the high marsh/upland transition zone and/or inner-marsh. Due to constraints on restorable land, habitat at Point Pinole marsh must be a minimum of 400 acres (162 ha), and have the same critical characteristics, as stated previously.

A/3. **Protection and management of habitat at the following marsh complex sufficient to support a population of 100 rails**

Suisun Bay Area Recovery Unit (**Figure III-2**):

- Western Grizzly and Suisun Bays and marshes of Suisun, Hill and Cutoff Sloughs.

Habitat Area: The habitat area for the Suisun Bay Area Recovery Unit must have a minimum of 5,000 acres[5] (2,023 ha) of contiguous high-quality tidal marsh habitat with well-developed channel systems and high-tide refugia/escape cover, at the high marsh/upland transition zone and/or inner-marsh.

A/4. **Protection and management of 800 acres[5] (324 ha) of habitat in the Central Coast Recovery Unit at Tomales Bay**, Marin County, to provide proximate, outercoast habitat for California clapper rail in the event of a catastrophic event within San Francisco Bay. The habitat must be contiguous high-quality tidal marsh habitat with well-developed channel systems and high-tide refugia/escape cover, at the high marsh/upland transition zone and/or inner-marsh.

A/5. **Reduction in extant *Lepidium latifolium* populations to less than ten percent cover (in and down-gradient of the high marsh-upland ecotone) for five years in each marsh complex described above.**

A/6. **Implementation of a system for early detection and control of future invasive plant infestations that minimize effects to the California clapper rail**.

A/7. **Implementation of site-specific management plans on lands owned by U.S. Fish and Wildlife Service, California Department of Fish and Game, East Bay Regional Park**

[4] Population densities in the San Pablo Bay have been historically lower than in the South Bay, with approximate density at the 90[th] percentile of 0.20 bird/acre (0.50 bird/ha) in high quality marshes adjacent to the bay). For more information on the calculation of carrying capacity, see **Appendix F**.

[5] Population densities in the Suisun Bay and in maritime marshes of Marin County area have been historically lower and more highly variable than in the San Pablo and South Bays. Long-term monitoring data from which to obtain maximum observed populations is lacking, therefore, carrying capacity and average density at the 90[th] percentile could not be calculated. Instead, target density and minimum acreage was developed in consultation with species experts.

District, and Mid-Peninsula Open Space District to reduce human-caused disturbance to rails, both by reduction of physical disturbance and predation to rails from domestic animals and humans and by elimination of litter and feeding stations which serve to attract predators, thereby degrading habitat quality.

Factor B: Overutilization for commercial, scientific or educational purposes. Though overutilization was a major factor for this species at the turn of the 20th century and set the stage for low population levels which existed at the time of the original listing, it has been eliminated and is not currently known to be a threat. Therefore, no recovery criteria have been developed for this factor.

Factor C: Disease or predation. Disease is not known to be a major threat to California clapper rails at this time. To downlist California clapper rail to threatened status, predation pressures need to be reduced. This will have been accomplished if the following has occurred:

C/1. **A predator management plan is developed and implemented at all sites with significant predation issues.**

Factor D: Inadequacy of existing regulatory mechanisms. Since we have not identified existing regulatory mechanisms for the California clapper rail as being inadequate, we have not developed recovery criteria under this factor.

Factor E: Other natural or manmade factors affecting its continued existence. To downlist California clapper rail to threatened status, the species must be protected from other natural or manmade factors known to affect its continued existence. This will have been accomplished if the following have occurred:

E/1. **To provide sufficient resilience to stochastic events, criteria under Factors A-C have been met and have resulted in at least the following average number of rails over a 10 year period, spread over a large geographic area:**

i. Central/Southern San Francisco Bay Recovery Unit: 1,060
ii. San Pablo Bay Recovery Unit: 936
iii. Suisun Bay Area Recovery Unit: 100

The average number of rails required for downlisting was calculated from the minimum required acreage above (criteria A/1. A/2, and A/3), derived itself from a population viability analysis conducted for California clapper rail. For further information on this analysis, see **Appendix F**. The minimum acreage was multiplied by the rail density corresponding to the 60th percentile of observed winter populations for that particular region. Respectively, those are 0.15 bird/ac, 0.09 bird/ac, and 0.02 bird/ac for the regions above.

Rather than specify a minimum number of rails that must be supported per marsh complex, it is assumed that a natural distribution over the entire recovery unit would result if the other minimum acreage protection and management criteria are met.

For downlisting of the California clapper rail to occur, habitat protection need not have resulted in the occupation of Tomales Bay marshes, within the Central Coast Recovery Unit, by the species.

E/2. **High marsh/upland transition lands must be preserved or created as part of new marsh restoration efforts and managed to provide opportunity for landward migration of species in response to sea level rise.**

This criterion will be met when sea level rise modeling shows sufficient uplands have been protected to accommodate landward migration while still allowing for acreage criteria to be met (see downlisting criteria A/1 and A/2).

Delisting criteria- California clapper rail

Factor A: The present destruction, modification or curtailment of its habitat or range. To delist the California clapper rail, threats to the species habitat must be reduced or removed. This will have been accomplished:

A/1. **When all conditions under *downlisting* criterion A/1 have been met.**

A/2. **When all conditions under *downlisting* criterion A/2 have been met.**

A/3. **When all conditions under *downlisting* criterion A/3 have been met.**

A/4. **When all conditions under *downlisting* criterion A/4 have been met.**

A/5. **When all conditions under *downlisting* criterion A/5 have been met. In addition, a plan must be developed for early detection and control of *Lepidium latifolium* (in and down-gradient of the high marsh-upland ecotone), to be implemented following any future increase beyond ten percent cover. Also, a funding source must be secured to fund such actions in perpetuity.**

A/6. **When all conditions under *downlisting* criterion A/6 have been met.**

A/7. **When conditions under d*ownlisting* criterion A/7 have been achieved at all sites.**

A/8. **Implementation of the *Suisun Marsh Habitat Management, Preservation, and Restoration Plan* (developed by the Suisun Marsh Principals Group[6]), San Pablo Bay National Wildlife Refuge Comprehensive Conservation Plan (in preparation by San Pablo Bay National Wildlife Refuge), and the *South Bay Salt Pond Restoration Plan* (U.S. Fish and Wildlife Service 2009*b*).**

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[6] A multi-agency group with primary responsibility to protect and enhance the Pacific Flyway and existing wildlife values, endangered species, and water-project supply quality in Suisun Marsh. Members include U.S. Fish and Wildlife Service, National Marine Fisheries Service, U.S. Bureau of Reclamation (BOR), California Department of Fish and Game, California Department of Water Resources, Delta Stewardship Council , and Suisun Resource Conservation District.

Factor B: Overutilization for commercial, scientific or educational purposes. Though overutilization was a major factor for this species at the turn of the 20^{th} century and set the stage for low population levels which existed at the time of the original listing, it has been eliminated and is not currently known to be a threat. Therefore, no recovery criteria have been developed for this factor.

Factor C: Disease or predation. Disease is not known to present a major threat to California clapper rails at this time. To delist California clapper rail, predation pressures need to be reduced or removed. This will have been accomplished if the following has occurred:

C/1. **All conditions under *downlisting* criterion C/1 have been met. In addition, predator monitoring indicates that for five consecutive years, predation pressure on California clapper rails falls below a level at which it negatively affects long-term population persistence.**

Factor D: Inadequacy of existing regulatory mechanisms. Since we have not identified existing regulatory mechanisms for the California clapper rail as being inadequate, we have not developed recovery criteria under this factor.

Factor E: Other natural or manmade factors affecting its continued existence. To delist California clapper rail, the species must be protected from other natural or manmade factors known to affect its continued existence. This will have been accomplished if the following have occurred:

E/1. **To provide sufficient resilience to stochastic events, criteria under Factors A-C have been met and have resulted in at least the following average number of rails over a 10 year period, spread over a large geographic area:**

i. Central/So SF Bay Recovery Unit: 3,180
ii. San Pablo Bay Recovery Unit: 2,080
iii. Suisun Bay Area Recovery Unit: 200
iv. Tomales Bay: 32

The average number of rails required for delisting was calculated from the minimum required acreage above, derived itself from a population viability analysis conducted for California clapper rail. For further information on this analysis, see **Appendix F**. The minimum acreage was multiplied by the rail density corresponding to the 90^{th} percentile of observed winter populations for that particular region. Those are 0.45 bird/ac and 0.20 bird/ac for Central/So SF Bay and San Pablo Bay, respectively. Species experts agreed on a realistic density of 0.04 bird/ac for the Suisun and Tomales Bay metapopulations.

Rather than specify a minimum number of rails that must be supported per marsh complex, it is assumed that a natural distribution over the entire recovery unit would result if the other minimum acreage protection and management criteria are met.

E/2. **High marsh/upland transition lands must be preserved or created as part of new marsh restoration efforts and managed to provide opportunity for landward migration of species in response to sea level rise.**

This criterion will be met when sea level rise modeling shows sufficient uplands have been protected to accommodate landward migration while still allowing for acreage criteria to be met (see delisting criteria A/1 and A/2).

E/3. **To minimize impacts sustained after oil spills occurring at or near rail populations, the San Francisco Bay and Delta Area section of the Sector San Francisco-Area Contingency Plan must be revised to place high priority on the emergency protection of California clapper rails.**

E/4. **A map must be developed which identifies sources and extents of mercury exposure in rails and a plan must be in place to remediate the most significant point sources of mercury.**

E/5. **Exposure of rails to mercury must be reduced such that the mean mercury concentration of all eggs sampled within a marsh complex must fall below 0.2 µg/g (fresh wet weight) for five consecutive years, the point above which it is believed developmental abnormalities and reproductive harm occur.** Current scientific understanding of mercury toxicity in rails prevents us from developing more refined recovery criteria at this time. Only fail to hatch eggs will be sampled.

e. *Salt marsh harvest mouse*

Downlisting criteria- Salt marsh harvest mouse

Factor A: The present destruction, modification or curtailment of its habitat or range. To reclassify the salt marsh harvest mouse to threatened status, threats to the species habitat must be reduced. This species has three recovery units: the Suisun Bay Area Recovery Unit, the San Pablo Bay Recovery Unit, and the Central/South San Francisco Bay Recovery Unit. Criteria for individual recovery units are specified as appropriate. This will have been accomplished if the following have occurred:

Protection, management and restoration of suitable tidal marsh habitat in each marsh complex sufficient to support multiple viable habitat areas (see below) occupied by salt marsh harvest mice, that are distributed among recovery units as specified below in criteria A/1 through A/3.

Each marsh complex must be as large and of as high a habitat quality as possible. These high quality marsh complexes will support larger populations of salt marsh harvest mice, and these complexes will likely persist, even in the face of such challenges as rising sea levels. Each marsh complex must meet a minimum acreage size, as specified below.

Marsh complexes will be comprised of one or more viable habitat areas (VHAs). VHAs for the salt marsh harvest mouse in the Central/Southern San Francisco Bay Recovery Unit, and San Pablo Bay Recovery Unit are defined as well-developed tidal marshes with the following specific features: 1) extensive *Sarcocornia* (pickleweed) on a mid to high marsh plain 200 meters (219 yds) or more deep (from shore to bay); 2) adjacent wide high marsh transition zone, wherever possible, that acts as a *refugium* for the mice during the highest tides with sufficient area and cover to minimize predation risks and; 3) stands of *Grindelia* (and in San Pablo Bay area, *Schoenoplectus* spp.) or tall forms of *Sarcocornia*, interspersed among shorter forms of *Sarcocornia* to provide additional high tide refugia within the marsh and away from the upland edge.

In addition, VHAs for salt marsh harvest mice in the Suisun Bay Area Recovery Unit may be defined as muted, as well as fully tidal marsh. Viable habitat areas in the Suisun Bay Area Recovery Unit include the above important habitat features, but also include interspersed taller vegetation (*Schoenoplectus americanus* and other species that are documented to be used by salt marsh harvest mice) (California Department of Water Resources *in litt*. 2007) as additional high tide refugia. Currently, a large proportion of salt marsh harvest mice in Suisun Marsh are supported by diked wetlands on Grizzly Island. Because of this and because lands here are severely subsided and would be nearly impossible to restore to tidal conditions, diked wetland acreage may be substituted for tidal marsh habitat when counting toward the viable habitat area acreage target within the Grizzly Island Marsh Complex only.

All VHAs within each marsh complex must be 150 acres or more, the minimum acreage thought to sustain a healthy mouse population (Shellhammer *in litt.* 2005). The VHAs must be connected by corridors broad and complex enough to allow the interconnected VHAs to function as one large population over time; however, these corridors will not be counted in the total marsh complex acreage, unless they are fringing marshes 500 feet deep or deeper, have a high marsh transition zone, and have substantial escape cover, both in the middle and high marsh zones.

Population criteria are based on capture efficiency data (*i.e.*, number of mice captured divided by effort in number of trap nights[7] expended times 100) because of high effort-low return on trapping and the great difficulty and great expense of obtaining dependable density estimates on a regular basis. Occupancy of multiple VHAs within a marsh complex at a capture efficiency level of 5.0 or better in some and 3.0 or better in most of the remaining VHAs is the primary indicator of a mouse population heading toward sustainability, while occupancy of multiple VHAs within a marsh complex at a capture efficiency level of 5.0 or better in most of the habitat areas is the primary indicator of a sustainable population (Shellhammer pers. comm. 2005). Further detail regarding capture efficiency thresholds follows in criterion E/1 below. The specific trap layout and spacing per site may differ.

[7] A measure of trapping effort, *e.g.*, 400 trap nights represents 100 traps set for 4 nights.

Recovery Units, Marsh Complexes, Viable Habitat Areas

A/1. **Protection and management of historic and restored marsh complexes within the Central/Southern San Francisco Bay Recovery Unit (Figure III-4) at:**

San Rafael Creek-Richardsons Bay, including Corte Madera Creek, 400 or more acres in size, with one VHA at:

- Corte Madera Marsh (State Ecological Area)

Bair-Greco-Ravenswood, 1,000 or more acres in size, with VHAs at:

- Foster City
- Bair Island
- Greco-Westpoint and Flood Sloughs
- Ravenswood Point and Slough

East Palo Alto-Guadalupe Slough, 1,000 or more acres in size, with VHAs at:

- East Palo Alto- Cooley Landing- Palo Alto Nature- Mountain View to Stevens Creek
- Stevens Creek to Guadalupe Slough

Guadalupe Slough-Warm Springs, 1,000 or more acres in size, with one VHA within the marsh complex

Calaveras-Mowry-Dumbarton, 1,000 or more acres in size, with one VHA within the marsh complex

Hwys 84 to 92 (Coyote Hills-Eden Landing), 1,000 or more acres in size, with VHAs at:

- Hwy 84 to Coyote Hills Slough
- Coyote Hills Slough to Hwy 92

Hwy 92- Arrowhead Marsh, 1,000 or more acres in size, with VHAs at:

- Cogswell-Hayward Shoreline
- Oro Loma
- Roberts Landing

Sub-criterion A: Protection of Documented Occurrences
Habitat supporting all extant salt marsh harvest mouse occurrences must be protected via habitat management.

Sub- criterion B: VHA Characteristics
Each marsh complex must support VHAs, as described above, that are connected by suitable habitat corridors with sufficiently deep pickleweed plains and/or sufficiently deep high marsh zones (and preferably both). This will allow movement of salt marsh harvest mice through these areas to occur unobstructed.

Sub- criterion C: Marsh Connectivity
Unless precluded by natural features or existing hardscape, the marsh complexes themselves must be connected to one another by marsh or restored tidal marsh of sufficient depth and complexity to allow for dispersal and recolonization.

Sub- criterion D: Marsh Complex Minimum Acreage
Marsh complexes must be 1,000 acres or more in size, except in the San Rafael Creek to Richardson's Bay complex where, due to constraints on restorable habitat, the marsh complex must be 400 acres or more in size. All VHAs within each marsh complex must be 150 acres or more in size.

A/2. **Protection and management of historic and restored marsh complexes within the San Pablo Bay Recovery Unit (Figure III-3) at:**

China Camp to the mouth of the Petaluma River, 1,000 or more acres in size, with VHAs at:

- China Camp to Gallinas Creek and Gallinas Creek
- Hamilton Air Force Base marshes to Petaluma Point, including Novato Creek

Petaluma River marshes, 1,000 or more acres in size, with VHAs at:

- Bahia-Black John Slough-mouth of San Antonio Creek
- Petaluma Marsh and east of Petaluma River
- South-east of Petaluma Marsh

Mouth of the Petaluma River to the mouth of Sonoma Creek, 1,000 or more acres in size, with one VHA within the marsh complex

Napa marshes from the mouth of Sonoma Creek to the southern tip of Mare Island, 1,000 or more acres in size, with six VHAs within the marsh complex. These areas are dependent on the locations of the restored marshes.

Point Pinole marsh, 400 or more acres in size, with one VHA at:

- San Pablo Creek marshes and northeast from mouth of San Pablo Creek

Sub- criterion A: Protection of Documented Occurrences
Habitat supporting documented salt marsh harvest mouse occurrences must be protected via habitat management.

Sub- criterion B: VHA Characteristics
Each marsh complex must support VHAs, as described above, and these areas shall be connected by suitable habitat corridors with sufficiently deep pickleweed plains and/or sufficiently deep high marsh zones (and preferably both). This will allow movement of salt marsh harvest mice through these areas to occur unobstructed.

Sub- criterion C: Marsh Connectivity
Unless precluded by natural features or existing hardscape, the marsh complexes themselves must be connected to one another by marsh or restored tidal marsh of sufficient depth and complexity to allow for dispersal and recolonization.

Sub- criterion D: Marsh Complex Minimum Acreage
Marsh complexes must be 1,000 acres or more in size, except in Point Pinole marsh where, due to constraints on restorable habitat, the marsh complex must be 400 acres or more in size. All VHAs within each marsh complex must be 150 acres or more in size.

A/3. Suisun Bay Area Recovery Unit (**Figure III-2**): historic and restored marsh complexes at:

Western Suisun/Hill Slough Marsh Complex, 1,000 or more acres, with VHAs at:
- Morrow Island
- Cordelia Slough (west of railroad tracks)
- Chadbourne/Upper Wells Slough (west *and* east of railroad tracks)
- Peytonia
- Hill Slough complex

Suisun Slough/Cutoff Slough Marsh Complex, 1,000 or more acres, with VHAs at:
- Lower Joice Island
- Upper Joice Island
- Rush Landing to Beldon's Landing (east of Suisun and Cutoff Sloughs)
- Beldon's Landing to Nurse Slough

Nurse Slough/Denverton Slough Marsh Complex, 1,000 or more acres, with VHAs at:
- Bradmoor Island- Little Honker Bay (plus all areas along Denverton Slough)
- Blacklock
- Upper Nurse Slough

Grizzly Island Marsh Complex, 1,500 or more acres, with VHAs at:
- Grizzly Island West
- East border of Grizzly Bay, plus Crescent unit
- Grizzly Island East, including Ponds 1 and 15
- Simmons-Wheeler Islands
- Van Sickle Island/Chipps Island
- Ryer Island
- Montezuma area

Contra Costa County Shoreline Marsh Complex, 500 or more acres, with VHAs at:
- Mallard Slough East
- Concord Naval Weapons Station marshes
- Hastings Slough to Carquinez Bridge

Sub- criterion A: Protection of Documented Occurrences

Habitat supporting documented salt marsh harvest mouse occurrences must be protected via habitat management.

Sub- criterion B: VHA Characteristics
Each marsh complex must support VHAs, as described above, and these areas shall be connected by suitable habitat corridors with sufficiently deep pickleweed plains and sufficiently deep high marsh zones (and preferably both). This will allow movement of salt marsh harvest mice through these areas to occur unobstructed.

Sub- criterion C: Marsh Connectivity
Unless precluded by natural features or existing hardscape, the marsh complexes themselves must be connected to one another by suitable habitat of sufficient depth and complexity to allow for dispersal and recolonization.

Sub- criterion D: Marsh Complex Minimum Acreage
Most marsh complexes must be 1,000 or more acres in size. However, the Grizzly Island Marsh Complex must be 1,500 or more acres and the Contra Costa County Shoreline Marsh Complex must be 500 or more acres in size. All VHAs within each marsh complex must be 150 acres or more in size. Individual Mouse Conservation Areas, as defined above in Chapter I under Tidal marsh conservation, restoration, and management, must be 150 or more acres in size and must have corridors to other preserves and/or to suitable habitat supporting salt marsh harvest mouse, wherever possible.

A/4. **Reduction in extant *Lepidium latifolium* populations to less than ten percent cover (in and down-gradient of the high marsh-upland ecotone) for five years in each marsh complex described above.**

A/5. **Implementation of a system for early detection and control of future invasive plant infestations that minimize effects to the salt marsh harvest mouse**.

Factor B: Overutilization for commercial, scientific or educational purposes.
Overutilization currently is not known to be a factor for this species. Therefore, no recovery criteria have been developed for this factor.

Factor C: Disease or predation. Disease is not known to be a major threat to the salt marsh harvest mouse at this time. An unnaturally high level of predation is thought to exist in some marshes where salt marsh harvest mice are concentrated into narrow *Sarcocornia* zones due to surrounding habitat loss. Though little is known about death rates related to the resulting predation, it is presumed that restoration of deep marshes with ample high tide refugia, both high marsh and intermarsh, will result in a reduction of predation rates. Therefore, focus is given to restoration of high quality marshes and no recovery criteria related to disease or predation have been developed.

Factor D: Inadequacy of existing regulatory mechanisms. Since we have not identified existing regulatory mechanisms for the salt marsh harvest mouse as being inadequate, we have not developed recovery criteria under this factor.

Factor E: Other natural or manmade factors affecting its continued existence. To reclassify the salt marsh harvest mouse to threatened status, the species must be protected from other natural or manmade factors known to affect its continued existence. This will have been accomplished if the following has occurred in the Central/Southern San Francisco Bay, San Pablo Bay, and Suisun Bay Area Recovery Units (**Figures III-2 through III-4**):

E/1. **Marsh Complex Population Occupancy Targets associated with A/1 through A/3**

- 40 percent of the VHAs of each large marsh complex must have salt marsh harvest mice present at the capture efficiency level of 5.0 or better AND
- an **additional** 50 percent of the VHAs of each large marsh complex must have salt marsh harvest mice present at the capture efficiency level of 3.0 or better.
- Each marsh complex must be monitored and found to meet the above criteria at least twice, with at least five years between surveys. Some marsh complexes may meet the target after only two surveys while it may take more than two surveys for other marsh complexes (restored marshes which eventually establish suitable habitat) to meet the target. After marsh complexes meet the criteria twice, there is no need to resurvey them, as long as no more than 20 years has passed and there has been no obvious negative change to habitat during that time (i.e., substantial loss of upland transition or high marsh refugia due to sea level rise).

E/2. **High marsh/upland transition lands must be preserved or created as part of new marsh restoration efforts and managed to provide opportunity for landward migration of species in response to sea level rise.**

This criterion will be met when sea level rise modeling shows sufficient uplands have been protected to accommodate landward migration while still allowing for acreage criteria to be met (see downlisting criteria A/1 and A/2).

Delisting criteria- Salt marsh harvest mouse

Factor A: The present destruction, modification or curtailment of its habitat or range. To delist the salt marsh harvest mouse, threats to the species habitat must be reduced. This will have been accomplished:

A/1. **When all conditions under *downlisting* criterion A/1 have been met.**

A/2. **When all conditions under *downlisting* criterion A/2 have been met.**

A/3. **When all conditions under *downlisting* criterion A/3 have been met.**

A/4. **When all conditions under *downlisting* criterion A/4 have been met. In addition, a plan must be developed for early detection and control of *Lepidium latifolium* (in and down-gradient of the high marsh-upland ecotone), to be implemented following any future increase beyond ten percent cover. Also, a funding source must be secured to fund such actions in perpetuity.**

A/5. **When all conditions under *downlisting* criterion A/5 have been met.**

A/6. **When implementation of the *Suisun Marsh Habitat Management, Preservation, and Restoration Plan*(developed by the Suisun Marsh Principals Group[8]), San Pablo Bay National Wildlife Refuge Comprehensive Conservation Plan (in preparation by San Pablo Bay National Wildlife Refuge), and the *South Bay Salt Pond Restoration Plan* (U.S. Fish and Wildlife Service 2009*b*) is completed.**

Factor B: Overutilization for commercial, scientific or educational purposes. Overutilization currently is not known to be a factor for this species. Therefore, no recovery criteria have been developed for this factor.

Factor C: Disease or predation. As described under the downlisting criteria, no recovery criterion related to disease or predation threat have been developed.

Factor D: Inadequacy of existing regulatory mechanisms. Since we have not identified existing regulatory mechanisms for the salt marsh harvest mouse as being inadequate, we have not developed recovery criteria under this factor.

Factor E: Other natural or manmade factors affecting its continued existence. To delist the salt marsh harvest mouse, the species must be protected from other natural or manmade factors known to affect its continued existence. This will have been accomplished if the following has occurred in the Central/Southern San Francisco Bay, San Pablo Bay, and Suisun Bay Area Recovery Units (**Figures III-2 through III-4**):

In addition to meeting all conditions under downlisting criteria above, to delist the salt marsh harvest mouse, a higher population occupancy target must be met, as follows:

E/1. **Marsh Complex Population Occupancy Targets associated with A/1 through A/3**

- 75 percent of defined VHAs within each of the marsh complexes must have salt marsh harvest mice consistently present at the capture efficiency level of 5.0 or better.
- As with the downlisting criteria, each marsh complex must be monitored and found to meet the above criteria at least twice, with at least five years between surveys. Some marsh complexes may meet the target after only two surveys while it may take more than two surveys for other marsh complexes (restored marshes which eventually establish suitable habitat) to meet the target. After marsh complexes meet the criteria twice, there is no need to resurvey them, as long as no more than 20 years has passed and there has been no obvious negative

[8] A multi-agency group with primary responsibility to protect and enhance the Pacific Flyway and existing wildlife values, endangered species, and water-project supply quality in Suisun Marsh. Members include U.S. Fish and Wildlife Service, National Marine Fisheries Service, U.S. Bureau of Reclamation (BOR), California Department of Fish and Game, California Department of Water Resources, Delta Stewardship Council , and Suisun Resource Conservation District.

change to habitat during that time (*i.e.*, substantial loss of upland transition or high marsh refugia due to sea level rise).

E/2. **High marsh/upland transition lands must be preserved or created as part of new marsh restoration efforts and managed to provide opportunity for landward migration of species in response to sea level rise.**

This criterion will be met when sea level rise modeling shows sufficient uplands have been protected to accommodate landward migration while still allowing for acreage criteria to be met (see delisting criteria A/1 and A/2).

E/3. **To minimize impacts sustained after oil spills occurring at or near salt marsh harvest mouse populations, the San Francisco Bay and Delta Area section of the Sector San Francisco- Area Contingency Plan must be revised to place high priority on the emergency protection of salt marsh harvest mice.**

Table III-3
Summary of California Clapper Rail and Salt Marsh Harvest Mouse Recovery Criteria

Marsh Complexes	California clapper rail Downlist	California clapper rail Delist	Salt marsh harvest mouse Downlist	Salt marsh harvest mouse Delist
CENTRAL/SOUTHERN SAN FRANCISCO BAY RECOVERY UNIT				
San Rafael Creek to Richardson's Bay	Minimum acreage[9]: 400 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 1,060 birds	Minimum acreage: 400 ac Recovery Unit target (10-yr mean) = 3,180 birds	Minimum acreage: 400 ac 1 VHA[10] 40% of VHA with CE[11] of 5.0 or greater **AND** an additional 50% of VHA with CE of 3.0 or greater VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 400 ac 1 VHA 75% of VHAs with CE of 5.0 or greater VHA monitored twice with at least 5 yrs between efforts
Bair-Greco-Ravenswood	Minimum acreage: 1,111 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 1,060 birds	Minimum acreage: 1,111 ac Recovery Unit target (10-yr mean) = 3,180 birds	Minimum acreage: 1,000 ac 4 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 4 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts
East Palo Alto-Guadalupe Slough	Minimum acreage: 1,111 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 1,060 birds	Minimum acreage: 1,111 ac Recovery Unit target (10-yr mean) =3,180 birds	Minimum acreage: 1,000 ac 2 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 2 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts

[9] Minimum acreage is defined as minimum acreage of suitable restored or existing tidal marsh habitat. In Suisun marsh, this may include suitable diked wetland habitat.
[10] VHA = Viable Habitat Area. Described in downlisting criteria for salt marsh harvest mouse.
[11] CE = Capture Efficiency. Described in downlisting criteria for salt marsh harvest mouse.

Marsh Complexes	California clapper rail Downlist	California clapper rail Delist	Salt marsh harvest mouse Downlist	Salt marsh harvest mouse Delist
Guadalupe Slough-Warm Springs	Minimum acreage: 1,111 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 1,060 birds	Minimum acreage: 1,111 ac Recovery Unit target (10-yr mean) = 3,180 birds	Minimum acreage: 1,000 ac 1 VHA 40% of VHA with CE of 5.0 or greater **AND** an additional 50% of VHA with CE of 3.0 or greater VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 1 VHA 75% of VHAs with CE of 5.0 or greater VHA monitored twice with at least 5 yrs between efforts
Calaveras-Mowry-Dumbarton	Minimum acreage: 1,111 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 1,060 birds	Minimum acreage: 1,111 ac Recovery Unit target (10-yr mean) = 3,180 birds	Minimum acreage: 1,000 ac 1 VHA 40% of VHA with CE of 5.0 or greater **AND** an additional 50% of VHA with CE of 3.0 or greater VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 1 VHA 75% of VHAs with CE of 5.0 or greater VHA monitored twice with at least 5 yrs between efforts
Hwy 84 to Hwy 92	Minimum acreage: 1,111 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 1,062 birds	Minimum acreage: 1,111 ac Recovery Unit target (10-yr mean) = 3,180 birds	Minimum acreage: 1,000 ac 2 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 2 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts
Hwy 92- Arrowhead Marsh	Minimum acreage: 1,111 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 1,060 birds	Minimum acreage: 1,111 ac Recovery Unit target (10-yr mean) = 3,180 birds	Minimum acreage: 1,000 ac 3 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 3 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts

Marsh Complexes	California clapper rail Downlist	California clapper rail Delist	Salt marsh harvest mouse Downlist	Salt marsh harvest mouse Delist
		SAN PABLO BAY RECOVERY UNIT		
China Camp to Petaluma River	Minimum acreage: 2,500 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 936 birds	Minimum acreage: 2,500 ac Recovery Unit target (10-yr mean) = 2,080 birds	Minimum acreage: 1,000 ac 2 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 2 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts
Petaluma River marshes	Minimum acreage: 2,500 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 936 birds	Minimum acreage: 2,500 ac Recovery Unit target (10-yr mean) = 2,080 birds	Minimum acreage: 1,000 ac 3 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 3 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts
Petaluma River to Sonoma Creek	Minimum acreage: 2,500 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 936 birds	Minimum acreage: 2,500 ac Recovery Unit target (10-yr mean) = 2,080 birds	Minimum acreage: 1,000 ac 1 VHA 40% of VHA with CE of 5.0 or greater **AND** an additional 50% of VHA with CE of 3.0 or greater VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 1 VHA 75% of VHAs with CE of 5.0 or greater VHA monitored twice with at least 5 yrs between efforts
Napa marshes	Minimum acreage: 2,500 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 936 birds	Minimum acreage: 2,500 ac Recovery Unit target (10-yr mean) = 2,080 birds	Minimum acreage: 1,000 ac 12 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 12 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts

Marsh Complexes	California clapper rail Downlist	California clapper rail Delist	Salt marsh harvest mouse Downlist	Salt marsh harvest mouse Delist
Point Pinole marshes	Minimum acreage: 400 ac Recovery Unit target (all marshes in unit combined; 10-yr mean) = 936 birds	Minimum acreage: 400 ac Recovery Unit target (10-yr mean) = 2,080 birds	Minimum acreage: 400 ac 1 VHA 40% of VHA with CE of 5.0 or greater **AND** an additional 50% of VHA with CE of 3.0 or greater VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 400 ac 1 VHA 75% of VHAs with CE of 5.0 or greater VHA monitored twice with at east 5 yrs between efforts
SUISUN BAY AREA RECOVERY UNIT (This recovery unit considered one large marsh complex for California clapper rail)				
Western Suisun/ Hill Slough marshes	Minimum acreage: 5,000 ac Recovery Unit target (10-yr mean) = 100 birds	Minimum acreage: 5,000 ac Recovery Unit target (10-yr mean) = 200 birds	Minimum acreage: 1,000 ac 5 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 5 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts
Suisun Slough/Cutoff Slough marshes			Minimum acreage: 1,000 ac 4 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 4 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts
Nurse Slough/ Denverton marshes			Minimum acreage: 1,000 ac 3 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,000 ac 3 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts

Marsh Complexes	California clapper rail Downlist	California clapper rail Delist	Salt marsh harvest mouse Downlist	Salt marsh harvest mouse Delist
Grizzly Island Marshes			Minimum acreage: 1,500 ac 7 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 1,500 ac 7 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts
Contra Costa County shoreline marshes			Minimum acreage: 500 ac 3 VHAs 40% of VHAs with CE of 5.0 or greater **AND** an additional 50% of VHAs with CE of 3.0 or greater Each VHA monitored twice with at least 5 yrs between efforts	Minimum acreage: 500 ac 3 VHAs 75% of VHAs with CE of 5.0 or greater Each VHA monitored twice with at least 5 yrs between efforts
CENTRAL COAST RECOVERY UNIT				
Tomales bay	Minimum acreage: 800 ac	Minimum acreage: 800 ac Recovery Unit Target (10-yr mean): = 32 birds	-	-

Additional Criteria				
Criterion	**California clapper rail-Downlist**	**California clapper rail-Delist**	**Salt marsh harvest Mouse-Downlist**	**Salt marsh harvest Mouse-Delist**
Factor A				
Future invasive plant control	X	X	X	X
Reduction of *Lepidium latifolium* to less than 10 percent cover for five years	X	X, plus funding commitment to control future infestations below10 percent cover	X	X, plus funding commitment to control future infestations below 10 percent cover

Implementation of *Suisun Marsh Habitat Management, Preservation, and Restoration Plan*, San Pablo Bay Comprehensive Conservation Plan (in preparation), and the *South Bay Salt Pond Restoration Plan*.	-	X	-	X
Implementation of management plans[1] to reduce recreation-based disturbance	X	X	-	-
Factor C				
Predator management	X	X, until predation does not negatively affect long-term population persistence for more than 5 yrs	-	-
Factor E				
Reduction of mean mercury in eggs, per marsh complex	-	X, to below 0.2 µg/g (fww) for five consecutive years	-	-
Oil spill response plans developed to protect species	-	X	-	X
High marsh/upland transition lands preserved or created and managed and partnership formed	X	X	X	X

[1]Specific sites described in text.

B. SPECIES RECOVERY AND CONSERVATION STRATEGIES

This section describes recovery and conservation strategies at three basic levels: ecosystem-level, regional-level, and species-level— each stepped down in increasing detail. Ecosystem-level recovery strategies are aimed at reducing or eliminating ecosystem-level threats. These general strategies address the common threats to most or all of the species covered by this recovery plan (and discussed in section I.D.), as well as the tidal marsh ecosystem upon which they depend. Some combination of the ecosystem-level strategies will be stepped down and applied at the regional level, depending upon the local threats and constraints of the covered species historically or currently present. A detailed discussion of strategies by region follows after Ecosystem-level recovery strategies below. Finally, some threats are very specific to individual tidal marsh species, as opposed to the ecosystem or the region as a whole. Recovery strategies specific to particular species will be discussed later in this section.

Due to shifting conditions in the ecosystem (*e.g.*, invasive species, sea level rise) and an evolving understanding of tidal marsh ecology in California, the U.S. Fish and Wildlife Service anticipates the need to adapt these strategies over time to meet new situations. Ideally, recovery strategies will supplement and complement effective tidal marsh conservation efforts that have already taken place or are underway.

1. Ecosystem-level recovery strategies

The following five ecosystem-level strategies are described further below:

- **Acquire existing, historic, and restorable tidal marsh habitat** to promote the recovery of listed species and the long-term conservation of species of concern and other tidal marsh species.

- **Manage, restore, and monitor tidal marsh habitat** to promote the recovery of listed species and the long-term conservation of species of concern and other tidal marsh species.

- **Conduct range-wide species status surveys/monitoring and status reviews** for listed species and species of concern.

- **Conduct research** necessary for the recovery of listed species and the long-term conservation of species of concern.

- **Improve coordination, participation, and outreach activities** to achieve recovery of listed species and long-term conservation of species of concern.

1. *Acquire existing, historic, and restorable tidal marsh habitat to promote the recovery of listed species and the long-term conservation of species of concern and other tidal marsh species.*

Since the publication of the *California Clapper Rail and Salt Marsh Harvest Mouse Recovery Plan* in 1984 (U. S. Fish and Wildlife Service 1984), many strides have been made in habitat acquisition for tidal marsh species. Specifically, the purchase by the U.S. Fish and Wildlife Service and CDFW in 2003 of 16,500 acres of former salt ponds surrounding San Francisco Bay went far to accomplish the acquisition needs of tidal marsh species. Between 1994 and 2007, 34,300 acres were acquired by government agencies and land trusts in that area (Save the Bay 2007). Whereas the former recovery plan focused relatively equally on habitat acquisition, restoration and management, this document places the majority of emphasis on restoration and management.

The limited amount of available tidal marsh habitat—much of it important to the conservation and recovery of various rare, threatened, or endangered species—makes protection of remaining tidal marsh habitat extremely important. Habitat loss and fragmentation is the primary reason that tidal marsh species are in danger of extinction, so additional habitat loss is counterproductive to recovery. Genetic diversity within each species must be retained to increase its likelihood of persisting through unpredictable events (*e.g.,* drought, climate change). Genetic composition has not been investigated for most of the featured taxa, so protection of remaining populations is prudent. Retaining the full range of site diversity in which a species occurs (as a surrogate for genetic diversity) increases the likelihood of persistence under unpredictable future environmental conditions.

Habitat protection includes permanent protection of landscape, topographic, and soil features that support hydrologically and ecologically functional tidal marsh ecosystems, including space for erosional and depositional dynamics, upland transition zones, and sea level rise. To protect remaining habitat, it is desirable to acquire privately owned tidal marsh habitat, restorable areas, or buffer land, from willing sellers, in fee title or conservation easement. Acquisition projects should consider the ability of a site to accommodate a range of sea level rise scenarios, be sufficient to allow habitat and listed species to migrate landward and provide for corridors, where possible, between separated populations under previous sea level scenarios. Additional lands dedicated to conservation will enhance restoration and management options over larger areas, and increase continuity and functionality of tidal marsh habitats.

From a regulatory standpoint, the general goal of avoiding disturbance to tidal marsh should be undertaken with an understanding of the larger restoration goal. For example, it likely would be advantageous to the ecosystem to eradicate non-native cordgrass in an existing marsh, even though it may require temporary destruction of native marsh vegetation in the short-term.

The Stepdown Narrative below includes actions to identify and protect remaining tidal marsh areas, as well as a series of research actions to characterize, maintain, and restore functional tidal marsh ecosystems.

2. *Manage, restore, and monitor tidal marsh habitat to promote the recovery of listed species and the long-term conservation of species of concern and other tidal marsh species.*

Managing, restoring, and monitoring tidal marsh ecosystems will speed the recovery process. Methods for effective habitat management, restoration, and monitoring in tidal marsh ecosystems are continuously being evaluated and improved. Therefore, strategies must remain adaptive (*i.e.*, responsive) and must be tied to population and ecosystem trends. Where populations of species covered in this plan are currently stable or increasing, existing habitat management may be adequate, but if populations or habitats of covered species begin to decline, changes in management must be considered. For populations that are declining, revised habitat management techniques must be based on the best available scientific data, research, or observed outcomes of management from similar situations. Planning for restoration, management, and monitoring is important, as is maintaining the flexibility to adapt plans in response to new developments or new information.

Management-- Appropriately managing habitat serves to maintain habitat quality and function, correct problems, minimize impacts, and provide benefits to species' and ecosystem recovery. Management includes all land, environmental, and species management actions, from flood control to eradication of invasive species. Many tidal marsh areas, whether existing, restored, or in process of restoration, will need active management for some time to foster ecosystem functions and native species.

Habitat management must be conducted adaptively, consciously investigating and clarifying the effects of various management methods or environmental factors, and adjusting management accordingly. Adaptive management requires, and is linked with, monitoring of habitat or population response. Written adaptive management plans should be prepared for all tidal marsh areas under conservation management. Adaptive management plans help assure comprehensive attention to recovery needs, while allowing—even requiring—change to meet new needs or new understanding. Like restoration projects, management plans should describe purposes and goals and incorporate explicit, measurable success criteria.

Below are some strategies for common management of tidal marshes:

A major focus of tidal marsh management at least in the near term must be monitoring and controlling invasive non-native species, beginning with some that actually threaten the continued existence of the native tidal marsh ecosystem. With control of invasive *Spartina* now nearly complete, the focus is on restoration of habitat for the California clapper rail, including revegetation with *Spartina foliosa* and other native vegetation. See further discussion below on invasive *Spartina* under the San Francisco Estuary regional recovery strategies. A variety of non-native cordgrass species present control problems in the San Francisco Bay Estuary, Bolinas Lagoon, Drakes Estero, Tomales Bay, Humboldt Bay, and elsewhere on the Pacific coast (Smith *et al.* 2002). Perennial pepperweed (*Lepidium latifolium*) and other non-natives also are affecting substantial areas of California tidal marsh and will require control (May *et al.* 2003).

Monitoring and control of non-native or artificially abundant predators that reduce survival or reproduction of rare or endangered native marsh species is another important element of invasive species control. Controlling non-native red fox predation on California clapper rails is one example, discussed further under regional recovery strategies for the San Francisco Estuary. Control techniques are evolving rapidly, so managers instituting control programs should consult the latest available information and contact personnel with recent field experience.

Other management issues include controlling water quantity and quality, dealing with contaminants of water or sediments, guiding recreation, coordinating with landfills on avian predator problems, managing grazing to limit destructive impacts and maximize potential benefits, and maintaining necessary roads, levees and other infrastructure. Consideration of reduction of impacts from recreation should be broad enough to account for yet-unidentified activities (*e.g*., as kiteboarding was in the recent past).

Restoration— Some of the greatest gains in tidal marsh recovery will be made from restoring historic former tidal marsh or other restorable area to functioning tidal marsh habitat. Because so much historic tidal marsh has been altered or lost, and the resulting limitation and fragmentation of habitat continues to threaten species covered in this recovery plan, habitat restoration will allow and speed the recovery and conservation of tidal marsh species. In fact, specifically, the prevention of tidal marsh species extinction is sure to hinge on the careful and prompt development and protection of the high marsh zone, including the laying back of levees at a 30 to 1 or gentler slope during rebuilding of necessary levees. Tidal marsh restoration projects can be quite varied, from removing fill and planting native species at engineered elevations, to breaching a levee and allowing sedimentation and natural colonization to gradually re-build a marsh. Partial restoration of tidal action (rather than full tidal action) or controlled water levels also can sometimes achieve certain conservation objectives, as can the beneficial re-use of dredge material. Deeply subsided former marsh areas present particular problems, but some projects are proposed to restore them by bringing in sediment to reduce depths. Significant challenges in tidal marsh restoration will include keeping non-native species from invading areas intended for restoration, balancing tidal marsh restoration with other regional conservation needs, such as conservation of shorebirds and waterfowl, and planning for rising sea level. A great deal of information is available about tidal marsh restoration needs, methods, and projects (Philip Williams and Associates, Ltd. and Faber 2004).

Any tidal marsh restoration project should include measurable success criteria by which the project can be objectively evaluated. Accepted criteria for successful tidal marsh restoration need to be agreed upon by experts in the field, with these criteria being improved as new information becomes available. The Bay Institute, in 2004, published *Design Guidelines for Tidal Wetland Restoration in San Francisco Bay* which evaluates and documents actual restoration experience in San Francisco Bay (Philip Williams and Associates, Ltd. and Faber 2004). The document, which discusses objectives, constraints, design guidelines, and recommendations central to most tidal marsh restoration projects, should be consulted prior to tidal marsh restoration conducted per recommendation of this recovery plan. Though Philip Williams and Associates, Ltd. and Faber (2004) is the best guidance available now, it may be replaced with a better document during the life of this recovery plan. As data from current and future restoration projects add to the knowledge base and understanding, design guidelines will become more refined. It is clear that key elements of restoration include vegetation structure (height and thickness relative to tide height); channel structure; and high tide refugia and transitional areas.

Timing and sequencing of tidal marsh restoration needs to be considered from a biological and evolutionary viewpoint. For example, successful habitat for the southern subspecies of the salt marsh harvest mouse is dependent on the ability to: 1) create complete tidal marshes with broad upper marsh plains dominated by *Sarcocornia pacifica* that grade into peripheral halophyte (*i.e.*, high marsh) and upland habitats; 2) create these marshes to connect existing and restored tidal marshes within and adjacent to the project area, and 3) create these restored marshes in close proximity to existing marshes that provide suitable salt marsh harvest mouse habitat. These nearby interim mouse refuges will be crucial for survival of populations while new adjacent habitat is maturing and becoming suitable. Given the potential trade-offs between restoring tidal marsh and preserving existing salt marsh harvest mouse populations in currently diked baylands, a spatially-explicit restoration sequence should be developed to optimize the viability of multiple species' populations over time.

The restoration of large blocks of tidal marsh has numerous advantages. For example, large marshes increase distances from upland predator den/nest sites and impede terrestrial predators. Large areas of marsh have fewer urban edge effects, including human-related disturbance, contaminant inputs, and litter that can attract rodent predators. In addition, the size and complexity of tidal slough networks increases as marsh size increases, providing more nesting areas and high tide refugia. Spautz *et al*. (2006) showed that song sparrow abundance increases with marsh patch size and surrounding natural upland proportion, common yellowthroat abundance decreases with perimeter-area ratio (an index of fragmentation), and black rail abundance increases with tidal marsh patch connectivity as well as surrounding natural upland proportion. Large-scale restoration projects are also more efficient than smaller efforts, and yield larger net benefits to the species covered in this recovery plan.

Long-term recovery actions should focus on increasing habitat suitability and abundance in an appropriate distributional pattern. Important priorities for habitat restoration are those areas with the most rapid restoration potential relative to the amount of time and effort invested. Habitat restoration should first occur on suitable habitat near existing large populations of California clapper rail and/or salt marsh harvest mouse and interim reserves, and then provide links between those areas. Areas in need of restoration but absent non-native species (especially invasive *Spartina* and non-native red fox) and areas least subsided may be considered first priority for restoration to tidal marsh, as well. Restored tidal marshes with California clapper rail or salt marsh harvest mouse populations should coalesce with one another to form extensive, contiguous habitats in large blocks, thus reversing fragmentation of habitats and populations. This can be accomplished by either restoring very deep (from shore to bay) marshes or by creating deep enough marshes and also creating deep and gentle enough sloped high marsh that such areas could act as fully functional corridors.

New marshes should be connected to each other and/or to existing marshes to decrease the number of isolated marshes. Broad corridors of appropriate vegetation will provide stepping stones to allow species to colonize newly created marshes and move between marshes that are currently isolated. Dispersal facilitates exchange of genetic material among subpopulations and promotes recolonization of any sites that experience declines or local extirpation.

While the mid-marsh should not be filled or over-engineered (because that results in marshes without complex channel structures), the high marsh must be engineered to have a more gradual slope in as many areas as possible. Transitional habitat used as high tide refugia can be created in the form of natural berms and levees along the larger channels within the middle marsh. Creating large marshes with complex channel systems provides sufficient drainage area to allow sedimentation to create natural levees along the larger channels. Philip Williams and Associates, Ltd. and Faber (2004) suggest that the technique of constructing starter channels and starter levee does not work; they suggest the best way to get complex internal channel systems is by slow deposition that naturally creates such channels if the marsh is large and deep enough to support them.

Restoration of tidal marshes must include foundations for large high marsh belts, wide, gently sloping gradients between mean higher high water and local elevations of storm high tide lines (driftlines). This restoration should include the laying back of levees at a 30 to 1 or gentler slope during rebuilding of necessary levees. This design feature may accommodate a range of sea-level rise scenarios. In particular, preserved and restored marshes must whenever possible be connected to broad undeveloped, gently sloped adjacent terrestrial habitats. Marshes separated from shore by ponds or levees run the risk of being submerged by increased sea level, or prevented by erosion from accreting new sediments or maintaining marsh elevations. Plans should be explored to reconnect flood control channels, where possible, with marsh flood plains to increase the amount of sediment reaching the tidal marsh. There are a few locations where high tidal marsh ecotone can be restored in areas that adjoin existing grasslands. Such locations warrant extra consideration as they are prime areas for restoring the transitional or peripheral halophyte zones critical to the salt marsh harvest mouse and other species during high tides. Also, it is more imperative to provide this ecotonal habitat where the adjacent middle marsh is shallow (from shore to bay).

Habitat Monitoring— Monitoring of habitat condition is an important component of good habitat management, to assess whether restoration or management actions are working, and to detect undesirable or unexpected conditions. In general, monitoring should be conducted for multiple years and involve implementing standardized species and habitat surveys and assessments. Monitoring may be more intensive at first to obtain baseline information, to ensure that the objectives are being met, or if progressive change in the habitat is expected, such as following restoration work. The data recorded must be adequate to address the success criteria of the restoration or management plan. Monitoring should always include an assessment of the existing threats. If a protected area is subjected to numerous threats, more frequent monitoring may be needed. If a location is highly protected (*i.e.*, strictly a preserve), then monitoring needs may not be as intensive. To be useful, habitat monitoring reports should be prepared promptly and made generally available to tidal marsh land managers and managing agencies, including the U.S. Fish and Wildlife Service.

Monitoring itself may have a negative effect on species and habitat if not carefully designed. This source of disturbance must be considered in the development of monitoring plans, together with other potential coinciding marsh activities (*e.g*., invasive plant control, mosquito management, research).

3. Conduct range-wide species status surveys/monitoring and status reviews for listed species and species of concern.

Species typically must increase in numbers of individuals, numbers of populations and/or geographic extent over the long term to achieve recovery. Declines or contractions in populations must be detected, halted, and reversed, if populations are to be self-sustaining. Species status surveys and monitoring allow us to follow such population trends. To delist a species, it must be determined that the species is no longer subject to the threats that caused it to be listed. Therefore, each threat a species faces also must be monitored to ensure recovery objectives and criteria are being met. Delisting will not be appropriate until the threats to population sustainability have been ameliorated or eliminated.

Monitoring is frequently conducted for known populations, yet the distribution and abundance of many of the species covered in this recovery plan are incompletely known. Therefore, range-wide population status surveys are needed, incorporating areas not recently studied, including areas where the species covered in this plan are not known to occur. Field surveys also will help to avoid or minimize impacts of projects proposing actions in or near potential habitat. Surveys should be conducted in all potential habitat types. Any new populations found may increase the speed and likelihood of recovery. Status surveys conducted for species not covered in this plan will increase the understanding of these species, identify needs and threats, and help lead to actions that may preclude the need to list them as threatened or endangered.

Species status surveys and monitoring should follow appropriate U.S. Fish and Wildlife Service and/or State guidance whenever it is available. Specific information can be obtained from the U.S. Fish and Wildlife Service and CDFW. Biologists monitoring certain species, such as salt marsh harvest mouse and California clapper rail, must obtain Endangered Species Act section 10(a)(1)(A) recovery permits as well as scientific collecting permits issued by CDFW.

Demographic monitoring, which includes trend analysis and determination of limiting factors (Pavlik 1994), is one method for predicting plant population trends and focusing efforts on the causes of population decline at a particular site. Animal species survey and monitoring requirements will vary depending on species, as well as site location, site conditions, and time of year. Status surveys and monitoring should always include assessment of the existing threats to the species.

Reports of survey and monitoring work should be completed promptly and made publicly available so that findings can be applied in all conservation and recovery efforts. In all cases, an attempt to quantify probability of detection is strongly recommended.

4. Conduct research necessary for the recovery of listed species and the long-term conservation of species of concern.

Research on many aspects of species' biology and tidal marsh ecology will help to meet recovery goals successfully and in a cost effective manner. Making recommendations on research needs and proposals will be a responsibility of the U.S. Fish and Wildlife Service and the Recovery Implementation Team (RIT), a group to be formed to implement this recovery plan and discussed further below. Examples of research topics include demographic analyses of covered species or techniques for ecosystem management or restoration.

5. Improve coordination, participation, and outreach activities to achieve recovery of listed species and long-term conservation of species of concern.

To most effectively implement the recovery plan, tidal marsh researchers, regulators, and managers must closely coordinate. As described further in the Stepdown Narrative below, a Recovery Implementation Team (RIT) will be developed which will include tiered regional or species-specific working groups. The purpose of the RIT will be to advise the Regional Director on matters associated with recovery of the species covered in this plan and to help the Regional Director coordinate, refine, and expedite recovery actions, including prioritization of research tasks. In addition to prioritizing and implementing technical recovery tasks, the RIT will be an outlet for effective public outreach and education.

Public participation is also vital to ecosystem recovery. One goal of the recovery plan is to coordinate and bring together landowners, both public and private, to achieve conservation and recovery needs and to form lasting partnerships. Because a substantial percentage of tidal marsh or restorable areas is under public ownership, working with public lands agencies to form beneficial relationships is key to the recovery strategy. In addition, the U.S. Fish and Wildlife Service recognizes the value of providing, with careful planning to reduce or avoid impacts to species, public access and recreational opportunities, as a powerful means to foster support and appreciation for tidal marsh species and habitat.

Partnerships with private landowners are extremely important as well, because of the need to link fragmented tidal marshes with appropriate species dispersal corridors and refugia. Many private landowners, local agencies, organizations and citizens are willing participants in recovery efforts, but they may not have the information necessary to make fully informed decisions. Outreach to develop working relationships with all interested parties is important. Education will be a key component in increasing the public's general awareness of tidal marsh ecosystems and participation in tidal marsh restoration and recovery. Outreach to all stakeholders in regards to climate change impacts on California tidal marsh ecosystems will be important given predictable future tensions over the allocation of water and land use for human needs versus ecosystem and species needs. Outreach and educational programs will be developed in cooperation with schools, agencies, conservation organizations, and stakeholder groups.

Age-appropriate educational materials should be prepared collaboratively by species experts and public educators, and distributed to (1) environmental journalists in the region, (2) public schools at all levels, and (3) undergraduate ecology programs at universities and colleges. Public outreach materials should avoid presentation of general priciples of biology and instead focus on clear audience-appropriate explanations of the principal threats to the species (with emphasis on local conservation issues), the rationale for recovery strategies and actions, and the results or progress of local recovery actions.

2. Regional-level recovery strategies

The general ecosystem strategies apply throughout the planning area, but there are regional differences that call for differing emphases or unique strategies in some areas. The level of detail is greatest for the San Francisco Bay Estuary, which has not only the greatest concentration and magnitude of endangered species recovery needs, but is the largest, most complex, and most altered of California's estuaries. A checklist of species to consider in recovery planning (species with and without special legal status) of estuaries in each region is below. These lists should not be considered exhaustive, however, and other sources and updates should be consulted to obtain complete lists, including a current species list from the appropriate U.S. Fish and Wildlife Service field office.

Humboldt Bay and north coast

Regional strategies for Humboldt Bay and the coast north from Bodega Bay focus on protection and restoration of tidal marsh habitat, particularly for sensitive plants. Though this area historically supported California clapper rail, no listed species covered by this recovery plan now exist within, or are anticipated to expand into this area. Therefore, no corresponding Recovery Unit for this area has been developed. Humboldt Bay, however, supports several sensitive tidal marsh species and many actions recommended in this recovery plan would benefit those species immensely. Further evaluation, planning, and funding are needed to advance tidal marsh conservation in the region. A checklist of species to consider in planning for the region is given in **Table III-4**. Please contact the U.S. Fish and Wildlife Service's Arcata Fish and Wildlife Office for an updated list.

Table III-4. Regional Species Planning Checklist: Humboldt Bay and North Coast

Federally listed species:

<u>Animals</u>

- western snowy plover (*Charadrius alexandrinus nivosus*)
- tidewater goby (*Eucyclogobius newberryi*)
- steelhead (*Onchorhynchus mykiss*)

Other species of regional conservation significance:

<u>Animals</u>

- harbor seal (*Phoca vitulina*)
- Bryant's savannah sparrow (*Passerculus sandwichensis alaudinus*)
- shorebirds, wading birds, waterfowl (multiple species)

Plants
Astragalus pycnostachyus ssp. *pycnostachyus* (marsh locoweed) *Baccharis douglasii* (salt marsh baccharis) *Chloropyron maritimum ssp. palustre* (Point Reyes bird's-beak) *Carex* spp. (salt marsh edge sedges) *Castilleja ambigua* ssp. *humboldtiensis* (Humboldt Bay owl's-clover, northern form) *Glaux maritime* (sea-milkwort) *Symphyotrichum subulatum* var. *ligulatus* (slim aster) *Zostera marina* (eelgrass)

Habitat should be secured to increase habitat and populations for endemic rare marsh plants. The Humboldt Bay National Wildlife Refuge is authorized to expand from the present approximately 1416 to 3683 hectares (3500 to 9100 acres); however, there is considerable overlap between the authorized refuge area and tidelands under the authority of the Humboldt Bay Harbor Recreation and Conservation District which does not specifically manage lands for rare plants. Currently the refuge has no large active acquisition projects. Tidal lands or potentially restorable tidelands for conservation should be identified, comprehensively reviewed and prioritized, and acquired from willing sellers. Existing fringing tidal marshes should be protected against filling or dredging.

Local initiatives to restore native tidal marsh and to control non-native species (such as dense-flowered cordgrass) should be supported. Tidal marsh enhancement and restoration projects should prioritize areas that will benefit rare plant populations, such as *Castilleja ambigua* ssp. *humboldtiensis*, *Chloropyron maritimus* ssp. *palustris*, *Astragalus pycnostachyus* var. *pycnostachyus*, and local endemic forms of the widespread *Grindelia stricta* var. *stricta* complex. Rare plant populations should be expanded in suitable habitat, both in restored and selected existing unoccupied marshes.

Diked baylands between the historic high tide line and Mad River Slough should be restored to full tidal action, allowing slow sedimentation to restore tidal marsh close to remnant populations of tidal marsh plant species of concern. A wide, deep block of tidal marsh should be restored in diked baylands at the north end of Arcata Bay, adjacent to wide tidal flats that buffer erosion and supply some local sediment source. Placement of suitable dredged sediments or fill from excavated, former marsh areas may be needed here to supplement the landward edge of the restored marsh, to enable marshes to keep pace with sea level rise and/or to raise the elevation of diked lands planned for restoration to allow for gradual evolution of vegetated marsh plain. In fact, a tidal restoration project is currently being conducted at McDaniel Slough (Pickart, *in litt.* 2009). Local in-bay tidal marshes at Field's Landing and Elk River Spit should be periodically surveyed and protected. Restoration at Salmon Creek may result in restoration of diked baylands at the south end of Arcata Bay to tidal action adjacent to wide tidal flats. Tidal flats in the South Bay should be studied to forecast the potential for natural accretion to elevations supporting pioneer tidal marsh succession. Opportunities for tidal marsh restoration in the tidal reaches associated with the Eel River mouth, just south of Humboldt Bay, should be explored and pursued. All existing and current restoration projects should be extensively monitored and adaptively managed to inform future restoration projects.

Dense-flowered cordgrass should be eradicated from Humboldt Bay, Eel River, and Mad River estuaries. Methods for mechanical eradication have been developed at Humboldt Bay National Wildlife Refuge, and an effort is underway, pursuant to the West Coast Governor's Agreement, to develop a regional eradication plan. Localized control is not feasible due to tidally dispersed seeds. Communication and cooperation with the San Francisco Bay Invasive *Spartina* Project should aid both cordgrass control efforts.

Potential habitat for rare plants should be mapped and comprehensively surveyed. Ongoing monitoring of rare plant populations should be established. Relict tidal marshes with native plant species of concern, particularly Indian Island—in collaboration with the Table Bluff Reservation Wiyot people and the Humboldt Bay NWR—should be periodically surveyed and protected.

Special consideration should be given to small pockets of tidal marsh along the coast in areas between Bodega and the Eel River estuary, such as along tidal reaches near the mouths of coastal rivers or creeks or around small tidal lagoons or sloughs. Examples of such tidal reaches include Big River, Tenmile River, and Mattole Creek. Such areas may serve as resting or even breeding areas for dispersing birds like California black rails or California clapper rails, and many need to be surveyed for rare or endemic plant populations.

San Francisco Bay Estuary

The San Francisco Bay Estuary as a whole encompasses Central/Southern San Francisco Bay, San Pablo Bay, and Suisun Bay Area Recovery Units. Specific subregional strategies are discussed in separate sections below. The following general strategies apply throughout the San Francisco Bay Estuary:

Protect remaining tidal marsh and tidal flats. Tidal marsh in the San Francisco Bay Estuary has been severely reduced and what remains is valuable for recovery of species included here. Historical tidal marsh remnants are particularly important (pre-existing, as opposed to recently formed marsh). However, these protective principles need to be flexible where restoration-focused projects would affect small marsh areas to restore much larger areas.

Tidal flats are valuable habitat for water birds, fish, mollusks and other species. They provide substrate and a source of sediment for tidal restoration and also are important in reducing wave energy and erosion. Tidal flats are essential to tidal marsh maintenance, since without tidal flats many marshes would erode and lose substantial area. Dredging, filling, or other direct modification of tidal flats should be severely discouraged.

Restore tidal marsh. Recovery of tidal marsh species will be fostered through significant amounts of tidal marsh restoration. Placement of suitable dredged sediments or fill from excavated, former marsh areas may be needed to supplement the landward edge of the restored marsh and to enable marshes to keep pace with sea level rise. This work should be conducted in coordination with regional agencies that regulate bay fill and water quality. Restoration strategies in the estuary should build on the following principles:

1) Restore tidal marsh ecosystems around nuclei of existing listed species populations;

2) Phase restorations to minimize local population impacts and maintain local source populations;
3) Focus restoration on large contiguous areas, where possible;
4) Restore functional connectivity between species populations with low mobility;
5) Seek extensive marsh creek development, pickleweed plains, high marsh halophyte zones, marsh-to-terrestrial ecotones, broad connection to adjacent uplands, and, where appropriate, natural salt pans and shallow ponded tidal habitat;
6) Seek buffers from developed areas;
7) Remove levees and other movement corridors for terrestrial predators, where feasible and where not in place for protection from erosion as part of restoration efforts;
8) Remove above ground poles, towers, and habitat-inappropriate trees to reduce raptor perches;
9) Accommodate a range of sea level rise scenarios, ideally with long, gentle gradients;
10) Plan and provide funding for long-term monitoring and adaptive management, including invasive plant control and predator control.

Non-native plant species control. Reduction of impacts from the growth of non-native plant species is an important component of the recovery strategy in the San Francisco Estuary and is further detailed below by region.

Predator control. Controlling local populations of non-native or artificially abundant predators will be an important recovery strategy for tidal marsh birds and mammals throughout the estuary. California clapper rails are well known to be decimated by predation from a variety of species, as discussed above in the California clapper rail species.

Reduction of litter is extremely helpful in reducing local predation problems. Use of predator-proof or predator-deterring trash cans (such as those used by the National Park Service to keep bears out) should be used at any park, trailhead, or other facility located within or near a marsh. Also, regular trash pickup should occur at all facilities in these areas to limit the attraction of corvids, gulls and mammals. New potentially litter-generating development projects or activities planned near marshlands should include a funded predator management program component.

To date the only effective methods for eliminating red fox involve limiting fox access to the marsh, trapping, and shooting by trained animal control specialists. In addition, denning habitat for foxes should be removed. Similar control techniques are applicable to other mammalian predators. These techniques should be applied, as appropriate, to thoroughly protect rail populations, and more effective methods should be investigated.

Predator control necessitates a public education component, as well. Numerous actions can be undertaken by local homeowners or visitors to the marsh to reduce the impact of predators on listed species. Local governments should be encouraged to prohibit feeding of feral or otherwise free-roaming cats within their boundaries, illicit feeding stations should be located and removed, and homeowners adjacent to tidal marshlands should be notified that cat trapping may be conducted to protect endangered species. In addition, where new housing developments are planned, funds to conduct predator management should be leveraged by homeowners groups.

Norway rats should be controlled by eliminating their nest habitat and attractive food sources (garbage, etc.) when practical, and by trapping or using bait stations in other areas. Rock slope protection (rip-rap) which provides rat habitat can productively be replaced with low-angle slopes vegetated with erosion-resistant native plants like *Leymus triticoides* (creeping wildrye) and *Distichlis spicata* (saltgrass). Vehicular barriers can be used to restrict illicit waste dumping near tidal marsh habitat; and buffer zones can separate main rat populations from the marsh. In addition, conducting trapping of target mammalian species near landfills and other food sources will help prevent these animals from dispersing to nearby marsh areas.

A potentially effective means of controlling terrestrial predators, but one likely to take time to implement fully, is to restore large marshes with no internal levee access. Terrestrial predators are less likely to venture deep into undiked marsh, so habitats in large continuous marshes are protected from serious predator impacts. Restoring high tide refugial habitat that is isolated from levees within large marshes might enhance this protection.

Avian predators are also important predators of tidal marsh birds and mammals, as discussed above in Chapter II in the California clapper rail species account. Landfills and urban areas provide food resources that would otherwise not be available, while buildings, towers, and other human-made structures provide nesting and roosting opportunities. To reduce predation levels, artificial food resources should be reduced and perches such as light poles, utility poles and towers, and habitat-inappropriate trees should be removed from marshes. When this is impractical, land managers should conduct local control of target avian species and should discourage nesting of these species in and near marshlands whenever possible. For instance, red-tailed hawk and raven stick nests could be removed from electrical transmission and distribution lines, with cooperation of utilities companies. Removal of nests must be done in accordance with the Migratory Bird Treaty Act of 1918.

Public use. Public use is important to tidal marsh appreciation and should be encouraged. However, public use should be designed with careful consideration of accompanying risks and impacts to tidal marsh species. Generally, public use should be guided to relatively few, lower impact areas. Visual access should be enhanced over physical access by providing viewing stands but minimizing trails into marsh habitat. Any shoreline trails considered vital and low-impact should be routed well away from high tide edge and high tide refugial habitat, especially at small marshes or those with little refugia within the marsh plain itself. The outboard sides of all levee trails adjacent to tidal marshes should be vegetated with native shrubs and grasses to provide buffers to protect refugial habitat. Discretion should be retained to restrict or close access to minimize impacts, such as during California clapper rail breeding season or extreme high tides. Pets should be excluded and feeding of feral or otherwise free-roaming animals prohibited.

Flood control. Levees that protect development from bay flooding (flood control levees) should be relocated to the development edge. Where development abuts tidal marsh and the levee effectively will be high tide refuge and upland ecotone for tidal marsh species, flood control levees (inboard levees) should ideally have long, gentle slopes (*e.g.,* 1:20 or less) from marsh toe to levee crown and be vegetated with appropriate native species. Flood control levees should be planned to accommodate a range of sea level rise scenarios. Tidal flats, marshes, and salt ponds or lagoons all act to dissipate the energy of flood surges, and these habitats should be encouraged outboard of flood control levees to increase protection. Flood control levees that are currently at the bayward perimeter of salt ponds or diked baylands should be graded to marsh elevations, or removed, consistent with restoration plans.

Remove dikes, utility lines, pipes, old right-of-ways, and other infrastructure. Existing infrastructure in baylands can present substantial obstacles to high-quality tidal marsh restoration. Levees provide predator habitat and access deep into tidal marshes, fragment marsh area, and block tidal flows and drainage. In general they should be removed or graded down to marsh elevations. Utility lines and pipelines (and any levee access roads that serve them) should be removed, re-routed or maintained by other access, such as boat, helicopter, hovercraft, track vehicle, or access across temporary mats. Consideration may be given to undergrounding utility lines, perhaps through mechanisms such as section 7 or section 10(a)(1)(B) of the Act.

Research. A great deal of research is needed to help us better understand how to recover the species of the San Francisco Bay Estuary. In the future, the Recovery Implementation Team (RIT) will advise the U.S. Fish and Wildlife Service on updated topics and priorities for study. Through an adaptive management framework, results of these studies will be applied to better manage for this recovery plan's covered species. Further research tasks that are presently identifiable are mentioned in recovery strategies below, and outlined in the Stepdown Narrative section.

Suisun Bay Area to the Delta

This discussion involves Carquinez Strait (east of the Carquinez [I-80] Bridge), Suisun Bay, Honker Bay, Grizzly Bay, Suisun Marsh, the Contra Costa shoreline east of Carquinez Strait, and portions of the Sacramento-San Joaquin River delta (**Figure III-2**), though the Recovery Unit of the same name does not extend to portions of the Sacramento-San Joaquin River delta. With rising sea level, it is anticipated that areas important to the recovery and conservation of tidal marsh species will extend upstream into present-day brackish to freshwater areas including parts of the Delta. A sample regional species planning checklist for the Suisun Bay Area Recovery Unit is given in **Table III-5**.

Restoration of tidal marsh will be a major recovery strategy in this region. Integrating restoration with appropriate habitat support for the migratory waterbirds of the Pacific flyway will be essential because of the great significance of the region for migratory waterfowl. In addition, substantial weight will be given to tidal marsh restoration to support the conservation and recovery of special status estuarine fish species (Delta smelt, white sturgeon). These species use tidal marsh habitat, particularly vegetated banks of brackish tidal creeks during low salinity phases.

Table III-5. Regional Species Planning Checklist: Suisun Bay area to the delta

Federally listed species:

Animals

salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*)
California clapper rail (*Rallus longirostris obsoletus*)
California least tern (*Sterna antillarum browni*)
western snowy plover (*Charadrius alexandrinus nivosus*)
California tiger salamander (*Ambystoma californiense*)
California red-legged frog (*Rana aurora draytonii*)
steelhead (*Onchorhynchus mykiss*)
chinook salmon (*Oncorhynchus tshawytscha*)
Delta smelt (*Hypomesus transpacificus*)
Delta green ground beetle (*Elaphrus viridis*)
vernal pool tadpole shrimp (*Lepidurus packardi*)
vernal pool fairy shrimp (*Branchinecta lynchi*)
white sturgeon (*Acipenser transmontanus)*

Plants

Cirsium hydrophilum var. *hydrophilum* (Suisun thistle)
Chloropyron molle ssp. *molle* (soft bird's-beak)
Lasthenia conjugens (Contra Costa goldfields)

Non-listed species covered by this recovery plan:

Animals

Suisun shrew (*Sorex ornatus sinuosis*)
California black rail (*Laterallus jamaicensis coturniculus*)
saltmarsh common yellowthroat (*Geothlypis trichas sinuosa*)
Suisun song sparrow (*Melospiza melodia maxillaris*)
old man tiger beetle (*Cicindela senilis senilis*)

Plants

Lathyrus jepsonii var. *jepsonii* (Delta tule pea)
Spartina foliosa (California cordgrass)

Other species of regional conservation significance:

Animals

North American river otter (*Lutra canadensis*)
Virginia rail (*Rallus limicola*)
sora (*Porzana carolina*)
Bryant's savannah sparrow (*Passerculus sandwichensis alaudinus*)
peregrine falcon (*Falco peregrinus*)
migratory waterfowl, shorebirds, wading birds (multiple species)
western pond turtle (*Clemmys marmorata*)

green sturgeon (*Acipenser medirostris*)

longfin smelt (*Spirinchus thaleichthys*)
Sacramento splittail (*Pogonichthys macrolepidotus*)
Pacific lamprey (*Lampetra tridentata*)
river lamprey (*Lampetra ayresi*)
Antioch anthicid beetle (*Anthicus antiochensis*)
Sacramento anthicid beetle (*Anthicus sacramento*)

<u>Plants</u>

Agrostis exarata, *Leymus triticoides*, tidal marsh edge populations (salt marsh edge grasses)
Astragalus tener ssp. *tener* (alkali milk-vetch)
Atriplex joachiniana (San Joaquin saltbush)
Baccharis douglasii (salt marsh baccharis)
Carex spp. (salt marsh edge sedges)
Castilleja ambigua ssp. *ambigua* (salt marsh owl's-clover)
Zeltnera trichanthum (alkali centaury)
Centromadia pungens ssp. *maritima* (maritime spikeweed)
Cicuta maculata var. *bolanderi* (Bolander's spotted water-hemlock)
Lasthenia glabrata ssp. *glabrata* (smooth goldfields)
Downingia pulchella (downingia)
Eleocharis parvula (small spikerush)
Glaux maritima (sea-milkwort)
Grindelia paludosa (Suisun gumplant)
Heliotropium curassavicum (seaside heliotrope)
Iva axillaris var. *robustior* (povertyweed)
Lasthenia platycarpha (alkali goldfields)
Layia chrysanthemoides (smooth tidytips)
Lepidium latipes (native peppercress)
Lilaeopsis masonii (Mason's lilaeopsis)
Plagiobothrys mollis var. *vestitus* (Petaluma popcornflower)
Plantago elongata (annual coast plantain)
Pluchea odorata (salt marsh fleabane)
Ruppia maritima (ruppia)
Senecio hydrophilus (salt marsh butterweed)
Sium suave (water parsnip)
Symphyotrichum lentum, A. chilensis and intergrades (Suisun and Chilean aster complex)
Symphyotrichum subulatum var. *ligulatus* (slim aster)

Restoration of tidal marsh creek habitat near the *null zone* of Suisun Bay and Honker Bay is a priority for recovery of estuarine fishes as well as a benefit to tidal marsh species. Morrow Island, western Grizzly Island, Simmons Island, Wheeler Island, Chipps Island, and Van Sickle Island are in favorable receptive positions for tidal sedimentation as well as flood deposition from the Sacramento and San Joaquin rivers, and as such may be good candidates for rapid establishment of tidal marsh habitats. The positional advantages of tidal marsh restoration in eastern Suisun Bay/Honker Bay sites, adjacent to the productive null zone of the estuary, raise their potential recovery value for estuarine fish, and may provide good habitat for rare plants like

Lilaeopsis masonii (Mason's lilaeopsis), and endangered plants like *Chloropyron molle* ssp. *molle* and *Cirsium hydrophilum* var. *hydrophilum.*

At present, the Suisun Bay area supports about 7,625 acres of tidal marsh out of an historical extent of roughly 65,000 acres (Estrella *in litt*. 2007). Based on all species habitat, connectivity, and ecosystem needs, it is anticipated that restoration will bring the total tidal marsh acreage in Suisun Bay area to a total of between 10,000 and 15,000 acres. Precedence should be given to restoring sites that would expand habitat adjacent to significant populations of listed species. Sites that include a gradual transition from high marsh to terrestrial areas also are important—not only to provide ecotonal habitat but also to allow marsh habitats to migrate up-gradient with rising sea level. Other priorities for restoration include sites that connect other tidal or restoration areas, sites that provide important ecosystem functions, and sites that otherwise support the recovery strategies of this recovery plan.

Since there is relatively less adjacent development, the Suisun Bay area offers greater opportunities than most San Francisco Bay Estuary areas for preserving and restoring natural transitions from tidal marsh to adjacent upland habitats. Unique tidal marsh-vernal pool grassland transitions with gentle gradients occur in the areas around Hill Slough, Nurse Slough, and Montezuma. These areas are especially deserving of attention for protection and restoration. Eastern Suisun represents one of the only places where landward migration of habitat and species may be possible, given anticipated future sea level rise. In Nurse Slough, fresh-brackish gradients created by Denverton Creek may provide low-salinity refugia for breeding delta smelt. Such drainages also provide potential for riparian habitat restoration near stream mouths, which would enhance ecotonal habitat diversity for species such as saltmarsh common yellowthroats. The area between Cordelia Slough and Peytonia Slough also may merit further restoration consideration. Also, the southeast portion of Rush Ranch should remain closed off to grazing to protect the largest population of Suisun shrews ever captured (Hays and Lidicker 2000).

Many diked areas of Suisun Marsh have subsided, so the initial phases of tidal marsh restoration in deeper areas would create shallow subtidal lagoons deeper than dabbling ducks would select. Sediment supply is less in Suisun Bay than in south San Francisco Bay, restricted by irregular flood flows and dams in the watershed. If marsh accretion is sediment-limited, such lagoons would be slow (years or decades) to achieve habitat values for dabbling ducks. Unassisted re-establishment of natural shallow "marsh ponds" attractive to dabbling ducks (tidal pans in mature brackish marsh) may take decades, or may even fail under accelerated sea level rise. These risks may require more careful site selection (*e.g.*, less-subsided sites) or engineering (*e.g.*, contouring) to ensure continuity of habitat support for both tidal marsh and waterfowl species and established land uses.

A potential restoration technique includes creation of "microtidal" or "muted" lagoons and marsh, which have some characteristics intermediate between non-tidal managed ponds and fully tidal restoration (approximating the "circulating ponds" of George *et al.* 1965). Microtidal areas have restricted tidal circulation, admitting tides only above a certain height or restricting the amount of water entering and leaving, or both. Unlike non-tidal management, they usually remain open to this limited tidal exchange, so some circulation is maintained, and excessive evaporative concentration of salts can be avoided. Because it impounds water, microtidal restoration typically supports ponded areas, and can provide waterfowl habitat. Microtidal areas need not be impervious to extreme high tides, so low-elevation, low-gradient levees or berms subject to occasional overtopping may be acceptable and provide high marsh habitat. With tidal sediment input and essentially continuous ponding, subsidence would be minimized. Salinity in microtidal areas in Suisun Bay would tend to vary seasonally, with salinities low into the late spring—due to water retention from rainfall input and low salinity winter spring tides during the season of elevated freshwater inputs—and ranging to somewhat more saline than open tidal waters in the late summer and fall if concentration by evaporation exceeds the limited tidal circulation. Although a common objective of microtidal restoration would be to minimize active management, some ability to manipulate salinity could be designed into particular projects (*e.g.*, gates to admit larger amounts of less saline water) so that adaptive management is possible. Engineering fixes to prevent subsided areas from ponding too deeply also may be feasible.

Restoring tidal flows to former diked baylands in Suisun Marsh is likely to increase the volume of tidal water (tidal prism) exchanged in the area. How much tidal prism would change would depend on the total volume of diked baylands restored to tidal flows, constraints on tidal flow, and the rate of accretion. Accretion of sediment and organic matter raises the bed elevations of restored baylands, reducing tidal prism as lagoons, flats, creeks and marshes become shallower. Since sedimentation rate is often proportional to water depth, tidal prism would be expected to increase initially, then diminish as mudflats and finally tidal marshes accrete. Tidal prism is one of several factors that affect salinity in the Suisun Bay area. Freshwater outflow from the Delta exerts the greatest control on salinity, but during years of low outflows (drought conditions), increased tidal prism associated with extensive tidal restoration could increase salinities in Suisun Marsh, according to preliminary hydrologic modeling (Suisun Marsh Levee Investigation Team 2000). Improved hydrologic modeling is needed to help plan tidal restoration that has minimal impacts on salinity during sensitive drought years. Tidal restoration should be phased and monitored in response to any regional changes in tidal prism and salinity.

Planning for tidal marsh restoration in the Suisun Bay area should proceed promptly, including decision-making about any levees that can be breached without extensive site preparation, or levees that can be allowed to decline while focusing maintenance dollars on levees with priority for long-term waterfowl management.

Several major restoration projects have begun in the Suisun Bay area. The Montezuma Wetlands project, which would provide a dredge spoil site and use the sediments to increase sub-tidal elevations for tidal marsh restoration. The site covers roughly 2,100 acres, including 340 upland and transitional acres, east of Montezuma Slough in the vicinity of Montezuma. In addition, in fall of 2006, a levee was breached near Little Honker Bay to restore tidal action to the Blacklock parcel, a 70 acre formerly managed wetland property. Currently, the project is in the monitoring phase. A 10-year program to monitor the physical and biological response to the restoration has been developed. Thirdly, the Department of Water Resources plans to tidally restore a 660 acre parcel at Meins Landing and is currently in the project planning phase. Restoration is slated to begin in 2010. Finally, tidal restoration is slated to occur on CDFW220 acre Hill Slough West parcel in approximately 2013.

High priority next steps in restoring tidal habitats in the Suisun Bay area include the following:

1. Expanded tidal marsh around Rush Ranch and Hill Slough, to reinforce the habitat for listed tidal marsh species in Suisun Marsh;
2. A large, continuous block of restored tidal marsh at Morrow Island (Goodyear Slough), the westernmost and more saline marsh, with good potential for increased clapper rail use, and potential linkage for vagrant rails moving between San Pablo Bay and the Suisun Bay area;
3. A corridor of tidal marsh linking restored Morrow Island tidal marsh with the remnant and restored tidal marshes of Rush Ranch and Hill Slough areas;
4. Restoration of tidal marsh around Potrero Hills, Nurse Slough, and Denverton, to re-establish ecotones between vernal pool grassland ecosystems and tidal marsh (benefits for *Chloropyron molle* ssp. *molle*, tolerance of sea level rise, and Delta fish);
5. Restoration or enhancement of large blocks of tidal marsh habitats along the Contra Costa shoreline, centered around populations of *Chloropyron molle* ssp. *molle* and salt marsh harvest mouse; and
6. Restoration of tidal marsh near the null zone (bayfront tidal marsh extending from Ryer Island to Browns Island: Simmonds, Wheeler, Van Sickle, Chipps Islands, and Montezuma Wetlands converted to tidal marsh), with benefits for fish and other species.

Adapting and optimizing management of tidal marsh in the Suisun Bay area will be a second significant recovery strategy in the region. Historical tidal marshes, such as at Hill Slough and Rush Ranch, should be protected and maintained as closely as possible to their natural conditions. Control of invasive non-native plants such as *Lepidium latifolium* is a pressing management need, especially wherever they threaten remaining populations of endangered plants or the integrity of existing preserves, such as Hill Slough, Rush Ranch, or BSRA. Future studies and management should coordinate with the U.S. Department of Agriculture-Agricultural Research Service, Exotic and Invasive Weeds Research Unit who partnered with the California Department of Parks and Recreation in 2009 to conduct a multi-year *Lepidium latifolium* control project at BSRA within habitat occupied by endangered *Chloropyron molle* ssp. *molle*. Preliminary results indicate significant decreases in *L. latifolium* cover and, of equal importance, indicate that careful weed management can proceed in sensitive habitat without loss of rare plants (Grewell 2011).

The non-native *Spartina patens* should be eliminated from BSRA and any other Suisun Bay area locations. The non-native competitor *Apium graveolens* (wild celery) within the very restricted high marsh subhabitats of *Cirsium hydrophilum* var. *hydrophilum* should be eliminated. Non-native predators such as non-native red fox should be monitored and their impacts assessed and controlled as needed, particularly in areas important to California clapper rail and California black rail. Monitoring and control of non-native species also should be a universal element of tidal restoration projects. Land management practices, including levee maintenance, should be adapted to discourage non-native species. Unnecessary levees should be removed or graded down to high marsh elevation to impede predator access to marsh habitat and to enhance tidal circulation and marsh creek development. Limited feral pig hunting has been allowed in portions of Suisun Marsh but a regional-scale eradication effort should be coordinated with CDFW to decrease the species' impact on habitat for sensitive plants. Appropriate grazing practices should be implemented, including minimizing damage to vegetation and banks along tidal creeks.

Salinity management practices using the Montezuma salinity control gates should be re-evaluated, along the lines recommended by the Brackish Marsh Subcommittee of the Suisun Ecological Workgroup (Suisun Ecological Workgroup 2001). While upstream water diversions result in salinities higher than pre-diversion conditions during the spring, analysis indicates the gate operations result in salinities lower than pre-diversion conditions during the fall (C. Enright pers. comm. 2005). Allowing greater tidal range and more variable salinities would improve conditions for rare native marsh plants, among other species (see recovery strategies for *Cirsium hydrophilum* var. *hydrophilum* and *Chloropyron molle* ssp. *molle*).

Management and habitat monitoring programs should be developed and implemented for tidal marsh conservation in the Suisun Bay area. These programs and associated plans should have provisions for adaptation to new information or changed circumstances. Habitat monitoring should be appropriate to identify management needs, including invasive species control problems and changes in habitat extent or quality.

Protecting additional tidal marsh or tidal marsh restoration areas will be a third significant recovery strategy in the Suisun Bay area, in addition to restoration and management. When opportunities exist, additional area should be protected under public ownership or easement. Areas that support listed plants, support recovery strategies for listed animals, support non-listed species covered by this recovery plan, connect existing preserves, or provide needed functions will be of interest for preservation and management. At the time of preparation of this recovery plan, roughly 17,000 tidal or formerly tidal acres are in public-trust ownership in the Suisun Bay area, mostly by CDFW (Bay Area Open Space Council online data). Much of this has historically been managed for migratory waterfowl.

The species recovery and conservation strategies for the Suisun Bay area emphasize endemic tidal species of the North Bay: *Cirsium hydrophilum* var. *hydrophilum*, endemic to Suisun Marsh, and *Chloropyron molle* ssp. *molle*, which is centered in Suisun Marsh and Contra Costa shoreline tidal marshes. The Suisun population of California clapper rails currently is concentrated in the more saline reaches of western Suisun Marsh, and the species reaches the limit of its range in the northern San Francisco Bay Estuary as it tapers off toward the east. The range limits of the clapper rail may shift eastward in the Suisun Bay area as sea level rises, and tidal marsh ecosystem recovery in this region must anticipate this trend.

The salt marsh harvest mouse naturally ranges to the eastern edge of Suisun Marsh, but its modern abundance and distribution in Suisun Marsh is strongly affected by artificial diked conditions of doubtful long-term sustainability. Before widespread diking of Suisun Marsh and development of pickleweed flats, the mouse's natural population density in diverse brackish tidal marsh probably was lower. The strategy for the northern subspecies of the salt marsh harvest mouse in San Pablo Bay and the Suisun Bay area is to transition the populations from reliance on artificially managed, unstable habitat to larger, more secure, more widespread populations in restored tidal marsh ecosystems. This strategy also is more consistent with a multi-species, natural ecosystem restoration philosophy. Projects with direct, indirect, and/or cumulative impacts to habitat of the northern subspecies of the salt marsh harvest mouse should offset their impacts in a manner consistent with and supporting this transition.

In the meantime, the conservation areas set aside for salt marsh harvest mouse on Grizzly Island Wildlife Area will provide source populations for restored tidal marsh habitat within the Grizzly Island marsh Complex. Diked wetlands in the Wildlife Area will also provide long-term habitat protection for the species if the levees are maintained and are not subjected to catastrophic flooding. These conservation areas, as well as the diked managed wetlands on public and private land in Suisun Marsh will provide refugia for salt marsh harvest mice until restored tidal marshes provide additional habitat.

The Suisun Marsh Principals Group has long been evaluating the balance of restoration, management and protection in Suisun Marsh. The Principals Group is a collaboration formed in 2001 to resolve issues of amending the Suisun Marsh Preservation Agreement (SMPA), obtain a Regional General Permit, implement the Suisun Marsh Levee Program, and recover endangered species. The Principals Group was charged with developing a regional implementation plan that would outline the actions needed in Suisun Marsh to preserve and enhance managed seasonal wetlands, restore tidal marsh habitat, implement a comprehensive levee protection/improvement program, and protect ecosystem and drinking water quality. The *Suisun Marsh Habitat Management, Preservation, and Restoration Plan* would be consistent with the goals and objectives of the Delta Science Program, and balance them with SMPA, Federal and State Endangered Species Acts, and other management and restoration programs within the Suisun Marsh in a manner responsive to the concerns of all stakeholders, and based upon voluntary participation by private landowners. The *Suisun Marsh Habitat Management, Preservation, and Restoration Plan* also would provide for simultaneous protections and enhancement of: (1) the Pacific Flyway and existing wildlife values in managed wetlands, (2) endangered species, (3) tidal marshes and other ecosystems, and (4) water quality, including, but not limited to, the maintenance and improvement of levees.

Surveys for *Chloropyron molle* ssp. *molle* and *Cirsium hydrophilum* var. *hydrophilum* are needed in Suisun Marsh. In addition, surveys for sensitive, though not federally listed species, such as Suisun shrew and salt marsh wandering shrew should also be conducted.

San Pablo Bay

This discussion involves areas west of the Carquinez bridge and continuing south to a line between Pinole Point (Contra Costa County) and Point San Pedro (Marin County) on both sides of San Pablo Bay (**Figure III-3**), completely overlapping the Recovery Unit with the same name. Restoration and habitat acquisition projects should be the focus in this area, with consistent attention being given to revegetating invasive *Spartina*-treated marshes and controlling *Lepidium latifolium*.

Tidal marsh species recovery in San Pablo Bay is moving forward at an encouraging pace, with tens of thousands of acres of preservation and restoration in place or planned. The U.S. Fish and Wildlife Service's San Pablo Bay National Wildlife Refuge and CDFW (notably at Napa-Sonoma Marshes, San Pablo Bay Wildlife Area, and Petaluma Marsh Wildlife Area) manage significant tidal and restorable lands. Numerous other conservation projects and proponents may be reviewed at a website created by San Francisco Estuary Institute (SFEI), Wetlands and Water Resources, and PRBO-Conservation Science: www.wetlandtracker.org. Rapid sedimentation and/or tidal marsh development in several less-engineered instances (Napa Marsh Pond 2A, Carl's Marsh, West End duck club, Port Sonoma Marina, Tubbs Island Levee Setback) indicate a highly favorable physical and biological environment for restoration in many areas.

Prompt implementation of tidal restoration projects is appropriate—compatible with the ecosystem and San Francisco Bay Estuary strategies above and additional recovery strategies below. Without prejudging particular restoration proposals, priority restoration areas appear as follows:

- Napa-Sonoma salt ponds, in particular ponds near the mouth of the Napa River or San Pablo Bay, and therefore close to major sediment sources, large tidal channels, and higher salinity waters. Some of these ponds should be restorable with a minimum of delay or engineering, as has happened with Pond 2A and Pond 3. Any needed desalination might be pursued by transferring brines to other ponds and admitting low-salinity winter flood flows. Ponds 9 and 10 also should be priorities for restoration, to expand habitat around the ecologically important remnant marsh at Fagan Slough.
- Petaluma baylands, on both sides of the river and toward the mouth, with opportunities for expanding habitat around rare species populations and restoring gradual gradients from high marsh well into uplands.
- Novato area baylands, including the former Hamilton Airfield, Bel Marin Keys, and Gallinas Creek, south to China Camp State Park, expanding and re-connecting habitat and populations.

Despite the extent of restoration planned in the region, gaps and barriers between marsh areas may remain, and it will be an additional priority to establish habitat connections between marsh areas to the greatest extent feasible. Habitat connectivity will increase the potential for population and genetic exchange, especially for less mobile species such as the salt marsh harvest mouse. If fringing marshes are used to establish connectivity, they should be as deep (from shore to bay) as possible from inboard to outboard edge, and should have wide and well vegetated high tide refugial habitat, capable of accommodating sea level rise.

Restoration around San Pablo Bay should seek to establish substantial areas of a wide diversity of tidal marsh and associated habitats. For example, sparsely vegetated pans in high marsh and gentle high marsh edges will increase habitat for *Chloropyron molle* ssp. *molle*; high tide refugial habitat will benefit California clapper rail, salt marsh harvest mouse, California black rail, San Pablo song sparrow, Suisun shrew, and other species; shallow open ponds within tidal marsh will encourage a variety of water bird species; and brackish marsh areas and riparian ecotones will support California black rail and salt marsh common yellowthroat. Seasonal wetlands above most tides may provide habitat for *Lasthenia conjugens* and California red-legged frog. Opportunities to restore upland ecotones and accommodate upper extremes of sea level rise exist, for example, around the Petaluma Marsh, at American Canyon, Sears Point, Pinole Point, and other locations.

Table III-6. Regional Species Planning Checklist: San Pablo Bay

Federally listed species:

Animals

- California clapper rail (*Rallus longirostris obsoletus*)
- salt marsh harvest mouse, northern subspecies (*Reithrodontomys raviventris halicoetes*)
- western snowy plover (*Charadrius alexandrinus nivosus*)
- California tiger salamander (*Ambystoma californiense*)
- California red-legged frog (*Rana aurora draytonii*)
- tidewater goby (*Eucyclogobius newberryi*)
- steelhead (*Onchorhynchus mykiss*)
- chinook salmon (*Oncorhynchus tshawytscha*)
- Delta smelt (*Hypomesus transpacificus*)

Plants

- *Lasthenia conjugens* (Contra Costa goldfields)
- *Chloropyron molle* ssp. *molle* (soft bird's-beak)
- *Suaeda californica* (California sea-blite)

Non-listed species covered by this recovery plan:

Animals

- Suisun shrew (*Sorex ornatus sinuosis*)
- California black rail (*Laterallus jamaicensis coturniculatus*)
- salt marsh common yellowthroat (*Geothlypis trichas sinuosa*)
- San Pablo song sparrow (*Melospiza melodia samuelis*)
- old man tiger beetle (*Cicindela senilis senilis*)

Plants

- *Spartina foliosa* (California cordgrass)

Other species of regional conservation significance:

Animals

- North American river otter (*Lutra canadensis*)
- harbor seal (*Phoca vitulina*)
- California sea-lion (*Zalophus californicus*)
- Virginia rail (*Rallus limicola*)
- sora (*Porzana carolina*)
- Bryant's savannah sparrow (*Passerculus sandwichensis alaudinus*)
- shorebirds, wading birds, waterfowl (multiple species)
- western pond turtle (*Clemmys marmorata*)
- green sturgeon (*Acipenser medirostris*)
- longfin smelt (*Spirinchus thaleichthys*)
- Sacramento splittail (*Pogonichthys macrolepidotus*)
- San Francisco forktail damselfly (*Ishnura gemina*)
- tiger beetles (*Cicindela* spp.)
- western tanarthrus beetle (*Tanarthrus occidentalis* Chandler)

Plants

Astragalus tener ssp. *tener* (alkali milk-vetch)
Chloropyron maritimum ssp. palustre (Point Reyes bird's-beak)
Agrostis exarata, *Leymus triticoides*, *Puccinelia nutkaensis* (salt marsh edge grasses)
Baccharis douglasii (salt marsh baccharis)
Carex spp. (salt marsh edge sedges)
Castilleja ambigua ssp. *ambigua* (salt marsh owl's-clover)
Zeltnera trichanthum (alkali centaury)
Centromadia pungens ssp. *maritima* (maritime spikeweed)
Cicuta maculata var. *bolanderi* (Bolander's spotted water-hemlock)
Glaux maritima (sea-milkwort)
Heliotropium curassavicum (seaside heliotrope)
Iva axillaris var. *robustior* (povertyweed)
Juncus spp. (perennial and annual rushes)
Lasthenia glabrata ssp. *glabrata* (smooth goldfields)
Lasthenia platycarpha (alkali goldfields)
Lepidium oxycarpum, *L. nitidum*, *L. latipes* (native annual peppercresses)
Lilaeopsis masonii (Mason's lilaeopsis)
Plagiobothrys mollis var. *vestitus* (Petaluma popcornflower)
Plantago elongata (annual coast plantain)
Polygonum marinense (Marin knotweed)
Ruppia maritima (ruppia)
Senecio hydrophilus (salt marsh butterweed)
Symphyotrichum lentum, *A. chilensis* and intergrades (salt marsh asters)
Symphyotrichum subulatum var. *ligulatus* (slim aster)
Trifolium depauperatum var. *hydrophilum* (salt marsh cow-clover)
Zostera marina (eelgrass)

Flood protection needs will figure into feasibility and costs of tidal restoration projects around San Pablo Bay. In particular, portions of Highway 37, Lakeville Road, and certain railroad tracks may need diking, elevating, or other modification. Utilities in restoration areas should be removed or re-aligned. Another option for minimizing impacts to species and habitat is to remove access levees to existing poles and other structures and to use alternative means to access them. Raptor and corvid nests should be removed from electrical towers and gates resistant to mammalian predator access should be installed. Boardwalk development should be discouraged due to their tendency to provide access routes to mammalian predators.

Some land acquisition from willing sellers may be needed to allow regional tidal marsh restoration in San Pablo Bay to work more effectively for species recovery. Rational integration of flood control, infrastructure, tidal circulation and habitat connectivity are likely to be important considerations.

A major contribution to marsh conservation was made in March 2011 when the 3,300-acre Skaggs Island, that was once a Navy communications base, officially became part of the San Pablo Bay National Wildlife Refuge.

Management improvements and enhancement of existing tidal marsh habitats will aid recovery, for example to maintain tidal circulation, manage public access, and remove non-native species. Management plans for particular sites should be developed to sustain ecosystems and suites of rare species. For example, management at Point Pinole Regional Shoreline can conserve *Chloropyron molle* ssp. *molle*, *Castilleja ambigua* ssp. *ambigua*, and *Suaeda californica*, as well as tidal marsh animals and tidal marsh ecosystems, ecotones, and buffers. Adequate long-term funding is needed for ongoing habitat management and monitoring.

Control and monitoring of invasive plants will be an ongoing management task in San Pablo Bay, as it is elsewhere in the estuary, with slightly different regional emphasis. Monitoring for invasive *Spartina* and development of a treatment regime that considers protection of all sensitive resources will be important, to protect existing marshes, *Spartina foliosa* populations, and restoration projects. Eradication of *Spartina densiflora* should proceed, where appropriate, at Point Pinole Regional Shoreline and Napa-Sonoma Marsh as well as south of San Pablo Bay in Marin County. *Lepidium latifolium* (perennial pepperweed) will present a major long-term challenge around San Francisco, San Pablo, and Suisun Bays, as this species is tenacious and has been increasing. This perennial may compete for space, light, and nutrients with native plants including *Chloropyron molle* ssp. *molle*, *Chloropyron maritimum* ssp. *palustre* (Point Reyes bird's-beak), and *Castilleja ambigua* ssp. *ambigua* (salt marsh owl's-clover), potentially displacing them. There is concern that *Lepidium latifolium* also may displace *Grindelia stricta* (gumplant), an important species in providing high tide refuge for salt marsh harvest mouse and other animals. Yet another plant pest problem in the region is *Carpobrotus* [*Mesembryanthemum*] sp. (sea fig or ice plant), including extensive stands in the Napa-Sonoma marshes, and elsewhere (H. Shellhammer pers. comm. 2005). Eradication of *C. edulis* should proceed at Napa marsh islands, many of which have been completely covered by the species. Restoration projects should include planning and dedicated, long-term funding for invasive species early detection, monitoring, and control from their outset. Control programs should specify success criteria and undergo periodic review.

Predators, notably non-native red fox, are a major problem for marsh birds—and probably species such as salt marsh harvest mice as well—around San Pablo Bay. Monitoring and control programs to address non-native or artificially abundant predators need to be implemented, maintained, and periodically reviewed. Though it has been determined that native Sierra Nevada red fox exist in the vicinity of Suisun Bay (Sacks *in litt*. 2009), further research is needed to determine whether that species is responsible for predation impacts to the rail there. Similar research will be necessary, particularly in the northern and western areas of San Pablo Bay if it is determined the native species of red fox resides there as well. Restoration projects should include planning and long-term funding for predator monitoring and control.

Sewage sludge (biosolids) disposal at Tubbs Island (at the mouth of Sonoma Creek) should be considered for relocation to an area with lower potential for clapper rail and salt marsh harvest mouse recovery, or to a non-bayland site. Hay cropping and sludge disposal could be transferred temporarily to another eventual tidal restoration site if Tubbs Island becomes available for restoration first.

Surveys. Biological inventory of remnant San Pablo Bay marshes has been incomplete: sporadic surveys over many years have been unevenly distributed, conducted with uneven thoroughness, and have failed to keep pace with rapid physical and biological changes. Though PRBO Conservation Science conducts an ongoing tidal bird survey effort, periodic comprehensive species surveys covering plants, invertebrates, and other vertebrates of conservation interest are needed throughout San Francisco Bay to identify critical declines in species abundance or distribution. Specifically, in regards tidal marsh birds, nest monitoring needs to be done to gain insight into reproductive rates and other factors that may be influencing reproductive success.

A research and planning need for the San Pablo Bay area is a regional spatial strategy for the management of *Lepidium latifolium*, mentioned above. Efficient spatial weed control strategies generally focus initially on outlying, pioneer colonies and seed sources, then gradually move inward toward core infestations, minimizing their area and extent of contact with unaffected lands. The spatial distribution of *Lepidium latifolium* and its modes and pathways of spread need to be better understood in the region and applied in determining an efficient regional strategy for control. San Pablo Bay National Wildlife Refuge has recently made considerable progress in this regard on refuge lands, having censused *Lepidium latifolium* in marshes of the refuge, analyzed spatial patterns, prioritized control, developed a long-term control plan, and begun regional coordination (*e.g.*, with CDFW) (Hogle *et. al.* 2007). Another unanswered research need is how best to manage the large impounded areas throughout the marshes of San Pablo Bay which result in *Sarcocornia* die-offs and mosquito production. Finally, research is needed to examine the effect of coyotes on California clapper rail, red fox, and salt marsh harvest mouse.

Central/Southern San Francisco Bay

This discussion involves tidal marshes and former baylands from the Golden Gate Bridge north to a line between Pinole Point (Contra Costa County) and Point San Pedro (Marin County), and south to the furthest extent of San Francisco Bay), completely overlapping the Recovery Unit with the same name (**Figure III-4**). An example species planning checklist for the region is provided in **Table III-7**. Contact the U.S. Fish and Wildlife Service's Sacramento Fish and Wildlife Office for an updated list.

Because of intensive development, remaining habitat preservation and restoration opportunities for many species covered by this recovery plan are limited in the northern and central portions of the region. Most of the remnant and historic tidal marshes of the central Bay (Richardson Bay, Corte Madera, San Rafael, portions of the Oakland and Emeryville-Richmond shoreline) lack sizeable areas suitable for tidal marsh restoration, and can only be maintained or expanded to a limited degree. Many of these are "pocket" marshes or fringing marshes that support important local populations of rare or declining species (such as *Chloropyron maritimum* ssp. *palustre* (Point Reyes bird's-beak) and *Polygonum marinense* (Marin knotweed)), or provide hard-to-find suitable settings for species reintroductions (such as for *Suaeda californica* and *Atriplex californica* (California saltbush)). Important pre-historic marsh remnants occur in central San Francisco Bay, such as Heerdt Marsh (Corte Madera) and Bothin Marsh (Mill Valley).

This recovery plan seeks to maximize connectivity for species that move through the Central Bay, providing resting or stepping-stone habitat in as large and healthy remnants as possible. It also seeks to reintroduce populations of *Suaeda californica* in appropriate or enhanced habitat. To that end, the isolated remnant marshes in this subregion should be protected against encroachment and degradation. Where feasible, they should be either expanded or modified to add missing associated habitats, such as terrestrial ecotones, shallow lagoons, pans, fresh-brackish ecotones, etc. Their associated intertidal mudflats also should be protected. Monitoring for invasive *Spartina* and development of a treatment regime that considers protection of all sensitive resources will be important, to protect existing marshes, *Spartina foliosa* populations, and restoration projects. In addition, in the South Bay, *Arundo donax* (giant reed grass) and *Phragmites australis* (common reed) hold a high priority for removal. *Tetragonia tetragonoides* (New Zealand spinach) holds a medium priority for removal.

As discussed in section I.E., aggressive efforts to eradicate invasive *Spartina* by the Invasive Spartina Project are nearly complete and revegetation of treated sites is a top priority. The Invasive Spartina Project also monitors the distribution and progress of the invasive *Spartina* invasion and control, and should be contacted for the latest information (California Coastal Conservancy offices, Berkeley, CA).

Predator control will be especially important in the south-central and south San Francisco Bay, around the significant population of California clapper rails. Field studies as well as population and viability modeling have shown that California clapper rail recovery is extremely sensitive to factors that affect survival rates or population growth rates, both of which are severely reduced by predation (Foin *et al.* 1997; also see **Appendix F**). Effective predator control will dramatically leverage the tidal marsh acreage restored for recovery of the rail.

Where appropriate invasive plant treatment has been completed, tidal marsh restoration in San Francisco Bay can proceed, but will need to seek a balance between increased tidal marsh area and conservation of shorebirds and waterfowl that depend on what are now extensive salt ponds. Restoration of tidal marsh in south San Francisco Bay is the subject of large, multi-party efforts, such as the SBSP Restoration Project. These efforts have explored alternatives that reflect many of the considerations and tradeoffs discussed. The proposed project will develop according to adaptive management triggers.

Conservation management of the ponds that are part of the SBSP Restoration Project typically may follow a tidal marsh restoration track or a managed pond track. Careful monitoring of habitats and species, and adaptive management to guide the projects toward desired ends, will be needed. Tidal marsh restoration will have to incorporate measures to protect flood-prone developed lands and infrastructure, and maintain regionally adequate shallow water habitats for waterbirds.

Table III-7. Regional Species Planning Checklist: Central/South San Francisco Bay

Federally listed species:

Animals

- salt marsh harvest mouse, southern subspecies (*Reithrodontomys raviventris raviventris*)
- southern sea otter (*Enhydra lutris nereis*)
- California clapper rail (*Rallus longirostris obsoletus*)
- western snowy plover (*Charadrius alexandrinus nivosus*)
- California least tern (*Sterna antillarum browni*)
- San Francisco garter snake (*Thamnophis sirtalis tetrataenia*)
- California red-legged frog (*Rana aurora draytonii*)
- California tiger salamander (*Ambystoma californiense*)
- tidewater goby (*Eucyclogobius newberryi*)
- steelhead (*Onchorhynchus mykiss*)
- chinook salmon (*Oncorhynchus tshawytscha*)
- vernal pool tadpole shrimp (*Lepidurus packardi*)

Plants

- *Suaeda californica* (California sea-blite)
- *Lasthenia conjugens* (Contra Costa goldfields)

Non-listed species covered by this recovery plan:

Animals

- salt marsh wandering shrew (*Sorex vagrans halicoetes*)
- San Pablo vole (*Microtus californicus sanpabloensis*)
- California black rail (*Laterallus jamaicensis coturniculatus*)
- saltmarsh common yellowthroat (*Geothlypis trichas sinuosa*)
- Alameda song sparrow (*Melospiza melodia pusillula*)
- Samuels song sparrow (*Melospiza melodia samuelis*)
- old man tiger beetle (*Cicindela senilis senilis*)

Plants

- *Spartina foliosa* (California cordgrass)

Species of concern or regional conservation significance:

Animals

- harbor seal (*Phoca vitulina*)
- California sea-lion (*Zalophus californicus*)
- Virginia rail (*Rallus limicola*)
- sora (*Porzana carolina*)
- Bryant's savannah sparrow (*Passerculus sandwichensis alaudinus*)
- shorebirds, wading birds, waterfowl (multiple species)
- peregrine falcon (*Falco peregrinus*)
- western pond turtle (*Clemmys marmorata*)
- green sturgeon (*Acipenser medirostris*)
- longfin smelt (*Spirinchus thaleichthys*)

Pacific lamprey (*Lampetra tridentata*)
river lamprey (*Lampetra ayresi*)
Sacramento splittail (*Pogonichthys macrolepidotus*)
San Francisco forktail damselfly (*Ishnura gemina*)
western tanarthrus beetle (*Tanarthrus occidentalis*)
Jamieson's salt marsh wasp (*Compsocryptus jamiesoni*)

Plants

Agrostis exarata, Leymus triticoides, Puccinelia nutkaensis (salt marsh edge grasses)
Astragalus tener ssp. *tener* (alkali milk-vetch)
Atriplex californica (California saltbush)
Atriplex joachiniana (San Joaquin saltbush)
Baccharis douglasii (salt marsh baccharis)
Chloropyron maritimum ssp. *palustre* (Point Reyes bird's-beak)
Castilleja ambigua ssp. *ambigua*, salt marsh populations (salt marsh owl's-clover)
native *Carex* spp. (salt marsh edge sedges)
Zeltnera trichanthum (alkali centaury)
Centromadia pungens ssp. *maritima, H. parryi* sspp. (spikeweeds, tarweeds)
Cicuta maculata var. *bolanderi* (Bolander's spotted water-hemlock)
Downingia pulchella (valley Downingia)
Glaux maritima (sea-milkwort)
Heliotropium curassavicum (seaside heliotrope)
Iva axillaris var. *robustior* (povertyweed)
Juncus spp. (perennial and annual rushes)
Lasthenia glabrata ssp. *glabrata* (smooth goldfields)
Lasthenia platycarpha (alkali goldfields)
Lepidium oxycarpum, L. nitidum, L. latipes (native annual peppercresses)
Plagiobothrys glaber (smooth popcornflower)
Plantago elongata (annual coast plantain)
Polygonum marinense (Marin knotweed)
Pyrrocoma racemosa (clustered goldenweed)
Pluchea odorata (marsh fleabane)
Puccinellia nutkanensis (alkali goosegrass)
Ruppia maritima (ruppia)
Sarcocornia subterminalis (Parish's glasswort)
Sanicula maritima (adobe sanicle)
Senecio hydrophilus (salt marsh butterweed)
Solidago confinis (southern goldenrod)
Suaeda moquinii (alkali-blite)
Symphyotrichum lentum, A. chilensis and intergrades (salt marsh asters)
Symphyotrichum subulatum var. *ligulatus* (slim aster)
Zostera marina (eelgrass)

In addition to invasive *Spartina*, an historic restoration constraint in the South Bay has been fresh wastewater discharge from the San Jose/Santa Clara Water Pollution Control Plant near San Jose. Though years 2006 through 2008 actually saw a net gain in tidal marsh, historically, increased freshwater influence has altered tidal marsh vegetation toward brackish marsh species, for example, in Artesian and Alviso Sloughs. Brackish marsh provides lower quality habitat for California clapper rails and salt marsh harvest mice. Given the recent reversal of habitat conversion, freshwater discharge does not appear to present the magnitude of constraint that it did previously. In fact, the degree of constraint that it poses to tidal restoration efforts in the future will likely be dependent on annual fluctuations in rainfall and delta outflows (H.T. Harvey and Associates 2008).

Excess nutrients or contaminants in the wastewater also may be having some effect; this has not been examined closely to date. Restoration within the influence of these fresh water discharges may be more likely to establish brackish tidal marsh than the typical tidal marsh vegetation once found there. On the other hand, supplying the fresher water to brackish marsh restoration might diffuse the fresher flows and reduce impacts to fringing tidal marshes along tidal sloughs in the area. The U.S. Fish and Wildlife Service will work with responsible agencies on all available means of reducing artificially high fresh water discharges to the South Bay.

Substantial subsidence in some South Bay ponds may make tidal marsh restoration that is reliant upon natural sediment deposition difficult or slow, and may require deposition of dredged materials or other fill material to increase pond bottom elevations prior to breaching. Some subsided ponds are within the influence of excess fresh wastewater discharges, and therefore, doubly problematic for marsh restoration. Ponds that are not among the highest priority candidates for tidal marsh restoration may be better allocated as waterbird habitat.

Without prejudging any particular restoration configuration, the following generalized restoration priorities in the San Francisco Bay region have been identified by various local restoration planning groups. Please note that these priorities do *not* take into account the invasive *Spartina* constraints discussed above, because those conditions are subject to rapid change. These preliminary priorities therefore must be subject to evaluation of the latest local and regional conditions before being put into action:

- Newark area (Dumbarton-Mowry)
- Eden Landing (Alameda Flood Control Channel and Old Alameda Creek)
- Redwood City area (Bair, Greco Islands, Ravenswood area)
- addressing invasive *Spartina* problems at Eden Landing area and Cogswell Marsh restoration projects
- Hayward shoreline
- Warm Springs (control tidal flooding to limit drowning of vernal pool habitat)
- projects to create contiguous habitat and habitat linkages for listed species

Ultimately, if the remaining active salt ponds in Newark and Fremont and west of the Ravenswood restoration area are someday no longer needed for salt production, they should also be considered for restoration to tidal marsh or water bird habitat. The Newark-Fremont section in particular otherwise creates a large separation in habitat between the Eden Landing project and the Dumbarton-Mowry, Warm Springs, and Alviso areas. The area northeast of Redwood City should be restored to create contiguous habitat between Bair Island and the Ravenswood Point salt ponds to be restored per the SBSP Restoration Project.

The San Francisco Bay region hosts many unique species with particular needs and opportunities. The southern subspecies of the salt marsh harvest mouse is restricted to this region, as is the Alameda song sparrow, and most populations of the California clapper rail are centered here. San Francisco Bay also has habitat important to California least terns (U.S. Fish and Wildlife Service 1985*b*) and western snowy plovers (U.S. Fish and Wildlife Service 2007*b*), which have their own recovery needs. Opportunities exist in the Warm Springs (Fremont) area to integrate tidal marsh recovery planning with vernal pool ecosystem conservation, including the tidal marsh to vernal pool grassland ecotone. This vernal pool area is home to *Lasthenia conjugens*, vernal pool tadpole shrimp, and California tiger salamander, among other species. Opportunities for *Suaeda californica* reintroduction abound in San Francisco Bay, as well.

Surveys. Biological inventory of remnant San Francisco Bay marshes has been incomplete: sporadic surveys over many years have been unevenly distributed, conducted with uneven thoroughness, and have failed to keep pace with rapid physical and biological changes. Periodic comprehensive species surveys covering plants, vertebrates, and invertebrates of conservation interest are needed throughout San Francisco Bay to identify critical declines in species abundance or distribution.

Research. A regional research need in San Francisco Bay is a better understanding of sediment dynamics, how sediment suspension and deposition interact with mudflats, how tidal restoration will affect sediment availability, sedimentation rates, and mudflat areas. Another area needing work concerns mercury contamination in the South Bay, from abandoned mines and other sources. Studies are needed on the impacts of fresh wastewater input to the South Bay, and of proposed solutions to this problem.

Central Coast

This discussion involves coastal habitat from Bodega Bay (Sonoma County) south to Elkhorn Slough (Monterey County) (**Figure III-5**), though the Recovery Unit of the same name extends only from Bodega Bay to Pescadero Marsh (San Mateo County). The emphasis along the Pacific coast from Bodega Bay to the Elkhorn Slough area will be to conserve and enhance natural pockets of healthy tidal marsh in appropriate locations so as to maximize the connectivity of habitat for tidal marsh animals and plants. This recovery plan also seeks to enhance tidal marsh nurseries for ecologically or economically significant fish, such as salmonids and tidewater goby. The goals of this recovery plan have been designed to complement the goals described for these species which are detailed in their own recovery plans. The decline of coastal California black rail populations should be addressed and to the maximum extent possible, reversed. A checklist of species to consider in planning for the region is given in **Table III-8**. Please contact the U.S. Fish and Wildlife Service's Sacramento Fish and Wildlife Office for an updated list.

Marin-Sonoma coast. Species recovery and conservation strategies for the coast of Marin and Sonoma counties emphasize range re-expansion of the California clapper rail and California black rail, and conservation of five rare plants with important localities in Tomales Bay and

Drakes Bay: *Astragalus pycnostachyus* ssp. *pycnostachyus*, *Castilleja ambigua* ssp. *humboldtiensis*, *Castilleja ambigua* ssp. *ambigua*, *Chloropyron maritimus* ssp. *palustris*, and *Polygonum marinense*. In addition, there are a number of plants which have declined in California's tidal marshes, particularly the San Francisco Bay Estuary, but which persist in coastal Marin County, such as *Lasthenia glabrata* ssp. *glabrata*, *Atriplex californica*, and *Rumex occidentalis*. The west Marin tidal marshes should be managed as an important refuge for *tidal* marsh plant populations otherwise in regional decline. Coastal *Spartina foliosa* populations should be protected, monitored, and any invasive *Spartina* eradicated immediately.

At the mouths of many small seasonal streams discharging into embayments of the coast are small brackish to fresh lagoons associated with small barrier beaches. These features include ecotones between riparian ecosystems, freshwater ponds and tidal marsh. These support sizeable populations of California red-legged frogs, and provide opportunities to integrate the recovery objectives for this species (U.S. Fish and Wildlife Service 2002*a*) with recovery of tidal marsh ecosystems.

San Mateo-Santa Cruz coast. The most significant estuaries of the coast of San Mateo and northern Santa Cruz counties for conservation of rare or listed species are at Pescadero Creek, Pomponio Creek, San Gregorio Creek, and Pillar Point marsh. Lake Lucerne at Bean Hollow (Arroyo de los Frijoles), a dammed estuary converted to a freshwater pond, has potential for tidal marsh restoration. Pilarcitos Creek, Tunitas Creek, Waddell Creek, and Scott Creek support high quality fresh-brackish marsh and riparian ecotones. All but Lake Lucerne and Tunitas Creek are publicly owned. In accordance with their respective recovery plans, sub-tidal, tidal and intermittently tidal (lagoon) aquatic habitat areas should be preserved in stream mouths to support tidewater goby and salmonid populations (U.S. Fish and Wildlife Service 2005).

Publicly owned stream mouth and lagoon wetlands should be managed with priority to protect or restore native ecosystems. Long-term habitat management plans should be prepared and implemented. Brackish tidal and riparian marsh ecotones in San Mateo coast estuaries should be protected and enhanced, where appropriate, for saltmarsh common yellowthroats and California black rails. Another important recovery strategy for these estuaries is to foster "stepping stone" habitats for vagrant California clapper rails, to support infrequent but biologically important future emigration from San Francisco Bay to Elkhorn Slough (Monterey Bay). These estuaries similarly provide habitats for dispersing yellowthroats and black rails. Managing and restoring upper fresh-to-brackish reaches of tidal marsh gradients also should provide habitat (backshore lagoons and ponds, riparian areas with scour pools) for California red-legged frogs.

Table III-8. Regional Species Planning Checklist: Central Coast

Federally listed species:

<u>Animals</u>

- California clapper rail (*Rallus longirostris obsoletus*)
- western snowy plover (*Charadrius alexandrinus nivosus*)
- southern sea otter (*Enhydris lutris nereis*)
- California red-legged frog (*Rana aurora draytonii*)
- Santa Cruz long-toed salamander (*Ambystoma macrodactylum croceum*)
- tidewater goby (*Eucyclogobius newberryi*)
- steelhead (*Onchorhynchus mykiss*)
- Chinook salmon (*Oncorhynchus tshawytscha*)

<u>Plants</u>

- *Lupinus tidestromi* (Tidestrom's lupine)

Non-listed species covered by this recovery plan:

<u>Animals</u>

- salt marsh wandering shrew (*Sorex vagrans halicoetes*)
- California black rail (*Laterallus jamaicensis coturniculatus*)
- saltmarsh common yellowthroat (*Geothlypis trichas sinuosa*)

<u>Plants</u>

- *Spartina foliosa* (California cordgrass)

Other species of regional conservation significance:

<u>Animals</u>

- harbor seal (*Phoca vitulina*)
- California sea-lion (*Zalophus californicus*)
- Virginia rail (*Rallus limicola*)
- sora (*Porzana carolina*)
- Bryant's savannah sparrow (*Passerculus sandwichensis alaudinus*)
- shorebirds, wading birds, waterfowl (multiple species)
- peregrine falcon (*Falco peregrinus*)
- tiger beetle species (*Cicindela* spp.)

<u>Plants</u>

- *Astragalus pycnostachyus* ssp. *pycnostachyus* (marsh locoweed)
- *Atriplex californica* (California saltbush)
- *Chloropyron maritimum* ssp. *palustre* (Point Reyes bird's-beak)
- *Castilleja ambigua* ssp. *ambigua* (salt marsh owl's-clover)
- *Castilleja ambigua* ssp. *humboldtiensis* (Humboldt Bay owl's-clover, southern form)
- *Castilleja ambigua* ssp. *ambigua* (salt marsh owl's-clover)
- *Lasthenia glabrata* ssp. *glabrata* (smooth goldfields)
- *Polygonum marinense* (Marin knotweed)
- *Hemizonia parryi* ssp. *congdonii* (Congdon's tarplant)

Agrostis exarata, Leymus triticoides, Puccinelia nutkaensis (salt marsh edge grasses)
Atriplex californica (California saltbush)
Baccharis douglasii (salt marsh baccharis)
Carex spp. (salt marsh edge sedges)
Centromadia pungens ssp. *maritima* (maritime spikeweed)
Cicuta maculata var. *bolanderi* (Bolander's spotted water-hemlock)
Glaux maritima (sea-milkwort)
Heliotropium curassavicum (seaside heliotrope)
Juncus spp. (perennial and annual rushes)
Lepidium oxycarpum, L. latipes (native annual mustards)
Leymus triticoides (creeping wildrye —salt marsh edge populations)
Plantago elongata (annual coast plantain)
Pluchea odorata (marsh fleabane)
Rumex occidentalis (western dock)
Ruppia maritima (ruppia)
Symphyotrichum subulatum var. *ligulatus* (slim aster)
Zostera marina (eelgrass)

The Pescadero Marsh Estuary is exceptional in supporting a major population of the California red-legged frog, principally in the managed, diked brackish-fresh marsh derived from and adjacent to the tidal estuary. Because of the high importance of this population to the recovery of the California red-legged frog (U.S. Fish and Wildlife Service 2002*a*), and the occurrence of a significant *Astragalus pycnostachyus* ssp. *pycnostachyus* (marsh locoweed) population on the low levee and in portions of the diked marsh, full tidal restoration (levee demolition) is not currently justified for Pescadero Marsh. Long-term planning for Pescadero Marsh, however, should re-investigate the feasibility of reducing artificial management (levees and water control structures) over time, and integrating fresh-brackish lagoons or ponds and marsh habitats within a matrix of mixed tidal and riparian marsh habitats. Examples of such systems may be found in the stream mouth estuaries in Tomales Bay, Drakes Estero, Halfmoon Bay, and Morro Bay.

Because estuaries can be affected by their upstream watersheds, estuarine enhancement actions in the San Mateo coast region should include floodplain and riparian vegetation restoration in derelict agricultural lands, such as at Pomponio Creek. When bridges or culverts over stream mouths are proposed for retrofitting or upgrading, they should be redesigned to minimize restrictions of flows and to allow unobstructed passage of fish, frogs, and other animals.

Invasive non-native plants, such as *Carpobrotus* sp. (iceplant) and *Ammophila arenia* (European beachgrass), should be eradicated from tidal marsh areas to the greatest extent feasible, concentrating on highest risk species and most effective control strategies first. Monitoring and management actions to control non-native species, including non-native invasive animals, should be instituted.

Privately owned stream mouths with brackish marsh or intermittent lagoon habitat, such as Tunitas Creek, should be protected by either easement or fee-title acquisition from willing sellers. If Lake Lucerne becomes available for land uses that do not require the impoundment, it would be a priority for protection and lagoon/marsh/riparian restoration. As the second largest stream-mouth estuary of this region, following Pescadero Marsh, a restored marsh at the present location of Lake Lucerne likely could support tidal marsh species of concern, as well as tidewater goby, red-legged frogs, and dispersing California clapper rails, in various restored habitats.

In appropriate publicly owned habitats, regular surveys for and monitoring of rare native plant and animal species should be conducted. Management plans and management activities should be adapted to address any populations discovered or significant changes in population size or distribution.

Elkhorn Slough and Monterey estuaries and lagoons. Elkhorn Slough is ecologically important as an estuary, and has much habitat potential for endangered tidal marsh species. Its current principal recovery strategies are to maintain habitat for western snowy plovers in the salt pan (former salt pond) habitats near its mouth, as well as southern sea otter habitat in the slough itself. The tidal marshes of Elkhorn Slough may have been important refuges for vagrant clapper rails from San Francisco Bay, and may have acted as founders of new populations in Monterey Bay or Morro Bay; however California clapper rails have not been detected in Elkhorn Slough for decades. Other species conservation strategies for Elkhorn Slough include maintaining riparian brackish marsh habitat for black rails and yellowthroats; high habitat quality and abundance for migratory shorebirds and waterfowl; supporting a persistent or recurrent population of tidewater gobies; and conserving plant species of concern.

Elkhorn Slough's endangered species recovery potential has also been greatly impaired by diking and agricultural reclamation, so tidal marsh restoration will be a principal recovery strategy here. Other long-term threats to tidal marsh that are potentially manageable at Elkhorn Slough are (1) invasion by non-native red fox, an important predator of clapper rails; (2) reduction and suppression of native high marsh vegetation and terrestrial ecotones that provide cover during high tides, a result of intensive rangeland management practices; and (3) excessive tidal prism, tidal energy and marsh erosion caused by the Moss Landing jetties which stabilize the tidal inlet and prevent natural tidal damping by sandspit growth.

Predator control is a high priority for ensuring breeding success of western snowy plovers already established at the Moss Landing salt pans, managed by CDFW. Mammalian predator control to protect plovers in Monterey Bay began at the Salinas River National Wildlife Refuge in 1993 (U.S. Fish and Wildlife Service *in litt.* 1993), focusing on removal of red fox and artificially abundant native species. Since that time, the program has expanded to include plover habitat on adjacent public and private properties, including Moss Landing *salt pans* and state beaches. In 2002, predator management was expanded to include avian predators (U.S. Fish and Wildlife Service 2002*b*). This management program protects both plovers and recolonization potential for clapper rails.

Conservation easements or land acquisition should be used to secure opportunities to manage, enhance, or restore high tidal marsh ecotones and floodplain and riparian areas around Elkhorn Slough, including brackish marsh areas and seeps. Important elements of restoration of high marsh ecotones would include revegetation with semi-evergreen sub-shrub vegetation such as *Grindelia* sp. (gumplant) and *Baccharis douglasii* (salt marsh baccharis) to provide high tide cover for clapper rails. Some tidal marsh edges at Elkhorn Slough may be suitable for restoration of tidal marsh/alluvial grassland ecotones, and potential establishment of *Hemizonia parryi* ssp. *congdonii* (Congdon's tarplant) within its *historic range*.

The *Elkhorn Slough Tidal Wetland Project*, began in 2004, is a collaborative effort to develop and implement strategies to conserve and restore estuarine habitats in the Elkhorn Slough watershed. Involving over a hundred conservation partners, the main goals are to: 1) conserve existing high quality estuarine habitats, 2) restore and enhance degraded estuarine habitats, and 3) restore the physical processes that support and sustain estuarine habitats. The first of the restoration projects, the Parsons Slough Restoration Project involves constructing an underwater sill to maintain a healthy slough ecosystem and correct the problem of tidal scour. The sill is designed to slow the tide coming out of the Parsons Slough and reduce erosion in Elkhorn Slough from Parsons Slough to Monterey Bay, thereby maintaining the diverse range of habitats there.

Several heavily-impacted tidal or muted tidal sloughs occur in the area around the Pajaro River, Elkhorn Slough, and the Salinas River. Their potential for rehabilitation and restoration may deserve consideration in local planning efforts.

Morro Bay and South Central Coast

This discussion involves the coast from Elkhorn Slough to Morro Bay and focuses on protection and enhancement of existing habitats and populations of sensitive tidal marsh species (**Figure III-6**). The Recovery Unit of the same name covers only Morro Bay not areas to the north. A list of some species of regional planning significance is given in **Table III-9**. Please contact the U.S. Fish and Wildlife Service's Ventura Fish and Wildlife Office for an updated list.

There was probably some loss of tidal marsh in Morro Bay historically, but total tidal marsh acreage has actually increased substantially over its historic extent in Morro Bay. This increase has occurred mostly at lower marsh elevations, however, and not in the high tidal marsh zones and tidal marsh/upland edge likely to provide habitat for endangered *Suaeda californica* (California sea-blite) and *Chloropyron maritimum* ssp. *maritimum* (salt marsh bird's-beak). The majority of Morro Bay Estuary edge is either in public or conservation group ownership (*i.e.*, state and city parks, Morro Coast Audubon) or has already been developed; the remaining area of private, undeveloped habitat is small.

Table III-9. Regional Species Planning Checklist: Morro Bay

Federally listed species:

<u>Animals</u>

- clapper rail (*Rallus longirostris*) (subspecies requires investigation)
- western snowy plover (*Charadrius alexandrinus nivosus*)
- California red-legged frog (*Rana aurora draytonii*)
- Tidewater goby (*Eucyclogobius newberryi*)
- Morro shoulderband snail (*Helminthoglypta walkeriana*)

Plants

Suaeda californica (California sea-blite)
Chloropyron maritimum ssp. *maritimum* (salt marsh bird's-beak)

Other species of regional conservation significance:

Animals

harbor seal (*Phoca vitulina*)
California sea-lion (*Zalophus californicus*)
California black rail (*Laterallus jamaicensis coturniculus*)
Bryant's savannah sparrow (*Passerculus sandwichensis alaudinus*)
large-billed savannah sparrow (*Passerculus sandwichensis rostratus*)
shorebirds, wading birds, waterfowl (multiple species)
peregrine falcon (*Falco peregrinus*)
steelhead (*Onchorhynchus mykiss*)

Plants

Atriplex californica (California saltbush)
Atriplex watsonii (Watson's saltbush)
Juncus acutus ssp. *leopoldii* (Leopold's spiny rush)
Lasthenia glabrata ssp. *coulteri* (Coulter's goldfields)
Sanicula maritima (marsh sanicle)
Solidago confinis (southern goldenrod)
Zostera marina (eelgrass)

The recovery strategies for Morro Bay tidal marsh species aim at supporting an extensive persistent wild population of *Suaeda californica* in its last naturally remaining locale, and maintaining the distinct northern population of *Chloropyron maritimum* ssp. *maritimum*. This strategy includes maintaining physical and ecological processes that maintain or regenerate habitat for these listed plants. Secondary strategies for this region include: (a) providing future habitat (and potential reoccupation of historic range) for the California clapper rail (or forms intermediate with the light-footed clapper rail); (b) protecting brackish marsh habitat, willow riparian/brackish marsh ecotone, and populations of California black rails and; (c) protecting or expanding local populations of *Lasthenia glabrata* ssp. *coulteri*, *Atriplex watsonii*, *Atriplex californica* (salt marsh ecotypes), and the tidal marsh population of *Solidago confinis*. The tidal marsh population of *Juncus acutus* ssp. *leopoldii* is at its northern coastal range limit at Morro Bay, and should be protected. It is important to seek compatibility of actions under this recovery plan with high quality habitat for shorebirds including western snowy plover, wading birds, waterfowl, eelgrass, tidewater goby and Morro shoulderband snail.

Remaining undeveloped shoreline around Morro Bay (tidal marsh to extreme high water, adjacent upland transition, and a buffer zone) should be protected from further encroachment by development or artificial shoreline, and from land use conflicts. Where possible, undeveloped private shoreline should be permanently protected by acquisition or conservation easement from willing sellers. Policies and oversight related to all land use practices in and adjacent to tidal marsh around Morro Bay should be reviewed and updated by the City of Morro Bay and other regulatory authorities to ensure that impacts to remaining shoreline and marsh are avoided.

Rules on haul-out of skiffs, canoes, and other watercraft on public properties, including State-owned tidal lands, should be evaluated, refined, and consistently applied to minimize impacts to existing and potential tidal marsh habitat of endangered plants. Recreational use of the shoreline should be managed to prevent impacts such as excessive trampling or off-road vehicle use. Monitoring and success criteria for these strategies should be established.

Management of conservation lands appropriate to the species covered by this recovery plan should be continued and enhanced. Management funding needs should be secured. Comprehensive adaptive management plans for each land unit, addressing these species, should be developed, reviewed, and implemented. Species and habitat monitoring and success criteria should explicitly be included and periodically reviewed. Population *augmentation*, or establishment of new subpopulations of rare plant species (particularly *Chloropyron maritimum* ssp. *maritimum*, *Suaeda californica* , and *Lasthenia glabrata* ssp. *coulteri* (Coulter's goldfields)) in suitable habitat around Morro Bay, should be planned and implemented (or continued) to reduce the risk of extinction.

Carpobrotus edulis (iceplant) and other invasive non-native plants should be eradicated, with highest priority in areas where they impact the survival or regeneration of rare native species. Non-native trees and shrubs such as *Eucalyptus* spp., *Myoporum laetum,* and *Cupressus macrocarpa* should be removed when they are adjacent to rare plant habitats or potential habitat—except at sites used as rookeries by herons, egrets, and cormorants. Invasion of weedy non-native *Cardaria draba* (whitetop) in deltaic brackish tidal marshes of the Chorro Creek mouth should be reduced to conserve habitat of California black rail.

Any future dredge disposal should be planned to avoid excessive dune migration onto tidal marsh habitat, and to maximize nesting habitat of western snowy plover. Subtidal colonies of *Zostera* spp. (eelgrass), which form wrack lines that influence seedling habitat in the upper marsh, should be monitored and protected from dredging.

Groundwater extraction in the Los Osos Valley area, and channelization or diversion of surface drainage, should be managed to prevent the intrusion of high-salinity water into what are now brackish alluvial edges of tidal marsh. This is needed to maintain the brackish edge flora of the tidal marsh, and to conserve potential habitat for *Sanicula maritima* (marsh sanicle). The current planning efforts for a new wastewater treatment facility in Los Osos (San Luis Obispo County 2008*b*) should consider ways to ameliorate the threat of salt water intrusion in the area.

3. Species-level recovery strategies

While many of the threats to tidal marsh species are common to all (see section I.B.4) and should be addressed at the ecosystem level (see section III.B.1), there are also specific threats to individual species that must be reduced or eliminated to recover those species. This section will address species-specific recovery/conservation strategies to reduce or ameliorate threats to the six listed species and the species of concern covered in this recovery plan.

Focal listed species

a. *Cirsium hydrophilum* var. *hydrophilum* (Suisun thistle)

Since habitat loss is the primary reason for the decline of *Cirsium hydrophilum* var. *hydrophilum*, restoration of extensive areas of tidal brackish marsh habitat in areas contiguous with currently occupied habitat is necessary for recovery of the species. However, it may take decades to achieve this long-term goal of favorable tidal marsh soil and hydrologic conditions. In the meantime, it will be important to protect existing populations from further decline and possible extinction.

Short-term recovery actions should be implemented concurrently with long-term habitat restoration and should focus on protecting and managing existing populations and habitats. Recovery strategies include:

- suppression of invasive non-native plant species,
- protection and management of nearby native bee and wasp habitats,
- control of *Cirsium vulgare,* if research indicates necessity,
- restoration of normal tidal range and salinity,
- seed banking of *Cirsium hydrophilum* var. *hydrophilum,*
- monitoring of populations and habitat, and
- research aspects of life history, population ecology, and seed predation of *C. hydrophilum* var. *hydrophilum.*

The major populations of *C. hydrophilum* var. *hydrophilum* occur at Hill Slough and Rush Ranch on lands owned by CDFW and Solano Land Trust. Although managed for conservation purposes, threats remain from grazing and trampling by cattle or feral pigs, as well as from invasion by *Lepidium latifolium* (perennial pepperweed) and *Apium graveolens* (wild celery). A comprehensive management plan for these lands is lacking and basic research on the biology of the species is needed before such a plan can be developed. Management actions to protect against known threats should be implemented immediately. Concurrently, important research should be undertaken to begin the preparation of a comprehensive management plan. For existing or newly dedicated conservation lands, management plans guiding actions for *C. hydrophilum* var. *hydrophilum* should be in place within 5 years; or if research and understanding is not adequate for a comprehensive plan, interim management plans should be completed and implemented. Adequate funding should be ensured to implement actions, operations, and maintenance required by interim or comprehensive management plans.

Successful long-term recovery will require large-scale habitat restoration and establishment of new populations. Extensive and variable habitat would ensure refugia during catastrophic events (*e.g.,* floods, droughts, pest and disease outbreaks) and progressive environment change (*e.g.,* sea level rise, climate change) and would spread the risks of extinction over many relatively independent populations. Extensive and contiguous bands of restored tidal brackish marsh, focused on areas north, west and south of Potrero Hills will be the foundation for long-term recovery. Restoration in a large portion of this area has already been initiated by CDFW. Restoration projects should include plans for establishing *C. hydrophilum* var. *hydrophilum* populations as well as comprehensive plans addressing project management both during and after restoration work. Adequate funding for long-term conservation management of the project lands should be ensured.

To protect against extinction, collection and banking of seed from wild populations of *C. hydrophilum* var. *hydrophilum* must occur. This would ensure that 1) populations could be re-established if known populations fail, and 2) genetic diversity could be maintained following a catastrophic population crash. Seeds should generally be collected in years of peak abundance, but a small collection should be established immediately, even during adverse population conditions. Collection protocols should follow basic scientific guidelines (Center for Plant Conservation 1991), but manipulation of randomly selected seed parents would be appropriate in low population years to ensure adequate production of seed for collection. This could include protection against seed or ovule predation by introduced thistle weevils (*Rhinocyllus conicus, Larinus planus*) and muslin bagging of maturing flower heads. Seed collection should not exceed 1 percent of the estimated total population seed output. Collected seed should be stored at two facilities: (1) a seed storage facility approved by the Center for Plant Conservation, and 2) a local research or vegetation management/restoration institution (*e.g.,* university, public refuge, or park) with greenhouse and nursery facilities that could propagate seed.

A cultivated population of *C. hydrophilum* var. *hydrophilum* should be established for research purposes. This cultivated population can provide seed to be used for research in basic biology, management, and propagation of the species, and thus avoid conflicts with conservation goals for the wild populations. The cultivated population should be established with founders sampled according to the same guidelines as seed banks and should be managed to minimize artificial selection and genetic drift in cultivation (Guerrant 1996). Suisun thistles should be seeded into tidal marsh restoration areas within the historic range of the species as soon as habitat is available, and if collection from the wild would risk impacts to the remaining populations there, seed from a cultivated population should be made available. Use of easily available cultivated seed also would make it possible to test the possible appropriateness of various habitat conditions more freely than with limited wild seed. Areas opened up by successful control of *Lepidium latifolium, Apium graveolens* or of other non-native plants may be appropriate for trials of cultivated thistle seed.

If hybridization with bull thistle (*Cirsium vulgare*) is detected, bull thistles within pollination distance of *C. hydrophilum* var. *hydrophilum* should be prevented from flowering. Similarly, if bull thistle is suspected of fostering introduced thistle weevil populations that are harming Suisun thistles, bull thistles near Suisun thistles should be controlled.

A long-term population monitoring plan for *C. hydrophilum* var. *hydrophilum* must be developed. The most basic data for conservation of the species, census of juvenile and adult plants in the wild, need to be collected annually. Population monitoring should include grid-based census and mapping of known populations, with surveys expanded in subsequent years to detect peripheral colonies or new populations. Preliminary data from initial monitoring studies should be gathered prior to development of the long-term monitoring plan. Long-term monitoring should include sufficient demographic sampling to identify factors and life-history stages that limit regeneration or expansion of populations (*e.g.,* non-destructive sampling of seed set, production of flower heads per plant, production of mature seed in seed heads, seedling density, juvenile survivorship, duration of juvenile phase, etc.).

Due to the extremely limited number of known populations, searches should include attempts to detect and resurrect soil seed banks of *C. hydrophilum* var. *hydrophilum*, especially in pre-historic tidal marshes within Suisun Marsh. Probe methods should include germination tests of shallow marsh soil cores, and experimentally induced small-scale vegetation gaps in unoccupied suitable habitat. Any seedlings recruited from exhumed seed banks should be grown and protected on-site if possible, or cultivated if artificial propagation is more likely to result in survival. Resurrected populations should be utilized as founders of reintroduced populations in unoccupied or restored habitat.

The highest priority research questions address regeneration of *C. hydrophilum* var. *hydrophilum* in the wild, particularly those factors subject to strong fluctuation or artificial manipulation. Research is also needed on the population ecology of the species in relation to marsh soil salinity and tidal regimes to inform decisions regarding salinity control gates and water quality standards. For ecologically meaningful results, this research must span more than a precipitation cycle (drought/post-drought) and include both monitoring of natural field conditions and controlled field experiments. This would take approximately 5 to 10 years. Other important research could be completed more quickly including 1) investigation of seed germination and establishment in natural and artificial conditions, 2) evaluation of seed predation by thistle weevils, 3) methods of control of *Lepidium latifolium* compatible with Suisun thistle and its habitat, 4) techniques for artificial propagation, and 5) potential for hybridization with non-native thistles (especially *Cirsium vulgare*).

b. *Chloropyron molle ssp. molle* (soft bird's-beak)

Recovery strategies for *Chloropyron molle* ssp. *molle* include both long- and short-term elements. Immediate steps are needed to protect and maintain remaining populations and habitat of the species. In the long-term, significant re-expansion of the range and population of the species, with an increase in the extent and quality of its habitat, will foster recovery. Large-scale habitat restoration is needed to allow natural fluctuations in population size and distribution to occur with a minimal risk of extinction. However, it will probably take several decades to develop adequate tidal marsh habitat through natural processes. In the interim, short-term recovery actions are necessary to ensure survival of the species while habitat restoration is underway.

Short-term recovery actions should be implemented concurrently with long-term habitat restoration and should focus on protecting and managing existing populations and habitats. Recovery strategies include:

- suppression of invasive non-native plant species,
- protection and management of nearby native bee and wasp habitats,
- management of grazing and control of feral pigs to reduce trampling and disturbance,
- management of vehicle access and recreation,
- management of urban runoff,
- restoration of normal tidal range and salinity,

- seed banking of *C. molle* ssp. *molle,*
- monitoring of populations and habitat, and
- research aspects of life history of *C. molle* ssp. *molle.*

Non-native plant control should target *Lepidium latifolium* at Hill Slough, Rush Ranch, BSRA, and other population locations. Control of this and other non-native perennials should be conducted to ameliorate threats involving competition and tendency toward monoculture. *Spartina patens* at BSRA should be eradicated if possible. Research also suggests that control of non-native winter annuals that invade upper tidal marsh habitats, such as *Polypogon monspeliensis* (annual beard grass), *Hainardia cylindrical* (barbgrass), and *Cotula coronopifolia* (brass-buttons), may increase survival of *C. molle* ssp. *molle* seedlings (Grewell *et al*. 2003). Control of non-native winter annuals should also be conducted for reasons discussed above, involving their inability to serve as appropriate host plants.

Protection of native pollinators and their habitats should maintain or enhance viable seed production. Ground-nesting species of bumblebees are probably among the more effective pollinators (*Bombus occidentalis*, *Bombus vosnesenskii*). Adaptive management for and monitoring of ground-nesting and other native bees, particularly near *C. molle* ssp. *molle* populations, is needed. Protection of predatory wasps that feed on moth larvae infesting *C. molle* ssp. *molle* inflorescences should reduce losses of reproductive output to seed-eaters. The nesting and feeding habits of these species will be important in determining appropriate management. The U.S. Fish and Wildlife Service recommends restoration of healthy ecosystem characteristics to support beneficial native species, as opposed to artificial enhancements.

Management of grazing should aim to reduce trampling and breaking of haustorial connections to host plants due to disturbance. In addition to direct mortality, soil and plant disturbance by domestic livestock can create conditions that encourage invasion by non-native plants. These sorts of effects should be minimized. Disturbance by feral pigs (*Sus scrofa*) is similar in effects, but includes digging (rooting), and is controlled differently. Limited feral pig hunting has been allowed in portions of Suisun Marsh, but a regional-scale eradication effort should be coordinated with CDFW to decrease the species' impact on sensitive plants and their habitats.

Controls should be erected and maintained to prevent illicit off-road vehicle use in habitat of *C. molle* ssp. *molle*. Necessary legitimate vehicular use near appropriate habitat, such as by levee crews, mosquito abatement or wildlife personnel, researchers and the like, is appropriate but potential impacts to the species should be considered and avoided. Similarly, planning for maintenance of levees, ditches, and other features or structures should consider and avoid impacts to *C. molle* ssp. *molle* and its habitat. Recreational and research access may need to be redirected or redesigned if impacts to the species or habitat appear likely.

Where urban runoff has displaced former tidal marsh habitat at BSRA with freshwater emergent marsh, solutions should be identified to direct the runoff away from sensitive habitat.

Natural tidal range should be maintained or restored, since their resulting effects on vegetation and soil chemistry are important to the persistence of *C. molle* ssp. *molle*. Upper marsh areas with periodic tidal flooding and moderate to high soil salinity (due to evaporative concentration of tidal salts), the resulting low-stature vegetation, and low abundance of non-natives or winter annuals, are vital to the species. In particular, recent modifications to tidal fluxes at the important Hill Slough population need to be examined and any necessary fixes implemented promptly. As discussed in section II.B.2.B.1., salinity and flow manipulations via the Montezuma salinity control gates should be evaluated in light of possible consequences for populations of *C. molle* ssp. *molle*.

Seed banking is recommended for *C. molle* ssp. *molle*, including banking from different population areas. Seed banking should represent the range of diversity of the species, at least geographically, and also genetically if this information becomes available. Seed collection should follow standard precautions to minimize impacts to rare plant populations (Center for Plant Conservation 1991).

In addition to monitoring needed for appropriate management and tracking of progress toward recovery, it is recommended that field surveys be conducted for additional, as-yet undiscovered populations of *C. molle* ssp. *molle*. Any populations found will assist in expanding the remaining distribution of the species, reducing extinction risk across all populations, and possibly increasing the scope of genetic diversity of the species. To minimize damage to individual plants, presence-absence surveys should be used, if possible, for reconnaissance purposes and in determining within marsh distribution of extant populations. *Hydrogeomorphic* landscape position of the population patch (*i.e*., high marsh, upland transition, first order tidal creek edge/natural levee, drainage divide, high marsh plain) should be noted. In areas where more detailed abundance information is required, a logarithmic abundance class approach to estimating population size should be used in place of attempting to count individuals (*i.e.*, 1-10, 11-100, 101-1000, etc,). The process of parting the plant patches for accurate counts also results in high mortality as counters often unintentionally dislodge fragile hemiparasite root connections to host plant roots (Grewell pers. comm. 2009).

Given the importance of a host plant community comprised of a matrix of native perennials, information on host plants within *C. molle* ssp. *molle* population patches should also be gathered. In late spring/early summer, sampling plots should be established and information gathered on percent cover of each species within the plot. This information should be compared to logarithmic abundance classes of *C. molle* ssp. *molle*. Survey databases maintained by the CDFW and the non-profit California Native Plant Society may aid in conservation planning and protection.

Research is needed on many aspects of life history and conservation of *C. molle* ssp. *molle*. Methods and effects of non-native plant control are among the highest priority topics. Other important subjects include, but are not limited to: effectiveness of various pollinators and any natural self-pollination; techniques to restore appropriate habitat; reintroduction methods; pre-dispersal seed granivory and other factors affecting seed dispersal, seed survival and seed germination; parasite-host relationships and relative benefit of various host species; and the benefits and impacts of different management practices.

In regards to pre-dispersal seed predation, research should be conducted into current herbivory rates by moth larvae (*Saphenista* spp., Tortricidae and salt marsh snout moth, *Lipographis* *fenestrella*, Pyralidae) in *C. molle* ssp. *molle* rangewide. To minimize damage to individual *C. molle* ssp. *molle* plants, only a subsample of capsules from plants of selected plots should be inspected for evidence of herbivory (frass, boreholes, damaged seed or lack of mature seed) (Grewell *in litt*. 2009). Also, preserving and managing nearby native habitat for predators, parasites, and diseases of the seed-damaging species would likely benefit *C. molle* ssp. *molle* population dynamics. If herbivory rates are shown to result in significant declines in *C. molle* ssp. *molle* numbers, investigation should be made into management techniques appropriate for reducing populations of seed damaging species and such management should occur.

Over the longer term, restoration of suitable tidal marsh habitat and introduction/ reintroduction of *C. molle* ssp. *molle* within its historic range will advance recovery of the species. Restoration efforts may take time to build higher marsh elevations used by the species. Tidal marsh restoration projects within the geographic range of *C. molle* ssp. *molle* are likely to contribute significantly to its recovery after several decades. Introductions and reintroductions within the historic range, particularly around San Pablo Bay and associated marshes, to the westward extent of the known range, should be pursued where and as soon as conditions are appropriate. Introductions and reintroductions into larger or higher quality habitat areas in the Suisun Bay area will also help speed recovery of the species.

Some independent experimental efforts to translocate seed of *C. molle* ssp. *molle* and initiate new colonies have been performed by the Contra Costa Mosquito Abatement District. These resulted in establishment of numerous new colonies in existing brackish marshes with tidal range restricted by adjustable tidegates along the Contra Costa shoreline. Some of these colonies have exhibited net population expansion and persisted for several years (K. Malamud-Roam pers. comm. 1998). No data are available on effects of seed translocation on parent populations. Artificial establishment of new populations is a potentially useful tool for recovery of this species, but it has limited conservation value unless it is linked with habitat protection and restoration. In 2000, Brenda Grewell reintroduced a population of *C. molle* ssp. *molle* from seed on protected Solano Land Trust lands at Rush Ranch and this population remains today. Because the establishment of long-term populations is highly unpredictable, translocation for mitigation purposes (*i.e.*, replacement of established populations with experimentally established new ones) cannot be viewed as a conservation measure and is presumably detrimental to conservation (Berg 1996, Howald 1996).

Many of the most important populations of *C. molle* ssp. *molle* occur in areas owned and protected by public agencies with conservation policies that benefit rare or endangered species: Fagan Slough Ecological Reserve, Hill Slough, Joice Island Bridge Marshes (California Department of Fish and Game); Rush Ranch (Solano Land Trust); BSRA and Point Pinole (East Bay Regional Parks District). The Middle Point and Hasting Slough populations occur on federally-owned lands of the U.S. Navy and are therefore subject to the conservation obligations and prohibitions of the Endangered Species Act. These agencies, however, often lack the resources or mandate to manage these lands, and seldom have the resources or institutional priorities to enforce land use restrictions to protect or benefit *C. molle* ssp. *molle*, or to monitor populations adequately.

The principal benefits to *C. molle* ssp. *molle* from conservation activities are mostly indirect. The species is protected against filling and degradation of wetlands by general prohibitions and their effects on land use planning. The species also indirectly benefits from the prohibition against take of listed wildlife species (California clapper rail, salt marsh harvest mice), which has discouraged additional degradation of remnant tidal wetlands with suitable habitat for *C. molle* ssp. *molle*.

c. *Suaeda californica* (California sea-blite)

Recovery of *Suaeda californica* has two principal components: 1) protection of the population at Morro Bay to ensure its long-term survival, and 2) re-establishment of suitable habitat with new populations in San Francisco Bay, the historical range of the species. Implementation of all recovery tasks will allow the species to reproduce and establish in dynamic shoreline environments across its natural range.

Preventing extinction of the last wild natural populations in Morro Bay is the highest priority task. Public lands that support the species should be managed to reduce or eliminate threats to the population and to foster its natural regeneration. Management plans are needed at Montaña de Oro State Park (Morro Dunes Nature Preserve), which contains the largest block of habitat and has good potential for effective protection because of its relative inaccessibility. Smaller parcels, such as Sweet Springs Marsh in Baywood Park, also need to be managed to avoid losing colonies and habitat. The populations at the Morro Bay State Marina and the sandy shoreline between White Point and Fairbank Point require protection against grazing by deer, trampling, and future shoreline engineering.

Suaeda californica colonies occurring in artificially stabilized shorelines should be presumed important to the species. Impacts to existing *S. californica* plants from unavoidable maintenance of existing facilities or uses must not jeopardize the species, and should be offset fully (preferably in advance, or else with adjustment for risks of failure and likely mortality) by removing threats and expanding *S. californica* populations in restorable, preserved habitat. Some shallow dredging specifically to enhance eelgrass communities may be compatible with retaining tidal marsh in its current configuration.

Remaining undeveloped shoreline and an upland buffer zone should be protected from further encroachment or land use alteration, in potential and occupied habitat of *S. californica*. For example, the population of *S. californica* along the retreating beach shoreline between White Point and Fairbank Point (Morro Bay State Park) should be allowed to re-seed landward with the retreating shoreline and shoreline stabilization or development should be minimized there. *S. californica* at Grassy Island should be protected against potential dredging activities. Where possible, undeveloped private shoreline should be permanently protected by acquisition or conservation easement.

Along the bayshore of the Morro sandspit (Morro Dunes Natural Preserve, Montaña de Oro State Park) and elsewhere around Morro Bay, the habitat quality of the high marsh zone for *S. californica* —particularly for seedling establishment—should be enhanced by control of invasive non-native *Carpobrotus edulis* (iceplant) and hybrids. Control of *Carpobrotus edulis* should extend in phases—first immediately around *S. californica* plants, then throughout *S. californica* potential habitat, then a buffer strip next to tidal marsh, then source areas for propagule sources (vegetative fragments from foredunes, seed sources from fruiting populations in stable dunes). *Carpobrotus edulis* control activities could have adverse impacts on the endangered Morro shoulderband snail (*Helminthoglypta walkeriana*; U.S. Fish and Wildlife Service 1994) and should be conducted so that impacts are minimized and offset, for example, by establishment of suitable native habitat. Any such work would need to be performed under the authority of a section 10 (a)(1)(A) permit for Morro shoulderband snail that includes habitat restoration as a covered activity. Non-native trees and shrubs also should be removed from the vicinity of *S. californica* habitat, except at those sites used by herons, egrets, and cormorants as rookeries. (Rookeries cause tree dieback, and *S. californica* is stimulated rather than injured by rates of guano deposition toxic to most other plants (P. Baye pers. comm. 2004).

Management of sand dunes upwind of areas inhabited by the species may be needed to control factors that affect survival and regeneration of *S. californica*. Dune mobility should be monitored, especially where it has been artificially increased by human actions, such as deposition of dredge spoil. If dune drift threatens to eliminate important stands of *S.californica,* it should be reduced, for example, by extensive replanting of native dune-stabilizing vegetation during years of above-average rainfall. Any future dredge disposal in the area should be planned to avoid unnatural dune drift onto tidal marsh habitat and to maximize nesting habitat of western snowy plover.

Areas of degraded habitat should be restored to encourage re-expansion of *S. californica* colonies there. Experimental augmentation of populations, including initiation of new colonies in suitable unoccupied habitat, should be continued to assist in local recovery following natural declines in population. Continued propagation and planting of *S. californica* is appropriate if monitoring indicates it remains successful and within ecologically appropriate bounds. Adequate propagation to allow for periodic translocation of *S. californica* plantings to San Francisco Bay is desirable.

Research within the Morro Bay population of *S. californica* is needed to determine those factors necessary for seed survival, germination and seedling establishment. Additional studies on the relative importance of impacts of grazing, trampling and disturbance there, such as from deer and recreational activities, and how to prevent or minimize impacts should prove useful.

A viable set of populations of *S. californica* in San Francisco Bay is necessary because 1) survival of the species is likely to depend on more than one geographically distinct population, each with independent risks of extirpation, and 2) continued evolution of the species in its full natural range of environmental variability must be restored to ensure long-term survival. The major historical habitat for *S. californica* in San Francisco Bay was the Oakland-Alameda sand-edged marshes, which have been destroyed and cannot be restored due to intensive urban land use. Recovery of the species in this urbanized estuary will depend on 1) establishment of local populations in pocket tidal marshes with sand or shell beach ridges formed spontaneously along artificially modified bay shorelines, 2) ecological engineering of new sand *spits* and backbarrier tidal marshes in suitable environments in the vicinity of historical localities, and 3) introduction and reintroduction to suitable unoccupied habitat. Cooperation of land managers and adjacent landowners, and preparation and implementation of scientifically sound introduction, reintroduction and management plans, will be essential to the recovery of *S. californica* in San Francisco Bay.

In San Francisco Bay, the Baylands Ecosystem Habitat Goals report (Goals Project 1999), a comprehensive overview of recommendations to restore wetlands in the San Francisco Bay Estuary, proposed specific objectives to restore suitable habitat and reintroduce *S. californica* to selected shorelines of San Francisco Bay. A pilot reintroduction project for the species, jointly managed by the National Park Service (Golden Gate National Recreation Area) and the non-profit Golden Gate National Parks Association, restored a small-scale barrier beach and tidal marsh at Crissy Field in the Presidio of San Francisco (Farrell and Heimbinder 2000). Successful techniques for vegetative and seed propagation of *S. californica* were developed at Strybing Arboretum and Botanical Garden, San Francisco, and at the Golden Gate National Recreation Area's two native plant nurseries at the Presidio and Fort Cronkite.

Initial reintroductions of *S. californica* to Crissy Field in the Presidio failed because of prolonged periods of non-tidal submergence along lagoon shorelines where it was transplanted by the National Park Service (NPS; in coordination with U.S. Fish and Wildlife Service) in 2000. The National Park Service provided excess propagation material of *S. californica* to Heron's Head marsh restoration (Pier 98, near a long-extirpated locality of *S. californica*), but transplants declined because of unsuitable substrate conditions. Seed dispersal from Heron's Head transplants, however, resulted in successful spontaneous seedling establishment of *S. californica* on a low, naturally formed shell and sand beach ridge with sparse tidal marsh vegetation (pickleweed, saltgrass, alkali-heath) elsewhere at Pier 98. The new Pier 98 colony now consists of very robust, vigorous plants with abundant production of viable seed (P. Baye pers. comm. 2007). The spontaneous spread and high vigor of the Pier 98 population, in the absence of any management at all, suggested a high feasibility for successful deliberate reintroduction of *S. californica* in suitable, dynamic high sandy marsh habitats along other urban shorelines of San Francisco Bay.

In 2006, under contract with the U.S. Fish and Wildlife Service, Peter Baye completed the *California Sea-blite (Suaeda californica) Reintroduction Plan, San Francisco Bay, California*. This document investigated and ranked the suitability of various potential *S. californica* reintroduction sites around San Francisco Bay. Candidate sites were evaluated in terms of indicators of physical shoreline structure and dynamics (beach profile, wave climate, erosion/accretion, shoreline stability, tidal litter characteristics), invasive shoreline vegetation, land ownership and use (compatibility, management feasibility), and population potential. In the document, four San Francisco Bay sites were considered highly feasible for reintroduction in near-term planning (one to three years): (1) Roberts Landing Beach (San Leandro); (2) Radio Point Beach marsh complex at Emeryville Crescent tidal flats (Oakland Bay Bridge approach, north shore), (3) Eastshore State Park beach, Berkeley; (4) Brisbane spit (bayshore gravel/shell spit south of Candlestick Point). Reintroduction plans for these sites are proposed.

The above project also included on-the-ground reintroduction at sites identified in the *California Sea-blite (Suaeda californica) Reintroduction Plan, San Francisco Bay, California* if landowner permission for reintroduction was granted. In March 2007, 14 transplants were introduced along the high tide line in the northeast portion of the Emeryville Crescent, Alameda County, portion of Eastshore State Park managed by East Bay Regional Park District, a regional recreation district. A monitoring visit in April of the same year revealed the mortality of only four transplants, presumably from moisture deficit, as no significant rain fell the week after transplanting. The remaining ten plants, however, were healthy and thriving. At least several plants had moderate to heavy seed production that initial year. The purpose of this specific reintroduction at Emeryville Crescent was to reintroduce self-regenerating populations of the species in suitable habitat that does not require intensive management.

The project was designed to utilize volunteers from the general public and non-profit conservation organizations to conduct annual monitoring and light maintenance activities. The U.S. Fish and Wildlife Service expects this demonstration project to provide scientifically sound evidence of reintroduction success with *S. californica* in San Francisco Bay through a highly cost-effective program and method capable of replication at other sites. In fact, a second reintroduction was conducted in March 2008 at Robert's Landing. It is too soon to determine whether these eight plants, which exist on City of San Leandro lands, will be self-sustaining.

A major goal of these founder populations in San Francisco Bay is to produce seed and spontaneously establish seedlings subject to natural selection in San Francisco habitats. The reintroduced founder populations were composed of clones or seedlings sampled throughout the Morro Bay area to increase genetic variation. Plants were propagated with permanently labeled stock plants (clonal pedigrees) to prevent over-representation of a few *genetic individuals*. Additional individuals were added to compensate for loss of founders and to offset limited initial founder population size. Propagated and transplanted individuals will not be counted toward recovery of the species because they do not reflect natural population or evolutionary processes. Experimentally reintroduced populations will only contribute toward recovery, as indicated in the recovery criteria, when plants produce seed which germinates and grows at the site over multiple generations. Long-term monitoring, education, and *stewardship* programs for *S. californica* should generate public interest and support for further habitat restoration and rare plant species reintroduction in San Francisco Bay.

Considerable research is likely to be needed on *S. californica* in San Francisco Bay, including best techniques for establishing and maintaining the species and methods for restoring or re-creating appropriate habitat. Understanding of dispersal and colonization patterns and the importance of various factors affecting them will also be useful, as will population demography.

Morro Bay State Park currently provides no programs to control exotic vegetation where it interferes with growth and reproduction of *S. californica*. Local municipal tidal marsh parcels in the residential Baywood Park do have some public education signs and voluntary restrictions on marsh access, which benefit some colonies. Two parcels have recently entered into conservation ownership: California Department of Parks and Recreation recently acquired a 19 acre parcel at the western terminus of Butte Drive near Los Osos and Morro Bay Audubon Society acquired a 12 acre parcel of habitat contiguous with Sweet Springs Nature Reserve, also near Los Osos (J. Vanderweir pers. comm. 2009). With few exceptions, there are currently no other major proposals or plans to manage or conserve *S. californica* populations in Morro Bay.

d. California clapper rail (*Rallus longirostrus obsoletus*)

A number of State and Federal statutes were employed over the last 15 years to protect California clapper rails. For example, in 1991, the Regional Water Quality Control Board, under provisions of the State's Porter Cologne Water Quality Act and section 402 of the Federal Clean Water Act, required about 385 acres of full replacement for habitat values and acreage lost due to conversion of approximately 270 acres from tidal marsh to fresh/brackish marsh in south San Francisco Bay from the City of San Jose waste water discharge. Under the provisions of section 7 of the Endangered Species Act and section 404 of the Clean Water Act, the U.S. Fish and Wildlife Service and U. S. Army Corps of Engineers have protected California clapper rail habitat from a variety of potential impacts or threats, including utilities and transportation incursions, flood control dredging, levee maintenance and several proposed commercial developments (*e.g.*, Cullinan Ranch and Shorelands).

Recovery of California clapper rails requires a combination of interim and long-term actions. Interim actions are those necessary to maintain current populations while long-term actions focus on recovering the species throughout its range. Interim actions involve monitoring current populations (number and distribution), non-native predator and invasive plant control, reducing human disturbance and protection of existing habitat. Long-term actions involve large-scale tidal marsh restoration and implementation of long-term management plans.

Habitat Acquisition

Acquisition efforts for the California clapper rail aim to provide or protect lands that can be used to create and expand clapper rail habitat, focusing on land sustainable as habitat given anticipated sea level rise. Recent habitat acquisition efforts focus on acquiring remaining tidal marsh, salt ponds, and other historic baylands and adjacent uplands in the San Francisco Bay Estuary. Acquisition in the San Francisco Bay Estuary as a whole focuses on diked baylands that can be restored to tidal influence, which is critical for providing lands for future tidal marsh restoration.

In March 2003, 6,677 hectares (16,500 acres) of salt ponds were sold and donated by Cargill Incorporated to CDFW and the U.S. Fish and Wildlife Service for tidal restoration. If successful, the restoration could be the single most significant step toward California clapper rail and salt marsh harvest mouse recovery and represent the largest tidal restoration project in west coast history. The acquisition included approximately 607 hectares (1,500 acres) of salt ponds in the Napa River watershed and approximately 6,070 hectares (15,000 acres) of salt ponds in the South Bay (specifically at the Eden Landing, Alviso, and Ravenswood areas). Collectively comprising the SBSP Restoration Project, the former commercial salt ponds are slated for phased restoration as a mosaic of tidal marsh and nontidal managed ponds and represent a significant portion of the restoration vision first articulated by the Bayland Ecosystem Goals Project. The Final EIR/EIS for the SBSP Restoration Project was published on December 12, 2007.

The Eden Landing site, formerly proposed as a racetrack and park complex (previously called Shorelands), is one of many key sites now protected in San Francisco Bay, and one of three major pond complexes comprising the SBSP Restoration Project. The Eden Landing site is owned and managed by the CDFW. The other two pond complexes at Alviso and Ravenswood are owned and managed by the Don Edwards San Francisco Bay National Wildlife Refuge. Tidal wetland restoration in these areas will add significant high quality habitat for tidal species as well as many species of shorebirds. While the final habitat acreage suitable for restoration to tidal marsh habitat is yet to be determined, thousands of acres of suitable habitat for tidal marsh species may eventually be enhanced or restored, and existing populations protected. The first phases of restoration are currently underway in all three complexes.

Other major acquisitions where tidal marsh restoration has or will soon occur to benefit clapper rails include Cullinan Ranch (647 hectares/1,600 acres), Hamilton Army Airfield (364 hectares/900 acres), Bel Marin Keys Unit V (647 hectares/1,600 acres), Bahia (256 hectares/632 acres), Skaggs Island Naval Reserve (1,214 hectares/3,000 acres), Bair Island (567 hectares/1,400 acres), Eden Landing Tract (338 hectares/835 acres), Oro Loma Marsh (Marathon property; 132 hectares/325 acres), Sonoma baylands (121 hectares/300 acres), and the Napa Marsh salt ponds (over 3,237 hectares/8,000 acres). Many important, but smaller restoration projects have occurred or will soon occur. This represents a major increase in habitat acquisition for clapper rail recovery since the 1984 recovery plan (U.S. Fish and Wildlife Service 1984). However, full recovery of the California clapper rail still requires a substantial increase in the amount of baylands restored to tidal conditions.

Habitat Restoration

In addition to the above restoration efforts associated with recent habitat acquisitions, tidal influence has been reintroduced to many other sites in the bay and will provide benefit for the California clapper rail. Restoration sites in the South Bay include the Faber Tract, Outer Bair Island, Hayward Shoreline, LaRiviere Marsh, the Island Ponds, and East Third Avenue. In the North Bay, restorations have included a portion of Muzzi Marsh, Toy Marsh, Carl's Marsh, Tolay Creek, Sonoma Baylands, and White Slough. These restorations have occurred by natural levee breaching, enhancement projects, or as mitigation to offset the impacts of commercial development. Other tidal marsh restoration projects have not been successful in establishing the quality clapper rail habitat that was expected, for example, Warm Springs restoration in Fremont, New Alameda Creek salt pond restoration, the majority of Muzzi Marsh, and Bel Marin Keys mitigation on Tubbs Island.

Long-term recovery actions should focus on increasing habitat suitability and abundance in an appropriate distributional pattern. The California clapper rail cannot be recovered simply through protection of habitat currently available. Active management and restoration of diked areas to tidal marsh is required, with a focus on lands sustainable as habitat given anticipated sea level rise. Large blocks of tidal marsh have numerous advantages and must be restored and maintained in perpetuity to ensure the continued existence of these birds. First, large marshes increase distances from upland predator den/nest sites and impede foraging efficiency of terrestrial predators. This reduces predation pressure on California clapper rail adults, chicks, and eggs. Secondly, large areas of marsh have fewer urban edge effects, including human-related disturbance, contaminant inputs, and litter and subsequent attraction of rodent predators. Thirdly, the size and complexity of tidal slough networks increases as marsh size increases (Collins *et al.* 1994). A complex network of tidal sloughs provides the combination of foraging habitat and cover required by clapper rails. In addition, as the order of tidal slough increases (from primary to tertiary and higher, or as one travels farther into the marsh from the bay), the elevation of marsh increases. This means that elevation-dependent nesting areas and high tide refugia are more prevalent in large marshes. Large-scale restoration projects are also more efficient compared to smaller, piecemeal efforts in terms of construction activities and management and will yield larger net benefits to clapper rails.

Key elements that will determine the suitability of each habitat block for clapper rails include: vegetation structure (height and thickness relative to tide height) sufficient for nesting, brooding, and loafing; channel structure sufficient for feeding and protected movement throughout the marsh; and high tide refugia and transitional areas. First priority for acquisition/restoration of baylands are those areas with the best quality habitat and the most rapid restoration potential relative to anticipated sea level rise and the amount of time and effort invested. Habitat acquisition/restoration efforts should first build suitable habitat around existing populations and then provide links between these areas. Areas nearest to large rail populations/habitat blocks, under the least pressure from non-native species (especially red fox), and least subsided or with the highest natural sedimentation rates, are included as first priority for acquisition/restoration to tidal marsh. In situations when dredge spoils become available for use in restoration, these priorities may shift slightly in placing a heavier emphasis on restoration in close physical proximity.

In addition, links must be maintained throughout the bay to facilitate dispersal and gene flow among subpopulations. These links should be in the form of smaller units of managed and protected tidal marsh located between two or more larger areas each capable of sustaining clapper rails over the long-term. Dispersal facilitates exchange of genetic material among subpopulations (outbreeding) and promotes recolonization of any sites that experience declines or local extirpation. Population increases for the rail must be distributed first throughout San Francisco Bay, and then throughout most of the formerly occupied coastal areas. Clapper rail reoccupation of historical range will diffuse the risk of catastrophic extinction resulting from events such as disease, predator outbreaks, and oil spills. Stable populations in independent estuaries will act as multiple refugia and survival insurance for the species as a whole. In addition, multiple populations in independent estuaries will allow for potential differentiation of populations and continuing evolution.

Existing tidal marshes that must be protected and/or enhanced include those north of Roberts Landing, north of Hayward Landing, north of Johnson Landing, the Hayward Area Recreation District Marsh, Alameda Creek, San Francisco National Wildlife Refuge lands, Coyote Creek, Laumeister Marsh, Greco Island, Bair Island, Colma Creek, Steinberger Slough, and Belmont Slough; Corte Madera Creek, Gallinas Creek, Muzzi and Heerdt Marshes, Arrowhead Marsh, Crescent Marsh, Wildcat Marsh, and Point Pinole; China Camp, Hamilton, Petaluma River and baylands, Tolay Creek, Sonoma Creek, Mare Island, and Napa River; BSRA, Bahia (Marin County), Goodyear Slough, Browns Island, Martinez East, Martinez West, Concord Naval Weapons Station, Point Edith, and Pacheco Creek; Mud River Slough, Indian Island, Daby Island, and Teal Island; Bodega Bay, Tomales Bay, Bolinas Lagoon, and Drake's Estero; Elkhorn Slough Estuarine Sanctuary and Moss Landing.

Establishing founder populations at the northern and southern extremes of the rail's historic range by way of translocation is not considered a viable recovery strategy at this time. Reliable translocation techniques and success criteria which would be critical to this endeavor have not been developed. Survival of adults has been identified as a key variable in maintaining clapper rail populations, so capture and translocation of the species without the benefit of proven techniques would be risky.

The expanding tidal marsh of the delta of Chorro and Los Osos creeks in Morro Bay contains tidal creek networks which may be, or may become, structurally suitable for clapper rails. A study may be needed of whether adequate foraging habitat and high tide refugial areas exist or could be restored to support the species. If California clapper rail populations in San Francisco Bay increase to sizes and densities that promote significant emigration of vagrants, they may wander to or recolonize Morro Bay. Tidal marsh and tidal creek networks there should be conserved to allow for such range re-expansion.

Management

In the San Francisco Bay region and southern California, management of clapper rails in recent years has focused on controlling introduced non-native predators, increasing habitat availability, and improving habitat quality. Continued non-native predator control in south San Francisco Bay, and expanded efforts in north San Francisco Bay (San Pablo Bay and Suisun Marsh area included), are necessary to protect current California clapper rail populations. The impact of non-native predators, particularly red fox, on clapper rails is well documented in San Francisco Bay and elsewhere (Roberson 1993, Albertson 1995, Harding *et al.* 1998). Management resources should be dedicated to continued and expanded predator control to reduce clapper rail loss and facilitate efforts to increase rail numbers and expand their range.

An integrated predator management program aimed at red fox, rats, skunks, raccoons, and cats was implemented at Don Edwards San Francisco Bay National Wildlife Refuge and adjacent areas in 1991 (U.S. Fish and Wildlife Service 1991). The Refuge evaluated the efficacy of its predator control program over 5 years and found that between 50-70 percent of the adult predator population, and 25-50 percent of the juvenile predator population, were removed annually (Harding *et al.* 1998). There was a positive relationship between the growth rate of clapper rail populations and red fox trapping success in the preceding year, which indicates that rail populations were depressed in areas with high numbers of red fox. In addition to trapping and removal, predator control has been achieved through debris removal, removing potential den sites, discouraging feeding of cats near marshes, and through public education.

Increasing habitat availability has been accomplished by restoring the full tidal prisms and lowering levees in many areas of restoration projects. A full tidal prism ensures that sufficient channel flushing occurs to prevent excessive sediment deposition and subsequent channel infill, thus maintaining slough channels in perpetuity. Reducing the elevation of levees in restored marshes to mean high water or mean higher high water and disrupting their contiguity (levee islands) will greatly decrease their use by predators for movement corridors and nesting/denning. In addition, the lowered, predator-free levees and levee islands may provide relatively elevated areas that function as high tide refugia for clapper rails.

Improving habitat quality has also been a management focus, via non-native species control programs, habitat enhancement projects, and human disturbance reduction. The Invasive

Spartina Project and the Don Edwards San Francisco Bay National Wildlife Refuge have led an aggressive control effort against invasive *Spartina* species. Though the physical structure of some invasive *Spartina* remains, eradication is nearly complete. Revegetation with native *Spartina foliosa* should now be the focus to provide refugial habitat for the rail without delay. A number of Federal, State and local agencies and individuals have been monitoring the progress of invasive *Spartina* growth, and a few agencies have been attempting to control/eradicate the species on their holdings as well.

U.S. Geological Survey and East Bay Regional Park District should continue to manage rails at Arrowhead marsh, through the use of artificial islands (Takekawa *et al*. 2011). Pending research explained below, this management should extend baywide.

Many of the restoration projects also include management plans to control or eliminate non-native *Lepidium latifolium* and other invasive plant species. The Refuge removed artificial raptor perches (posts and stakes) from most of their property in the South Bay, enhancing habitat quality for rails by reducing predation pressure. Marsh managers also worked to reduce disturbance to rails resulting from recreational use of marshes, including off-trail activities, noise, and off-leash pets. These efforts should be continued and incorporated into management plans for future marsh restoration projects throughout the bay.

Surveys

Annual clapper rail monitoring should continue on Don Edwards San Francisco Bay National Wildlife Refuge, and expand to other Federal and State owned lands. Monitoring provides data that are useful both in the short-term for adaptive management of existing tidal marsh, and in the long-term to determine success of recovery efforts. Monitoring protocol should approximately follow current monitoring design used by PRBO Conservation Science in their estuary-wide surveys for long-term analysis purposes and should help to capture normal population fluctuations and to asses rail response to invasive *Spartina* control. In addition to annual monitoring conducted throughout the current range of the rails, intensive monitoring should be conducted at the edges of the current range, particularly in Suisun and Tomales bays. As recovery efforts proceed, California clapper rail population distribution will expand. Intensive monitoring will be necessary to document the resulting range expansion.

Research

Prior to the late 1980s, research on California clapper rails was limited to basic life history studies (*e.g.*, Degroot 1927, Applegarth 1938), population surveys and censuses (Gill 1972, Harvey 1980), and nesting success studies in localized areas (Harvey 1980). More recently studies by the Environmental Contaminants Division of the U.S. Fish and Wildlife Service and the U.S. Geological Survey have revealed elevated levels of selenium and mercury in fail-to-hatch rail eggs, lowered nesting success due to predation, and declining rail populations in the South Bay (Foerster 1989, Lonzarich *et al.* 1992, Schwarzbach *et al.* 2001, Schwarzbach *et al*. 2006). A radiotelemetry study was conducted by the U.S. Fish and Wildlife Service in 1991-92, investigating home range size and the impacts of predation on rails in the South Bay (Albertson 1995). The CDFW has funded studies on breeding populations and habitat use in the North Bay (Evens and Collins 1992, Collins *et al.* 1994). Other studies being initiated include *Spartina alterniflora* use by rails (Casazza *et. al.* 2008, Casazza *in litt.* 2009), population genetics (R.

Fleischer unpubl. data), population modeling (M. Johnson unpubl. data), and use of artificial nesting islands in areas previously treated to control invasive *Spartina* (USGS, unpublished data). Annual winter and breeding surveys are conducted in selected areas (U.S. Fish and Wildlife Service unpubl. data).

Further research is needed on clapper rail fledge success, adult survival, and dispersal. An assessment of the remaining genetic diversity of California clapper rails is needed, including comparisons between different reaches of the bay. Continued assessment of clapper rail population status and research on population dynamics are important for predicting potential colonization rates of restored marshes. To accomplish this, there needs to be a better understanding of subadult clapper rail survival, subadult and adult dispersal rates among marshes and bay reaches, and relationships between dispersal rates and inter-marsh distances and other environmental factors. Development of clapper rail population models that incorporate meta-population dynamics would facilitate these efforts and also aid in potential future translocation efforts. In 2008, the U.S. Fish and Wildlife Service provided funding to the U.S. Geological Survey to continue home range studies of California clapper rails using radio-telemetry in three San Francisco Bay marshes. These studies had initially been funded by the Invasive Spartina Project to determine effects of invasive *Spartina* control on California clapper rails. Later in 2008, the U.S. Geological Survey was awarded additional funding to add a diet analysis component of the project, focusing on identification of contaminated prey items.

U.S. Geological Survey and East Bay Regional Park District should continue research into the use of artificial islands by California clapper rails displaced by decreasing amounts of invasive *Spartina* at Arrowhead Marsh. It is believed that these islands will provide important refugial habitat to rails while native vegetation establishes. Preliminary results show that the islands were indeed immediately inhabited by rails and show promise for providing interim refuge (Takekawa *et al*. 2011).

Hatchability of California clapper rail eggs in San Francisco Bay has been shown to be low (Schwarzbach *et. al.* 2006). Previous studies have suggested that environmental contaminants, primarily mercury, are a contributing factor. PCBs and dioxins have not been ruled out, however, and more research is needed using congener specific techniques to assess their contributions to embryo toxicity.

The sensitivity of California clapper rails to mercury and other contaminants prevalent throughout the bay is not known and currently may only be estimated based on toxicity tests on species from other families (*e.g.* Phasianidae). As stated above under threats to California clapper rail, comparisons of hatchability results and egg mercury results is complicated by the fact that mercury concentrations in successfully hatched eggs could not be tested- only those in fail-to-hatch rail eggs, a limitation of working with an endangered species. However, recent work by Heinz (2002) using carefully developed techniques for injection of methylmercury into eggs of many different wild species suggest that avian species vary greatly in the sensitivity of their embryos to methylmercury and that the California clapper rail embryos may be among the more sensitive of avian species to methylmercury. Therefore, based on egg injection work on mallards (*Anas platyrhynchos*) and assessments of the rail's current reproductive status, it has been estimated that observed adverse effects, in the form of developmental abnormalities and reproductive harm could be seen above 0.2 µg/g fresh wet weight (fww) methlymercury in rail eggs (U.S. Fish and Wildlife Service 2003). Since we do not currently know with certainty what proportion of the rail population can sustain developmental abnormalities and still have a self-sustaining population, research should be conducted to investigate developmental thresholds in regards to mercury. Only fail to hatch eggs will be sampled; sampling will occur opportunistically as fail to hatch eggs are available. Toxicity tests and studies with similar species such as the non-endangered east coast rails (*Rallus longirostris crepitans* or *Rallus elegans*) may provide a better idea of the relative sensitivity of rails to contaminants compared to standard test species. We do not know for certain what proportion of the rail population can sustain developmental abnormalities and still have a self-sustaining population. Results of future research on toxicity of mercury to rails should be used to revisit Delisting Criterion E/5 for the rail. If rail numbers rebound to a sufficient level due to achieving other recovery criteria, it is possible that a status review may indicate that downlisting or delisting is warranted although not all recovery criteria are met (*i.e*., mean mercury concentrations may be allowed to reach 0.2 µg/g (fresh wet weight) within a marsh complex). Conversely, it is possible that the recovery criteria could be met and a status review may indicate that downlisting or delisting is nonetheless *not* warranted (*i.e*., mean mercury concentration must fall below an even *lower* threshold within a marsh complex).

Perhaps more important in the long term, is research on wetland restoration techniques and design efficacy, and contaminant concentrations in wetland sediments (especially methylmercury production). The ramifications of failed tidal marsh restoration are large and long-term due to the large number (and large total acreage) of restoration projects that are currently in various stages of planning and implementation.

Outreach and education

Public information and education programs about the habitat needs of clapper rails, and the function and value of intact tidal marshes, should be expanded. To assure protection and management of key areas, participation plans should be in place among cooperating agencies, landowners, and conservation organizations.

e. Salt marsh harvest mouse (*Reithrodontomys raviventris*)

Past Conservation/Restoration

Numerous conservation measures that benefit the salt marsh harvest mouse directly or indirectly have been implemented since the publication of the 1984 recovery plan. The most ecologically significant conservation actions have been habitat protection, enhancement, and restoration. Beneficial habitat modifications have been performed both for their own sake and as mitigation for authorized actions that harm salt marsh harvest mouse populations and habitat.

Several critical sites in the range of the southern subspecies proposed for full development in the 1980s were modified significantly to minimize areas and impacts in salt marsh harvest mouse habitat and to provide habitat protection and enhancement over the remaining habitat. This resulted in net benefits to the population. Outstanding examples are Roberts Landing (Citation Homes, San Leandro) and Mayhews Landing (Newark). In both these sites, the majority of habitat was protected and enhanced by re-engineered tidegates to improve salinity and moisture of tidal marsh, while providing tidal drainage to prevent prolonged impounding of flood waters. These restorations have not been free of management problems, but the key habitats and populations are substantially improved in terms of security and quality. Monitoring and reporting requirements of project permits, however, were limited, so the long-term ecological and population trends of these sites will be difficult to determine.

The 6,677 hectares (16,500 acres) of salt ponds sold and donated by Cargill Incorporated to CDFW and U.S. Fish and Wildlife Service in March 2003, and the ponds restoration through the SBSP Restoration Project (US. Fish and Wildlife Service 2009*b*), could be the single most significant step toward California clapper rail and salt marsh harvest mouse recovery. The Eden Landing site, to be owned and managed by CDFW, will add significant high quality habitat for tidal species as well as many species of shorebirds. Thousands of acres of suitable habitat for tidal marsh species may eventually be enhanced or restored, and existing populations protected. Similar phased restoration is planned for pond complexes at Alviso and Ravenswood areas, which will be owned and managed by the Don Edwards San Francisco National Wildlife refuge.

The engineered tidal marsh restoration at Pond 3 (Alameda Creek) is among the oldest in San Francisco Bay, constructed by the U.S. Army Corps of Engineers using dredged materials from the adjacent flood control channel. Although the project had some unanticipated and somewhat undesirable outcomes (spread of invasive *Spartina*, overfilling of dredged sediment), it has resulted in a large, high-elevation tidally influenced *Sarcocornia* marsh and an expanded population of salt marsh harvest mice. The marsh, however, has been only trapped twice, once in 1984 and again in 1985; capture efficiencies were 1.75 and 1.5 percent respectively, considerably below the 2.355 percent average for all projects. The overfilling of the site above design criteria minimized clapper rail habitat, but provided exceptionally thick *Sarcocornia* habitat that should be well buffered against rise in sea level, providing a major refuge for the species in a subregion where its populations and stable high-quality habitats are scarce.

Two other important habitat sites for the southern subspecies, New Chicago Marsh (Alviso) and Renzel Marsh (ITT Marsh, Palo Alto) have been acquired and protected for wildlife, with high management priority for the salt marsh harvest mouse. The Renzel Marsh was protected and enhanced as mitigation for wastewater impacts (brackish marsh conversion) in Palo Alto, and New Chicago Marsh was acquired as an addition to the San Francisco Bay National Wildlife Refuge (Refuge). These marshes were re-engineered with tidegates to minimize the impoundment of floodwater and hasten flood drainage and to provide limited, managed tidal flows to enhance *Sarcocornia* habitat. They have succeeded in increasing the quality and abundance of *Sarcocornia* habitat, but water management will require ongoing adjustment (Woodward-Clyde 1996, Shellhammer pers. comm. 1998). In addition, as part of the asbestos removal program in that vicinity, the flood tidegates at New Chicago Marsh have since been removed and the responsibility for alleviation of marsh flooding lies jointly with the City of San Jose and the Refuge. The City pumps water out of New Chicago Marsh only during extreme high water events using the facilities at the Alviso pump station (Duke pers. comm. 2005). These facilities are only designed to begin pumping when the water is extremely high in the marsh, so the Refuge is responsible for preventing the water from reaching this stage. Current Refuge outflow pumps were not designed to handle this volume of water, so the Refuge has had to rent pumps on several occasions. The Refuge is planning to improve water inflow and outflow structures to allow better water management in the marsh to enhance mouse habitat and to prevent excessive flooding (Albertson *in litt.* 2009*a*).

One south San Francisco Bay mitigation site, the engineered *Sarcocornia* “mouse pasture” at Bayside Business Park at Warm Springs (Fremont), has been colonized by a continually low population of salt marsh harvest mice. The adjacent Bayside Business Park II development nearer Dixon Landing Road on Coyote Creek was reduced in size from its original footprint to minimize urban fill in *Sarcocornia* habitat. It is engaged in a long-term, phased conversion from diked, non-tidal *Sarcocornia* /salt pan habitat subsided well below sea level, to a tidal marsh with a wide, sloping, high tidal brackish marsh zone along the landward edge (U.S. Fish and Wildlife Service *in litt* 1996). Both sites are small and relatively isolated and the long-term outcome of this habitat restoration remains to be seen.

Other sites subject to mitigation have less auspicious results for recovery of the salt marsh harvest mouse. The large saline field adjacent to Mayhews Landing (former Jarvis Avenue) in Newark with sparse, but restorable, salt marsh harvest mouse population and habitat was almost completely developed as a business park in the mid-1990s leaving a highly reduced engineered flood detention basin with restricted tidal flows in a highly reduced area of tidal marsh. It is unclear whether this habitat will sustain a viable population of salt marsh harvest mice, or whether it will act as a dispersal sink for adjacent habitats in the San Francisco Bay National Wildlife Refuge and Mayhews Landing.

Two highly important sites in San Pablo Bay are of significance for the northern subspecies. The 258 hectare (632 acre) Bahia property, along the lower Petaluma River, was purchased by Marin Audubon Society in 2003, which transferred 330 acres to CDFW and 250 acres to the Marin County Open Space District. In 2008, in partnership with CDFW, Marin Audubon Society restored 153 hectares (377 acres) of diked baylands to tidal action. The restoration project design included a wide 10:1 slope, complete with refugial habitat. Though salt marsh harvest mice were present before the pre-existing water control structure broke in 2004, the area is now flooded and not likely to support mice in the short-term. However, as the area is now open to full tidal action and the project was designed with a 10:1 slope, with refugial habitat, the area may provide high quality habitat for salt marsh harvest mice when the marsh reaches maturity. Secondly, as mitigation for a median barrier/shoulder widening project along the highway, the California Department of Transportation (Caltrans) engineered flood drainage enhancements to the Highway 37/Mare Island strip marsh, the eastern half of which suffered flooding and drainage problems caused by the intake canal berm. The project resulted in rapid sediment accretion and decreased the depth and duration of flooding from storm surges and rain. The project would have restored 647 hectares (1,600 acres) to highly valued tidal marsh habitat. However, though initially successful, infilling and waves eventually re-built the berm and the added drainage was lost after approximately 6 years (P. Baye pers. comm. 2007).

Another major tidal drainage enhancement project that reduced persistent storm-tide flooding of salt marsh harvest mouse habitat is located in San Pablo Bay at the mouth of Tolay Creek in the San Pablo Bay National Wildlife Refuge. This was completed in 1999 and is being monitored for the Refuge.

Management of habitat in Suisun Marsh favorable for salt marsh harvest mice has been minimal in the past, and compensation requirements for the northern subspecies in the subregion from the 1980s were not met in a timely manner. In 2000, a collaborative program established by the California Department of Water Resources, the CDFW, and an ad hoc interagency group, the Suisun Marsh Environmental Coordination Advisory Team, established an action program to fulfill and exceed delinquent monitoring and compensation requirements. The implementation of this program should establish 1,012 hectares (2,500 acres) of preferred salt marsh harvest mouse habitat (California Department of Fish and Game *in litt.* 2000). The Delta Stewardship Council's goals for ecological restoration in Suisun Marsh were revised to 2,833 hectares (7,000 acres) of tidal marsh restoration in Suisun Marsh (M. Thabault pers. comm. 2001). By 2009 three tidal marsh restoration projects were either fully or partially Delta Stewardship Council-funded and are in some phase of development (Blacklock, Meins Landing, and Hill Slough). Levees have already been breached at Blacklock and Meins Landing projects, led by California Department of Water Resources. Restoration at Hill Slough by CDFW is currently on hold pending availability of funds (Barthman-Thompson *in litt*. 2009). The Montezuma Wetland Project near Collinsville has not been completed, but it contributed precedent-setting and thorough habitat restoration designs that included interim management to conserve resident populations of salt marsh harvest mice in diked wetlands, and engineered high marsh habitat to facilitate early recolonization by the species.

Much of the variation in morphology and color among harvest mouse populations is quantitative, and traits of individual specimens may overlap. To improve consistency, standardized trait-scores for key harvest mouse morphological variables have been developed (Shellhammer 1984). Intergrades between western harvest mice and salt marsh harvest mice have become more common in trapping surveys (Zetterquist 1976, Steinberg 1997). It is not known whether intermediate populations are the result of hybridization, the convergence of western harvest mouse populations that invade tidal marsh habitats and evolve traits typical of salt marsh harvest mice, such as darker coloration (Steinberg 1997), or are a byproduct of the classification system of Shellhammer (1984) (*i.e.*, more animals score intermittent scores when trappers pick more intermediate scores for various tail traits and hence some animals that might be either salt marsh harvest mouse or western harvest mouse fall out as categorical but not necessarily biological "intermediates").

Current recovery strategy

The basic strategy for recovery of the salt marsh harvest mouse is the protection, enhancement, and restoration of extensive, well-distributed habitat suitable for the species. There are short- and long-term components of the general recovery strategy as well as specific geographic elements. Both interim and long-term components are necessary; neither alone is sufficient to recover the salt marsh harvest mouse.

Management

An interim reserve system is needed to ensure the immediate survival of a minimum number of populations of salt marsh harvest mice. These reserves should also provide sufficient numbers and variety of founder populations to expand and colonize new habitat for recovery in the long term. Large habitats and populations, selected to represent the full range of each subspecies, should receive the highest priority for protection, active management as needed, and monitoring, to minimize the risk of population declines or extirpation. Each core reserve should be supplemented with a series of smaller satellite reserves where feasible. Interim reserves may include both natural and artificial habitat, and must be maintained at least until large-scale tidal marsh restoration sites support well-established, resilient new populations of salt marsh harvest mice. The relative emphasis on diked tidal marsh and tidal marsh as interim reserves will differ between San Francisco Bay and the rest of the estuary. Populations of the southern subspecies in San Francisco Bay must rely heavily on engineered, highly managed habitats, due to the unstable populations of salt marsh harvest mice in modern tidal marshes there.

Currently, a large proportion of salt marsh harvest mice in Suisun Marsh are supported by diked wetlands on Grizzly Island. Because of this and because lands here are severely subsided and would be nearly impossible to restore to tidal conditions, diked wetland acreage may be substituted for tidal marsh habitat when meeting acreage-based recovery criteria within the Grizzly Island Marsh Complex only. Diked tidal marshes, although important in the short-term for the survival of both subspecies, have numerous limitations. They require perpetual repair and maintenance. Because most are subsided below sea level, they remain subject to catastrophic flooding. They are also incompatible with the recovery of the other principal endangered tidal marsh species. The short-term predictability of habitat quality provided by diked managed tidal marsh is offset by the cost and artificial nature of their ecosystems. This reliance on artificial habitats for recovery is inconsistent with Service policy regarding the ecosystem approach to recovery, which emphasizes the Endangered Species Act purpose of "conserving the ecosystems on which endangered species depend." The long-term liabilities of diked tidal marshes can be addressed by the eventual transition to tidal habitat in restored or enhanced tidal marsh ecosystems.

Diked marshes maintained as interim reserves should be evaluated for conversion to microtidal tidal or brackish marshes. These are better habitats for salt marsh harvest mice than nontidal tidal marshes and are less susceptible to degradation. Diked nontidal tidal marshes should be converted to diked microtidal marshes when 1) habitat conditions for the salt marsh harvest mouse are poor and would probably be improved by restricted tidal flows; 2) adequate access to tidal sources is feasible, and installation of tidegates and inlet channels would not cause excessive environmental impacts; and 3) site elevations relative to sea level are compatible with operation of tidegates with or without addition of dredge materials.

Microtidal marsh salt marsh harvest mouse reserves in Suisun Marsh showed an increase in salt marsh harvest mouse populations between 2000 and 2005, possibly due to conducting surveys in areas other than *Sarcocornia* marshes. Overall, however, microtidal marshes seem to be less important now than they once might have been, given the extent and distribution of existing and/or restorable tidal marshes. Though Suisun's diked marshes have sometimes supported higher salt marsh harvest mouse numbers than fully tidal marshes, they are not appropriate substitutes for full tidal marsh because they require perpetual maintenance of levees, ongoing tidegate adjustment, monitoring, maintenance and repair. Also, they cannot equilibrate with rising sea level, so they are vulnerable to more severe, prolonged flooding than fully tidal marshes. These are poor prospects for long-term survival of salt marsh harvest mouse populations.

Habitat Restoration
In the long term, large-scale units of restored tidal marsh (thousands of acres) should be located around interim reserves. These tidal marshes will restore functional, resilient natural ecosystems for the continued survival of the salt marsh harvest mouse and avoid perpetual management of smaller habitats that are more vulnerable to catastrophe and extirpation. It is crucial that restoration of tidal marshes include foundations for large high marsh belts; wide, gently sloping gradients between mean higher high water; and local elevations of storm high tide lines (driftlines). Where possible, restoration of tidal marshes should proceed from baylands adjacent to existing populations, and coalesce with one another to form extensive, contiguous habitats in large blocks, thus reversing fragmentation of habitats and populations.

Large-scale tidal marsh restoration is likely to take at least several decades, and likely as much as 50 years in deeply subsided areas, to reach the ecological maturity required for secure establishment of large, resilient populations of salt marsh harvest mice. Sea-level rise and declining sediment availability (Goals Project 1999) may retard the rate of tidal marsh succession in some or all parts of the estuary. The effects of invasive *Spartina* add unpredictability to the timing of restored salt marsh harvest mouse habitat. In addition, much of the potential large-scale tidal marsh restoration in south San Francisco Bay has complex engineering requirements (salt pond retrofitting, desalinization) that may take time to plan, design, and implement. In brackish Suisun Marsh, restoration of mature tidal marsh plains may take a very long time, and is likely to result in habitat that provides for low density of salt marsh harvest mice compared with the high density, but unstable, patches of *Sarcocornia* in diked marshes.

The long-term uncertainty regarding the timing of restored tidal marsh plains can be addressed by engineering foundations for wide high tidal marsh zones along the edges of perimeter levees. These preconstructed ecotones between upper middle marsh zones and high marsh habitat (with *Grindelia* vegetation and trapped tidal debris as tidal refugia) can ensure a minimum of rapidly formed suitable habitat for recolonization by salt marsh harvest mice.

A recurrent dilemma for the recovery of salt marsh harvest mice is that restoration of tidal marshes is often accomplished by conversion of diked nontidal tidal marsh currently occupied by salt marsh harvest mouse populations. Conversion of these subsided areas requires sedimentation to restore mature marsh plains, resulting in a prolonged period (at least a decade, but usually several) in which resident populations are displaced by uninhabitable aquatic habitats. Conservation of existing populations is important when the populations are large or isolated or are relicts in an area where most other populations are small, unstable, or at high risk of extirpation. The premium on conserving existing populations is lower where tidal marsh restoration sites contain very small, unstable populations in poor and declining habitat that lie adjacent to large areas of high quality habitat and significant populations. The goal is to conserve founder populations with adequate genetic diversity and initial numbers to persist over the long periods until restored tidal marshes are ripe for recolonization. In this way, important habitat restoration will, for many marsh species, including salt marsh harvest mouse, inevitably result in short-term losses for the benefit of long-term gains.

Unoccupied and unsuitable habitats are the highest priority for tidal marsh restoration, particularly when these sites are large and near existing populations. Some marginal habitats may be important as transient refugia where no alternative habitat exists, but may not be independently viable for conservation. Large marginal, unsustainable diked habitats should have a high priority for restoration where feasible. Potential tidal marsh restoration sites with large acreages of *Sarcocornia* habitat and salt marsh harvest mouse populations, in subregions where mouse populations have become scarce (*e.g.*, Montezuma wetlands, Bayside Business Park II), should generally be lower in priority for tidal restoration, or restoration should be implemented either in phases or after secure populations are established on-site or adjacent. These priorities will promote a regional pattern and sequence of tidal marsh restoration sites that maximizes long-term benefits to the species, and minimizes short-term impacts on populations. The unavoidable impacts to salt marsh harvest mice in diked baylands must be addressed at a subregional or regional scale. A spatially-explicit restoration sequence should be developed by a working group of the Recovery Implementation Team (RIT) to optimize the viability of multiple species' populations over time.

Active translocation of live-trapped individuals should be considered only when no other practical alternatives are feasible, as the efficacy of this method has not yet been determined. Reliance on colonization by natural, long-distance dispersal of salt marsh harvest mice from remote habitats is less desirable than conservation of internal founder populations because colonization is improbable, unpredictable, and unreliable. Low initial founder numbers from long-distance dispersal would increase the risk of founder population failure, inbreeding depression, and genetic bottlenecks.

Tidal marsh restoration plans that require conservation of founder populations of salt marsh harvest mice must accomplish three basic tasks:

1) Interim management of habitat quality (vegetation, salinity, flooding, and drainage) in diked tidal marshes to maintain any resident populations present while tidal restoration projects are planned;

2) Where proximity of existing strip marshes does not provide sufficient local sources of colonists, construction of temporary refuges to sustain ample resident populations that would otherwise risk extirpation during the period of site preparation and early phases; and,

3) Construction of directly adjacent suitable salt marsh harvest mouse pioneer habitat in high tidal marsh zones to serve as temporary refuges at the time tidal restoration is initiated. This will avoid a prolonged period during the early phases of restoration when habitat is deficient. This pioneer habitat may be identical to temporary refuges, extensions of them, or independent of them, depending on restoration logistics, but must be directly adjacent to avoid excessive predation of mice trying to reach the temporary refuges. Pre-construction of high marsh pioneer habitat must involve grading wide gently sloping benches at and above the planned mean higher high water line at the restored tidal marsh edge. Cultivation of spearscale, alkali heath and Australian saltbush well in advance of tidal restoration should also be considered.

Many restoration projects being implemented in the bay area are designed with only general or superficial analysis of salt marsh harvest mouse requirements. Design teams for marsh restoration or enhancement projects should include qualified experts to provide restoration designs affecting salt marsh harvest mouse recovery. An interdisciplinary review panel or similar group, including experts in salt marsh harvest mouse ecology, tidal marsh vegetation, and hydrology or *geomorphology* of estuarine marshes, should review tidal marsh restoration designs before they are funded for construction. The review panel should be supported collaboratively by willing Federal, State, and responsible local agencies with expertise and jurisdiction in the recovery of the salt marsh harvest mouse.

Surveys
The most important data/research need at present is to fill in gaps in understanding of the current distribution, density, and demographics of the salt marsh harvest mouse. Most records are greater than ten years old and no systematic surveys have been carried out in key areas. Expectations of salt marsh harvest mouse population expansion into restored marshes are dependent on the presence of extant populations adjacent to restoration areas that can serve as source populations of the mouse. Resources for salt marsh harvest mouse surveys should be shifted from site-specific presence/absence surveys, to systematic regional surveys with replicated sampling over time. Surveys should give special emphasis to building upon information gained after the 2005 floods by tracking salt marsh harvest mouse (and other small tidal marsh mammal) populations before and several years after major flood events, comparing population regeneration and extinction probabilities for a range of habitat types, sizes, and landscape positions (location along sloughs or bays, distances from nearest known populations or habitats). Regional survey programs for both subspecies should be established and funded for a minimum of 10 years or one flood/drought cycle.

Research
Taxonomic research is needed to make field identification methods as accurate as possible as well as making them consistent with the true genetic identities of harvest mice in brackish and tidal marshes. Molecular genetic research is needed to resolve the genetic identity of ambiguous (intergrade or intermediate) salt marsh and western harvest mice and to test whether actual hybridization or *introgression* has occurred. It is also very important to assess the amount of genetic variability within populations. Knowledge of genetic variation should guide the restoration process, helping us to identify which populations contain unique or rare genetic material. To prevent misidentification, diagnostic genetic markers are needed to verify the accuracy of field identification throughout the ranges of both salt marsh harvest mouse subspecies. Initial work on this is in progress at the California Polytechnic State University, San Luis Obispo by Francis Villablanca (Finfrock 2000).

Ecological studies should determine the conditions under which competition with other small mammals may have significant adverse effects on salt marsh harvest mouse populations. Environmental or biotic variables that affect population interactions between small tidal marsh mammal species should be analyzed if significant species interactions are confirmed.

Combined studies of vegetation structure, plant community composition, and salt marsh harvest mouse live-trapping should be conducted over multiple years in all seasons at representative geographic subregions within the range of both subspecies. The interdisciplinary survey approach should determine the full range of salt marsh harvest mouse habitats and their ecological variations. These surveys should provide special emphasis on the ecology of salt marsh harvest mice in *Lepidium latifolium*.

Detailed demographic studies, including development of population models, may be useful for assessing the viability of isolated populations. Demographic and population modeling studies, however, should generally have lower priority than population studies that are directly applicable to enhancing and managing existing habitats and populations or to restoring habitats and re-establishing new populations. Specific demographic research is needed for habitat restoration design and management. Detailed telemetry studies should be applied to understand high tide movements of salt marsh harvest mice, both along landward marsh edges, bayward marsh edges, and deep within wide marshes. If translocation is proposed to minimize take, it should be preceded by experimental research using telemetry methods to determine the fate of both introduced and resident salt marsh harvest mice affected by translocation.

Outreach
Although the salt marsh harvest mouse is relatively well-known in the bay area, public understanding of its ecological needs should be improved. Age-appropriate educational materials should be prepared collaboratively by species experts and public educators, and distributed to public schools, university programs and environmental journalists. Public outreach materials should focus on the principal threats to the species (with emphasis on local conservation issues), recovery strategies and actions, and the results or progress of local recovery actions.

Geographic strategy

San Francisco Bay (southern subspecies): Existing tidal marshes should be protected against filling and dredging impacts. The design of outboard levees around the San Francisco Bay, and especially in southern areas where subsidence has taken place, merits reevaluation when they are replaced during marsh restorations. The outboard slope of such levees in marsh restoration sites should be changed from the typical 1 to 1 slope at present to a 10 to 1 or greater slope, especially in areas of subsidence such as the southern end of the South San Francisco Bay. Such a change would allow for the correction of deficiencies in the distribution, abundance, and quality of high tide refugial habitat by establishment of an effectively wider high marsh zone as marsh restoration proceeds. Slopes of levees in microtidal marshes should be similarly improved. Existing diked nontidaland microtidal *Sarcocornia* marshes should be protected and maintained or enhanced to improve the vegetation, salinity, and floodwater drainage. Wastewater discharges into South Bay sloughs should be reduced and discharged diffusely in brackish microtidal lagoons and marsh edges, rather than at point within *sloughs*. *Lepidium latifolium* should be eradicated along high marsh edges and levees, and replaced with native vegetation suitable for these zones (primarily *Grindelia* and *Sarcocornia* below, and *Grindelia* and *Leymus triticoides* [creeping wildrye] above). Tidal marsh restoration should proceed with highest priority in baylands that are not strongly subsided and are not subject to high invasion pressure by invasive *Spartina.*

San Pablo Bay (northern subspecies): Existing tidal marshes should be protected against filling and dredging impacts. Existing diked nontidal and microtidal *Sarcocornia* marshes should be protected and maintained or enhanced to improve *Sarcocornia* vegetation, salinity, and floodwater drainage. Artificial obstructions to lateral drainage of Highway 37 strip marshes should be removed to minimize flood duration and maintain extensive thick, tall *Sarcocornia* vegetation for the salt marsh harvest mouse population. *Lepidium latifolium* should be eradicated along high marsh edges and levees and replaced with native vegetation suitable for these zones (primarily *Grindelia* and *Sarcocornia* below, and *Leymus triticoides* above). Tidal marsh restoration should proceed with highest priority in baylands that have not suffered strong subsidence, are closest to major populations of salt marsh harvest mice, and are major sources of tidal sediments and salts (adjacent to San Pablo Bay and the mouths of major rivers and sloughs).

Suisun Bay Area (northern subspecies): Existing tidal marshes should be protected against filling and dredging impacts, adverse modifications of tidal circulation, and impacts on tidal datums and reduced salinity caused by salinity control gates. Management of waterfowl-priority diked marshes should be modified to be independent of salinity control gate operation in Montezuma Slough. Interim reserves of non-tidal habitat should be developed at locations in and around existing large patches of habitat with large populations. The locations of these sites may change with habitat conditions and require updating with surveys. Waterfowl-priority diked marshes should be re-engineered to increase compatibility with salt marsh harvest mouse populations by (1) converting many managed non-tidal waterfowl marshes to microtidal systems, including shallow lagoons and brackish marsh with high *Sarcocornia* marsh edges; and (2) modifying non-tidal flooding regimes to minimize submergence of *Sarcocornia* marsh; or (3) engineering unflooded benches or terraces along interior levee edges to maintain wide, minimally flooded, saline *Sarcocornia* marshes. Along the Contra Costa shoreline, existing diked nontidal and microtidal *Sarcocornia* marshes should be protected and maintained or enhanced to improve *Sarcocornia* vegetation, salinity, and floodwater drainage. *Lepidium latifolium* should be eradicated along high marsh edges and levees in the region and replaced with native vegetation suitable for these zones (primarily *Grindelia* and *Sarcocornia* below, and *Leymus triticoides*, native riparian forbs, and shrubs above). Tidal marsh restoration should proceed with the highest priority in baylands closest to major populations of salt marsh harvest mice and major sources of tidal sediments and salts (adjacent to mudflats of Grizzly Bay, Suisun Bay, and Honker Bay mudflats, and mouths of major rivers and sloughs). High priority for tidal marsh restoration should also be assigned to diked baylands with potential for wide, gently sloping high marsh ecotones, regardless of position in subregional salinity gradients.

f. *Chloropyron maritimum* ssp. *maritimum* (salt marsh bird's-beak)

Chloropyron maritimum ssp. *maritimum* has been mapped at Morro Bay. There are no other conservation efforts currently underway (Walgren *in litt.* 2006)

Conservation easements or fee-title purchase from willing sellers should be sought to place remaining undeveloped shoreline under protective ownership. Adjacent upland buffer lands also should be sought, in part to protect viable populations of pollinator species.

Many of the threats facing the subspecies are aggravated by its small population size and limited range-wide distribution; therefore population augmentation and initiation of new subpopulations in suitable unoccupied habitat at Morro Bay should be planned and implemented to reduce the risk of regional extinction. These activities should only occur, however, after a conservation geneticist has assessed the distribution of genetic diversity and recommended population sampling methods.

Morro Bay populations of *Chloropyron maritimum* ssp. *maritimum* are sensitive to trampling and disturbance and should be protected, by use of fencing, against recreational pressures from nearby residential areas and from park visitors. Access and trails should be routed away from sensitive habitat. Boat haulouts near populations of *C. maritimum* ssp. *maritimum* must be curtailed. Dredge disposal should be managed to minimize the risk of sand movement burying subpopulations of the species.

Shoreline stands of *Carpobrotus edulis* (iceplant) should be eradicated and replaced with native marsh-upland ecotone vegetation. Other non-native plants should be controlled to prevent crowding, shading, or other impacts to the salt marsh bird's-beak and its habitat.

Populations of *Choropyron maritimum* ssp. *maritimum* should be monitored annually for distribution, abundance, and reproductive output. Continuing and new threats should be identified and reported. Disturbances and sand dune movement should be monitored, and measures to address impacts—as well as to evaluate the success of these measures—should be developed. In addition to monitoring, research is needed--especially on demography, ecology, and threats--to ensure that recovery actions effectively benefit the species.

The Service will coordinate with California Department of Parks and Recreation, the City of Morro Bay, and other public or non-profit as well as interested private landowners to achieve comprehensive planning, protection, and recovery benefits for the subspecies. Management plans that address protective and population augmentation actions for *Choropyron maritimum* ssp. *maritimum* should be developed and implemented for lands in public or conservation ownership.

C. RESTORATION MAPS

To accomplish recovery of the covered species, protection and restoration of the species habitat must occur. The restoration maps in **Figures III-7 through III-32** illustrate only one vision by which recovery may be reached. Segment letters next to the figure numbers correspond to the segment letters used for the similar geographic area in the Baylands Ecosystem Habitat Goals (Goals Project 1999). The restoration maps delineate the highest priority areas for protection of existing habitat, restoration of tidal marsh, and restoration of ecotonal habitat. Lands bayward of the recovery unit boundary are considered within the recovery unit. The recovery unit boundary in the San Francisco Estuary has been delineated to follow the extent of sea levels predicted by year 2050, under the medium to medium-high emissions scenario described in the 2009 Pacific Institute Study (Heberger *et al.* 2009). Therefore, these lands incorporate not only historic tidal marsh, but also adjacent lands which could play important roles in recovery of the tidal marsh ecosystem, in light of anticipated sea level rise. Geospatial data for sea level rise in areas of the recovery plan outside of San Francisco Bay were not available at the time of writing, therefore the recovery unit line for the Central Coast and Morro Recovery Units is reflective of the 100 year flood line, irrespective of sea level rise. We recognize that not all lands within the recovery unit boundary will be necessary for recovery of the covered species and that participation by private landowners in recovery plan implementation is entirely voluntary.

It is important to note that preservation of diked wetlands or ponds with muted tidal influence may be critical to the survival of some covered species, at least in the short-term. In addition, many sensitive bird species not supported entirely by tidal marsh habitat rely on these non- or muted tidal features (*e.g.*, western snowy plover, California least tern, etc). Areas have not been delineated for preservation specifically for these non-covered species, although they may be required to accommodate the complete needs of all species using San Francisco Bay.

Map legend definitions:

Existing Tidal Marsh:	Lands currently functioning as tidal marsh, including muted tidal marsh.
Near-term Tidal Restoration:	Lands for which restoration plans have been completed and which are slated for tidal restoration within the next five years.
Likely Future Tidal Restoration:	Lands being considered for tidal restoration, but lacking formal restoration plans to date.
Potential Future Tidal Restoration:	Lands appropriate for tidal restoration, but with potential pending development proposals, unwilling sellers, or environmental or engineering constraints.
Future Ecotone Restoration:	Lands appropriate for high marsh-upland ecotone creation/restoration.

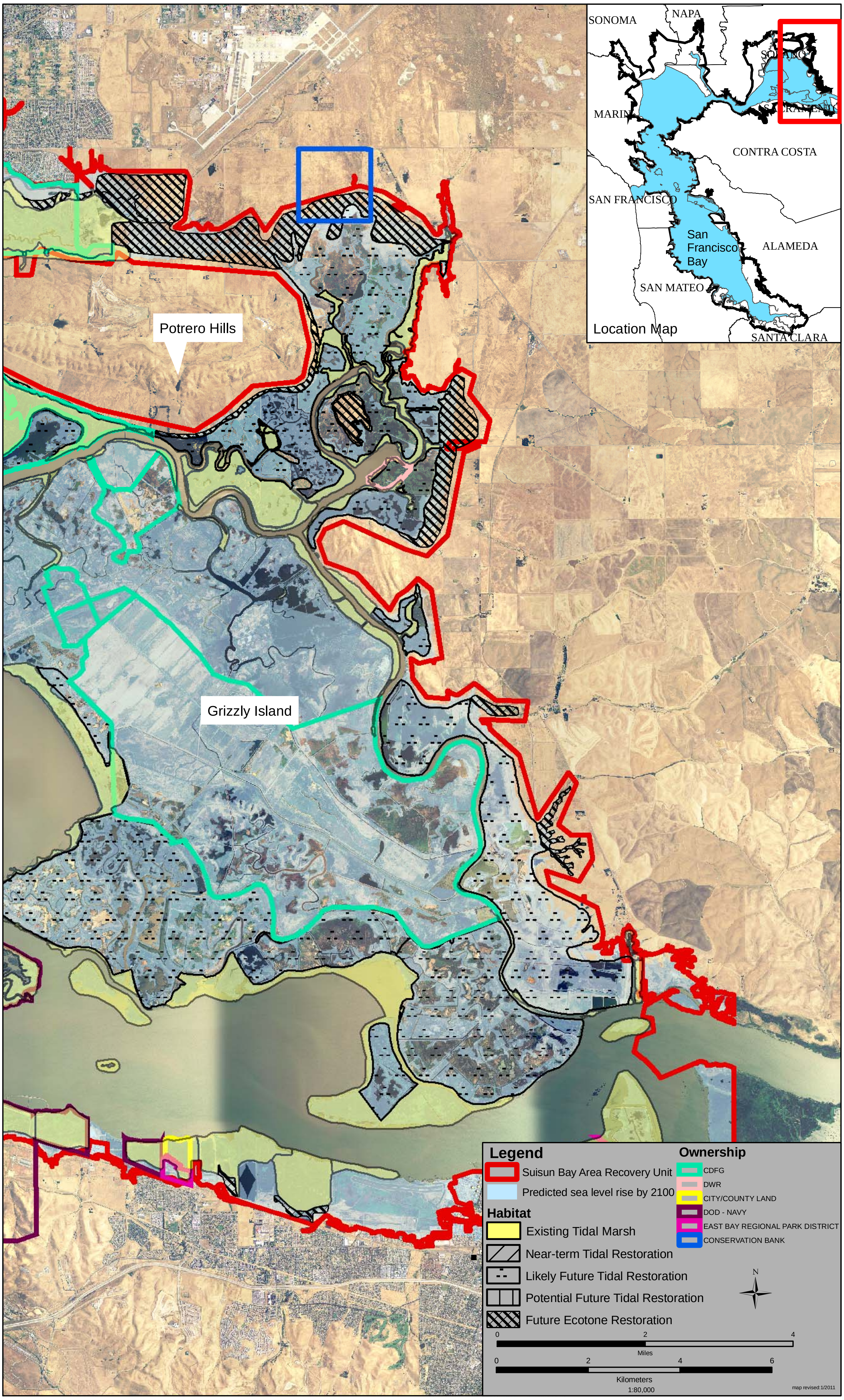
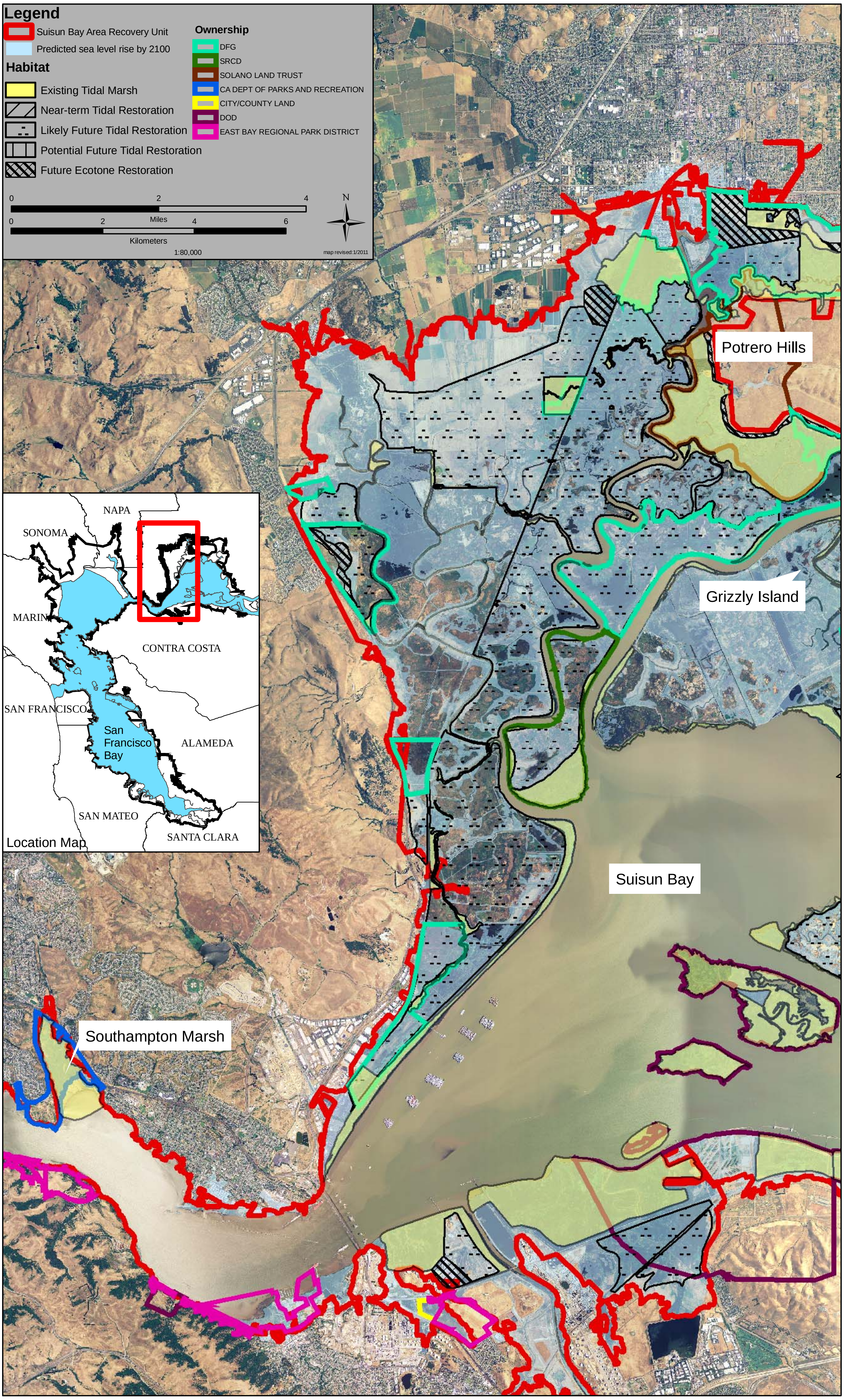


Figure III-7. Segment A



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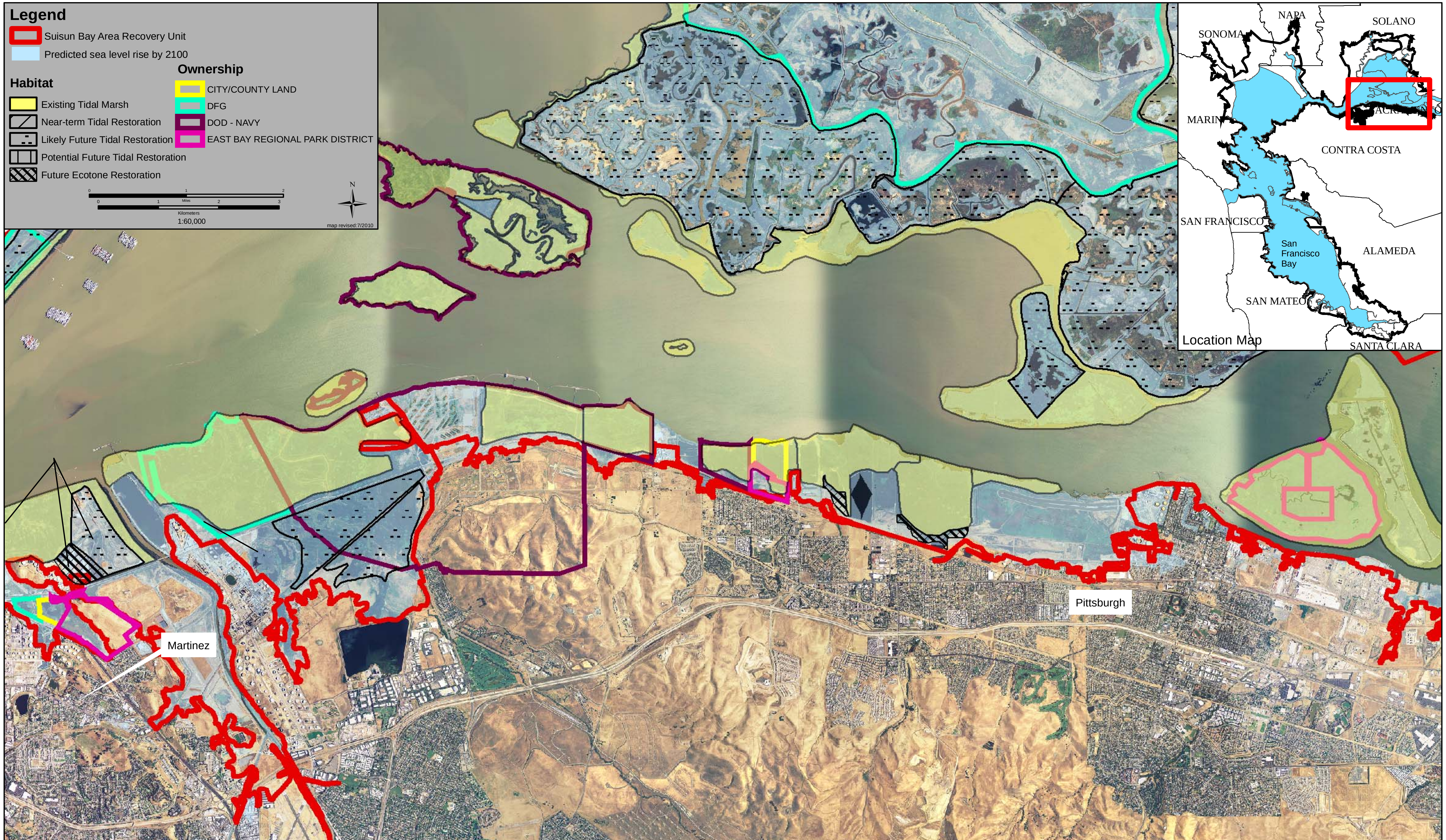

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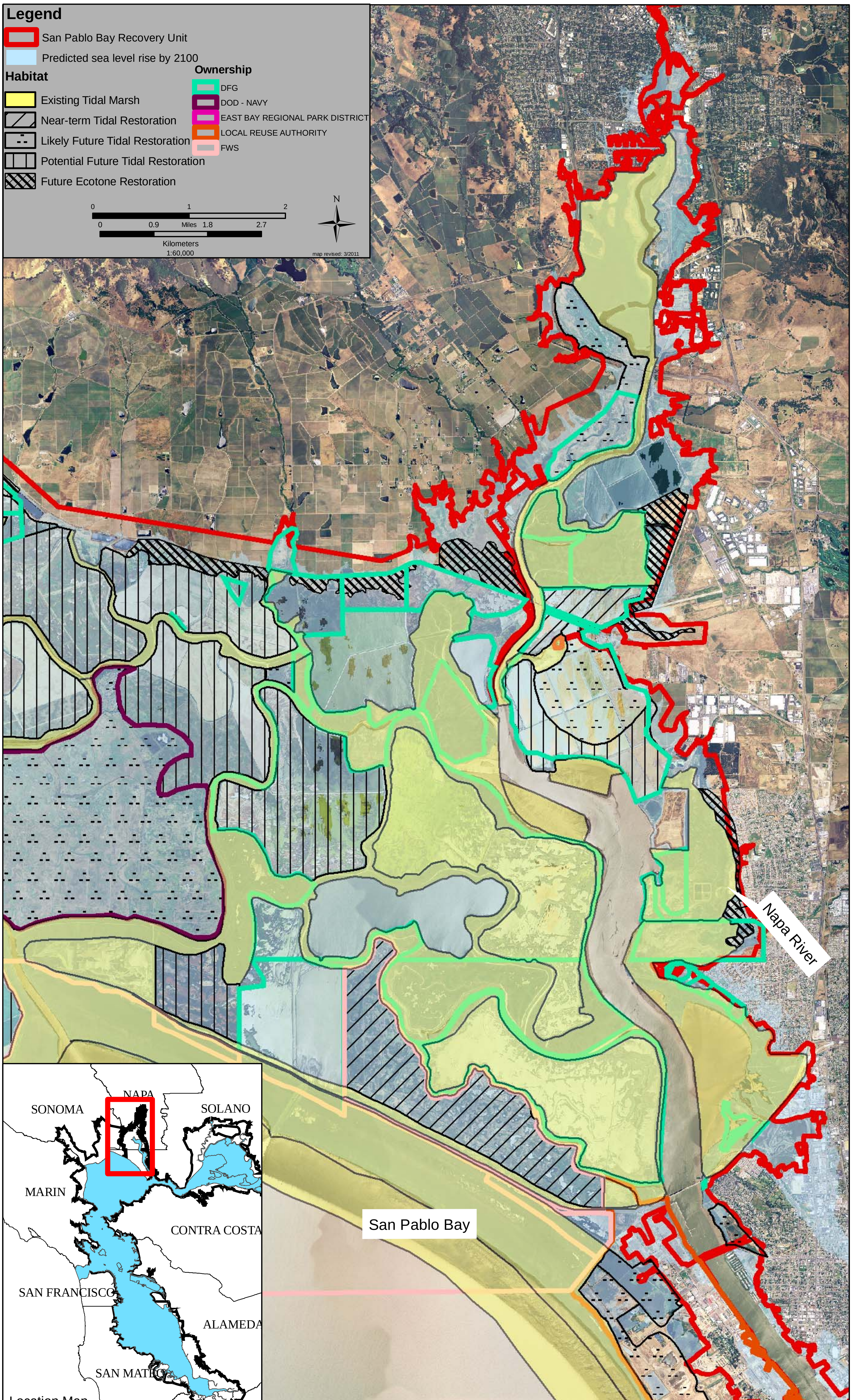
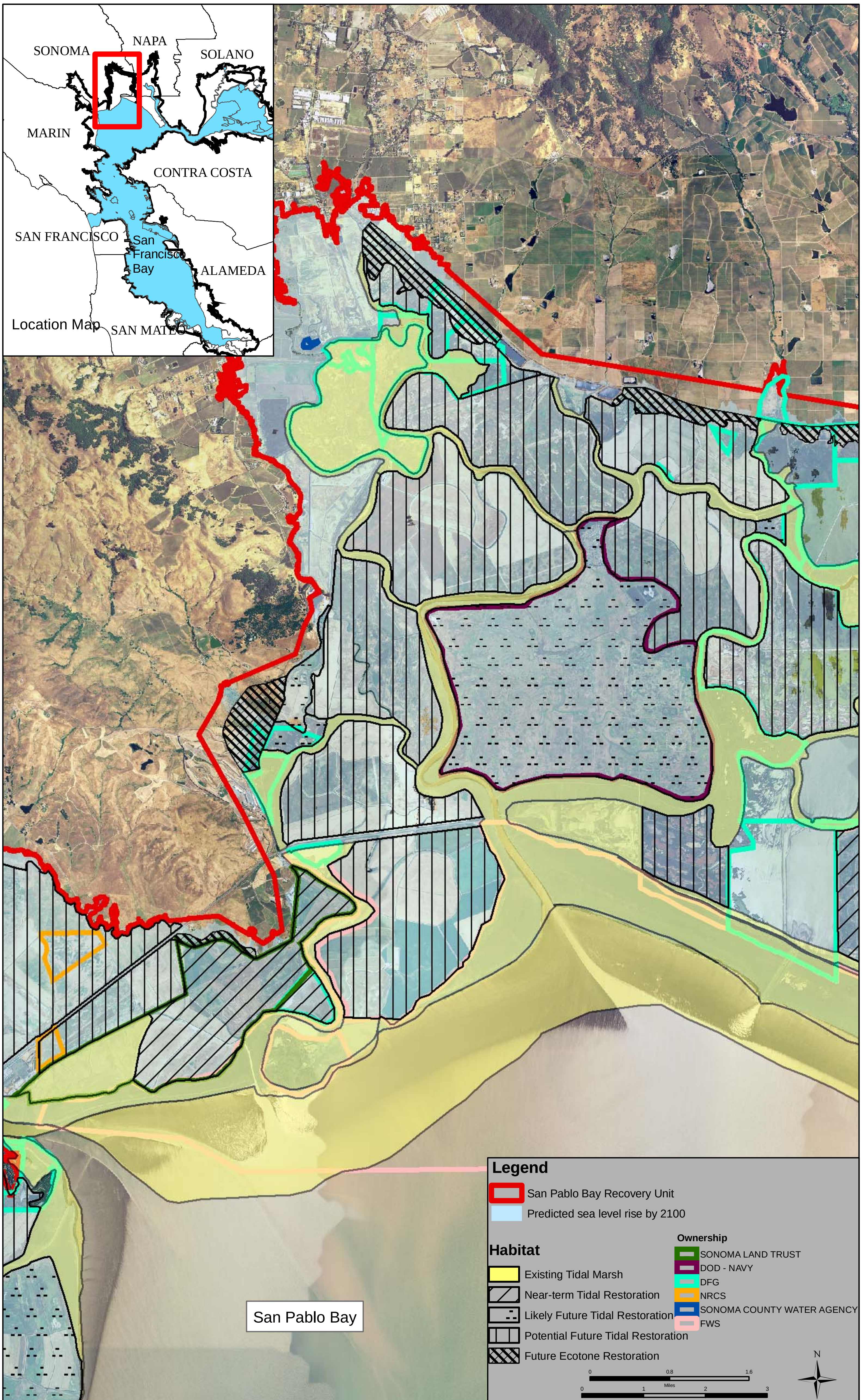


Figure III-10. Segment D



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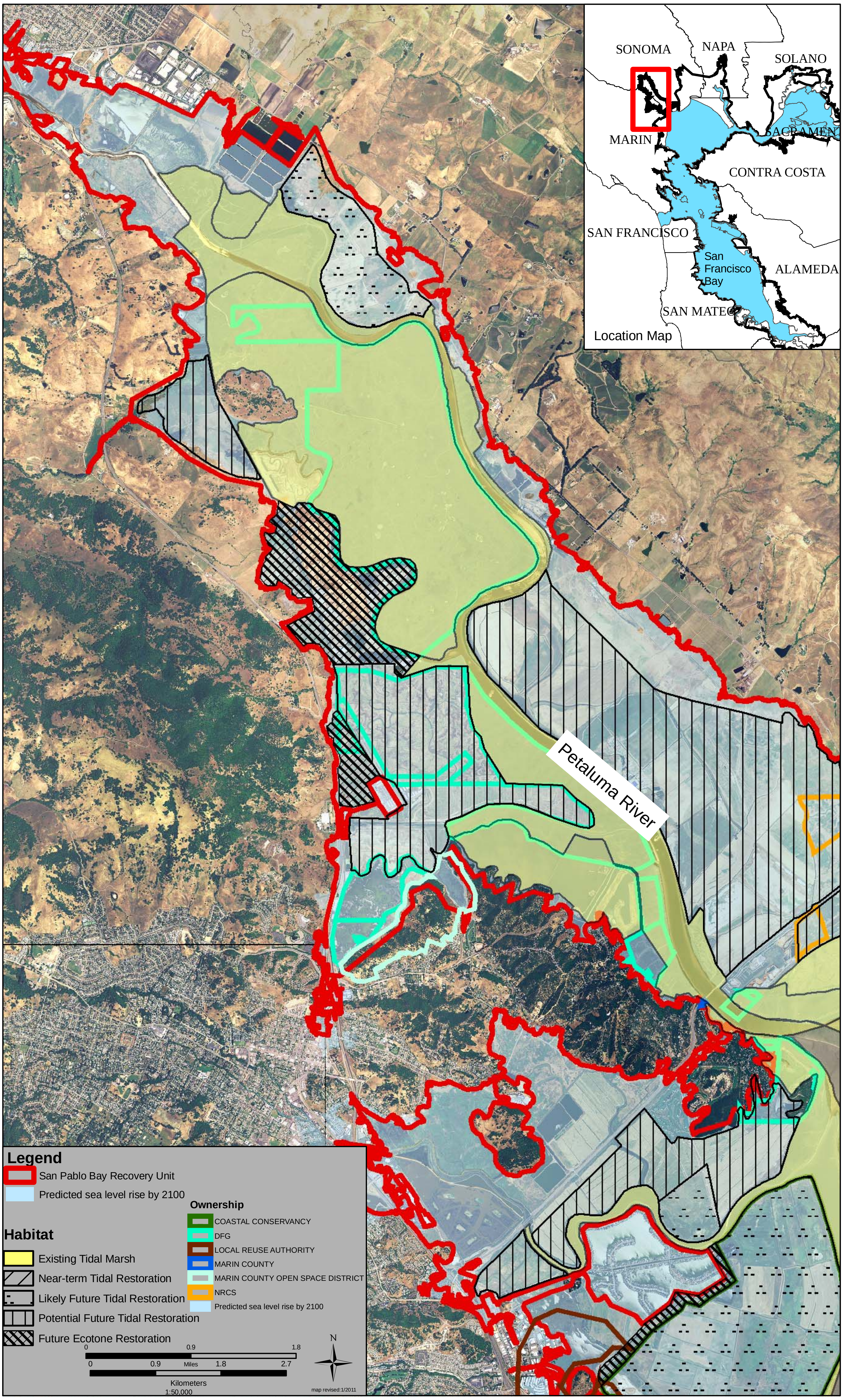

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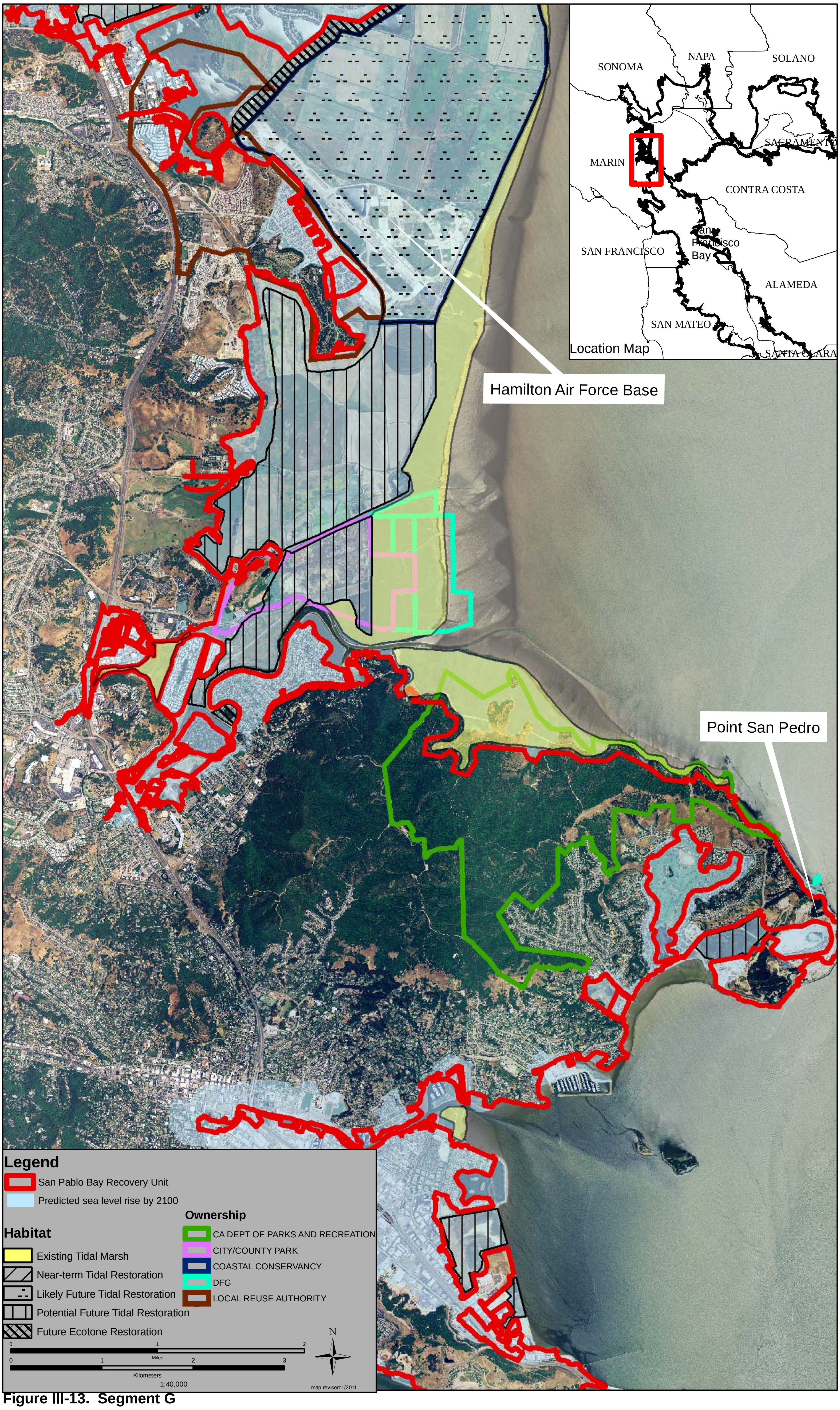

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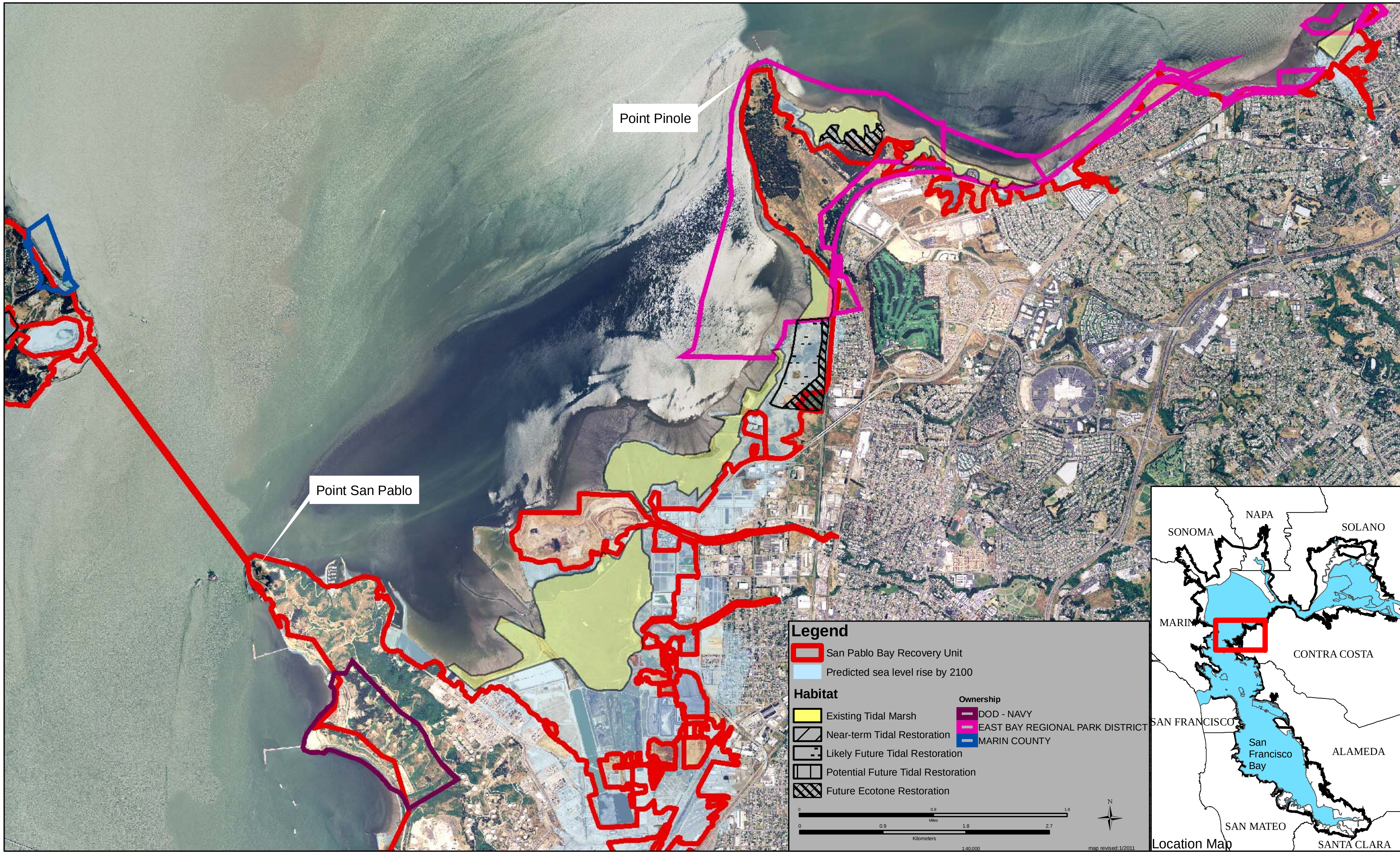

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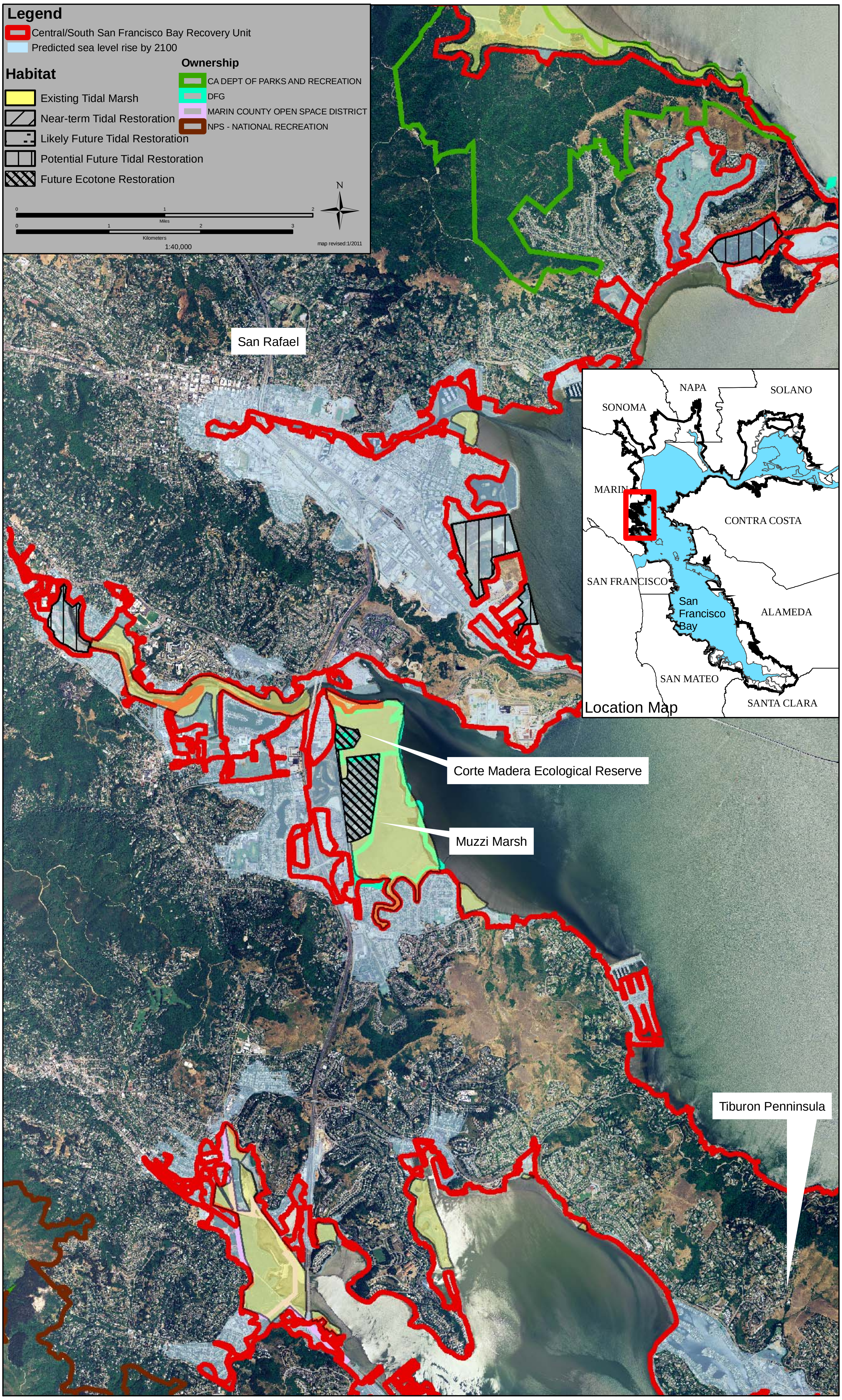
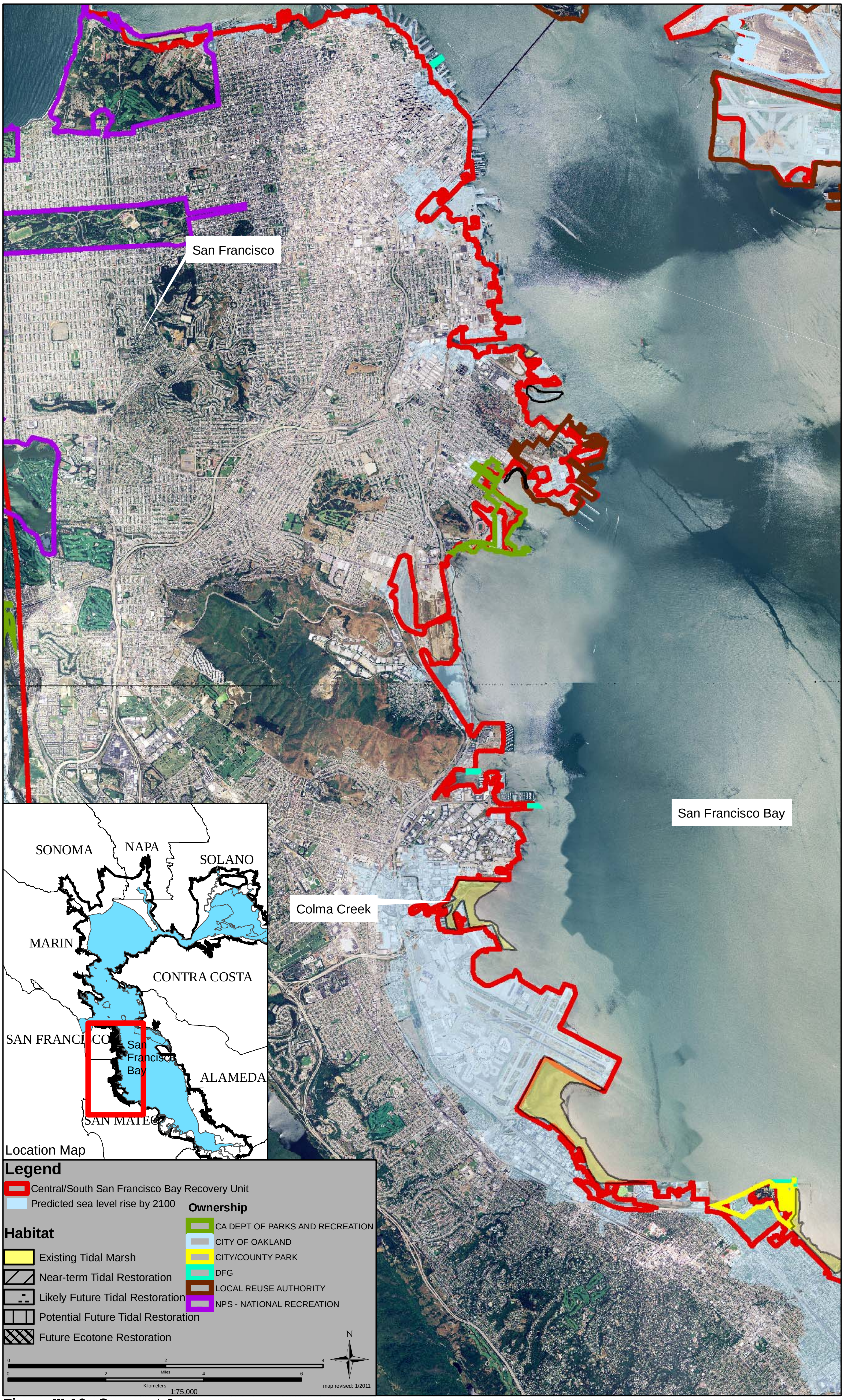


Figure III-15. Segment I



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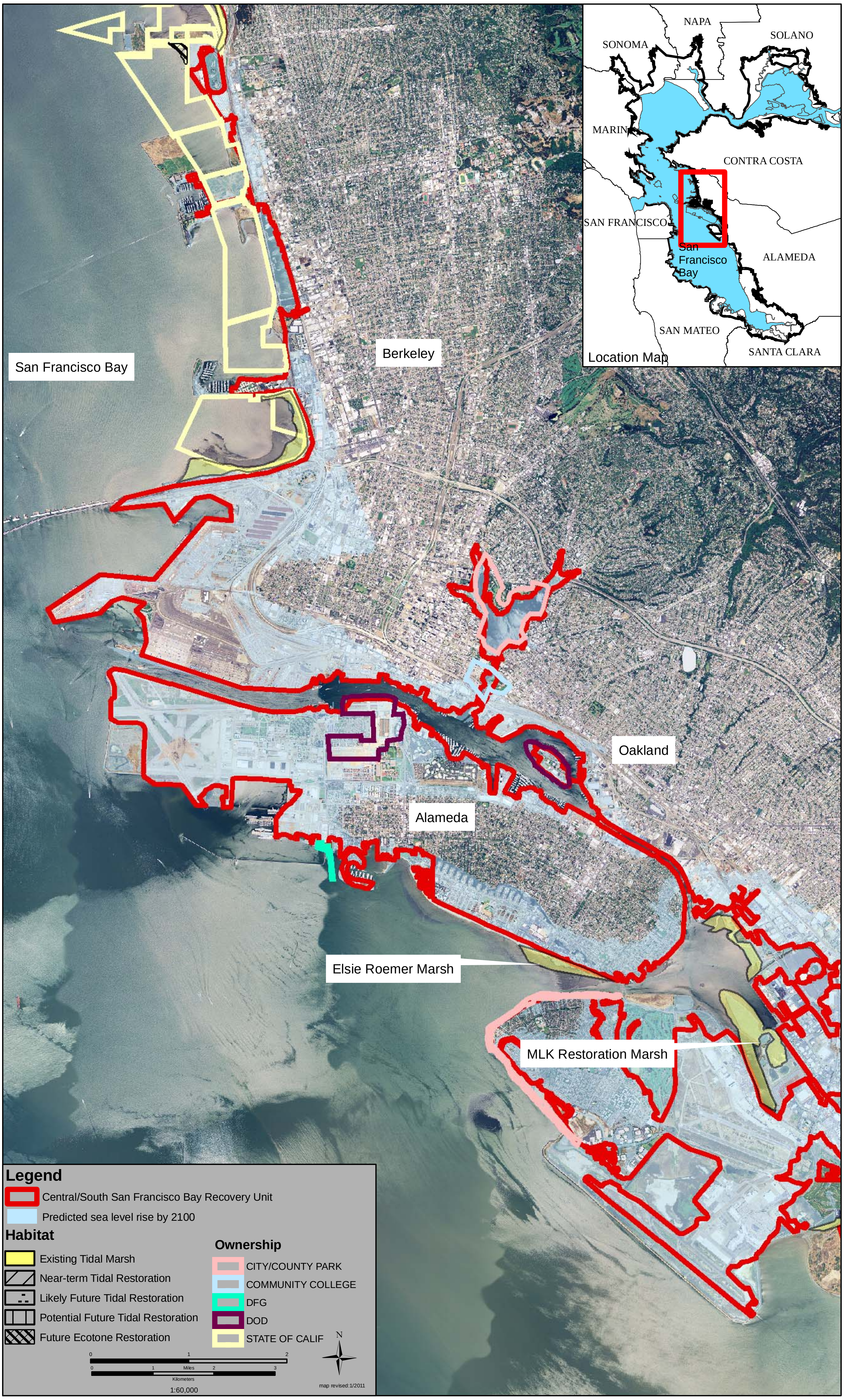

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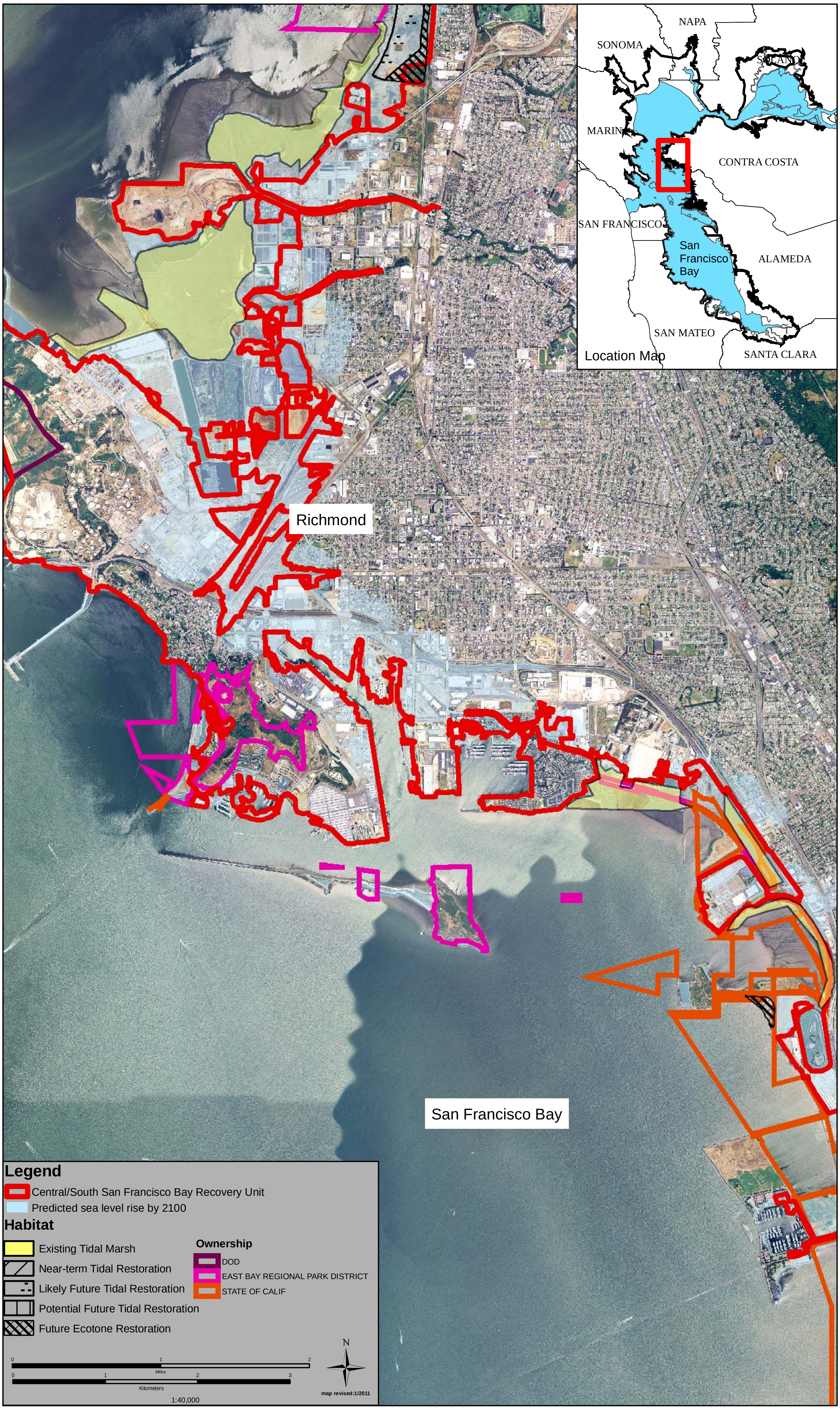

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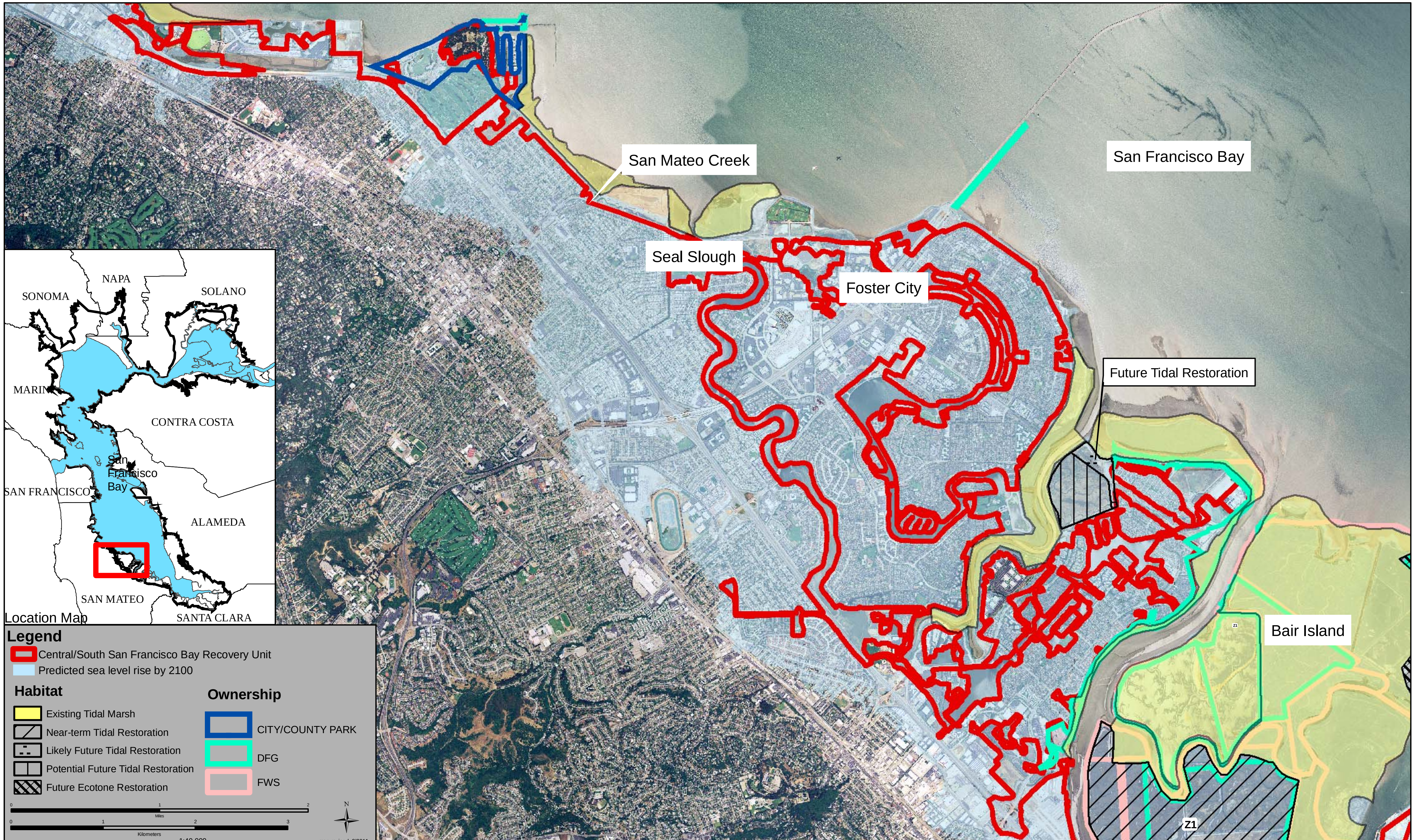


Figure III-19. Segment M

Figure III-20. Segment N

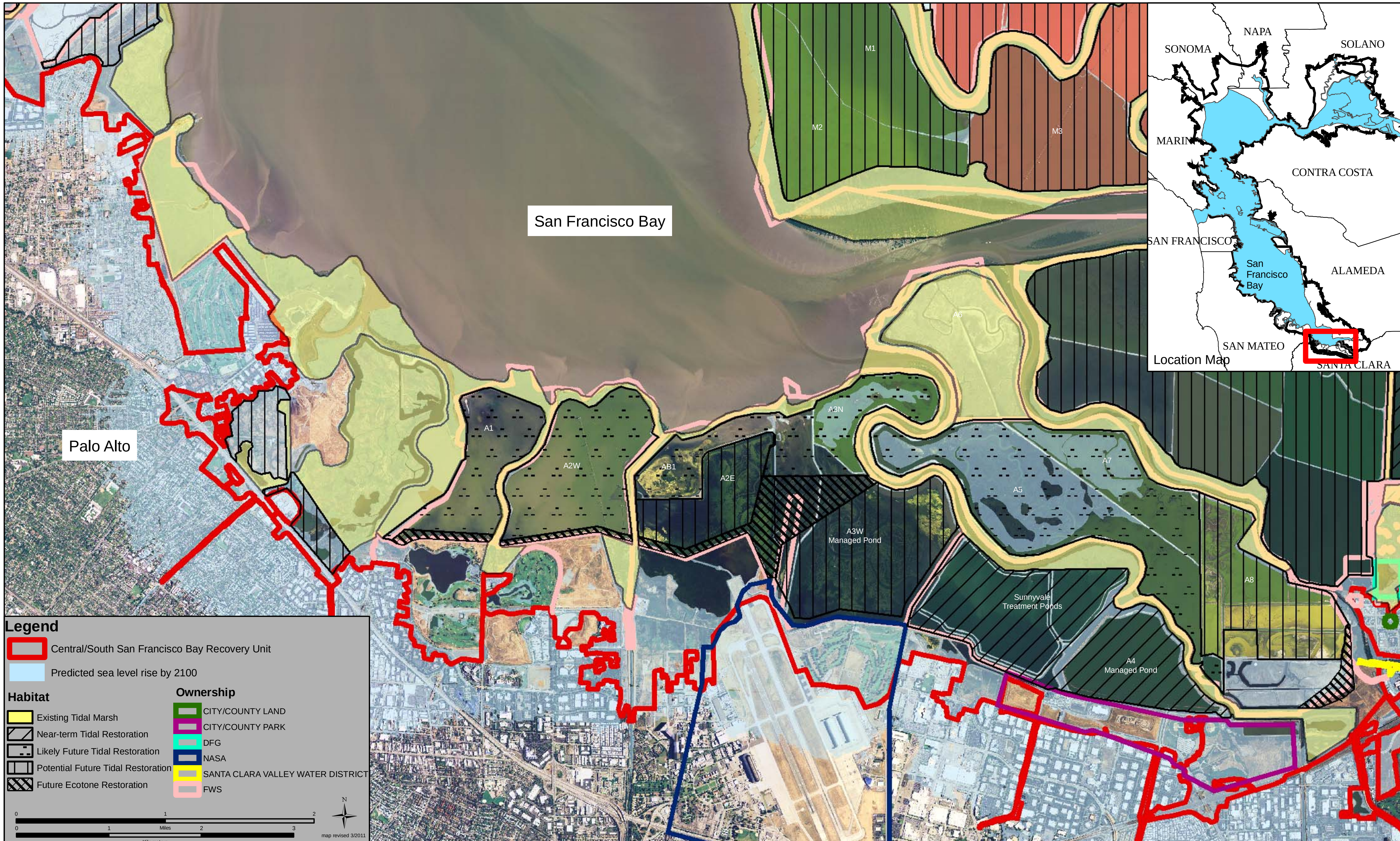


Figure III-21. Segment O

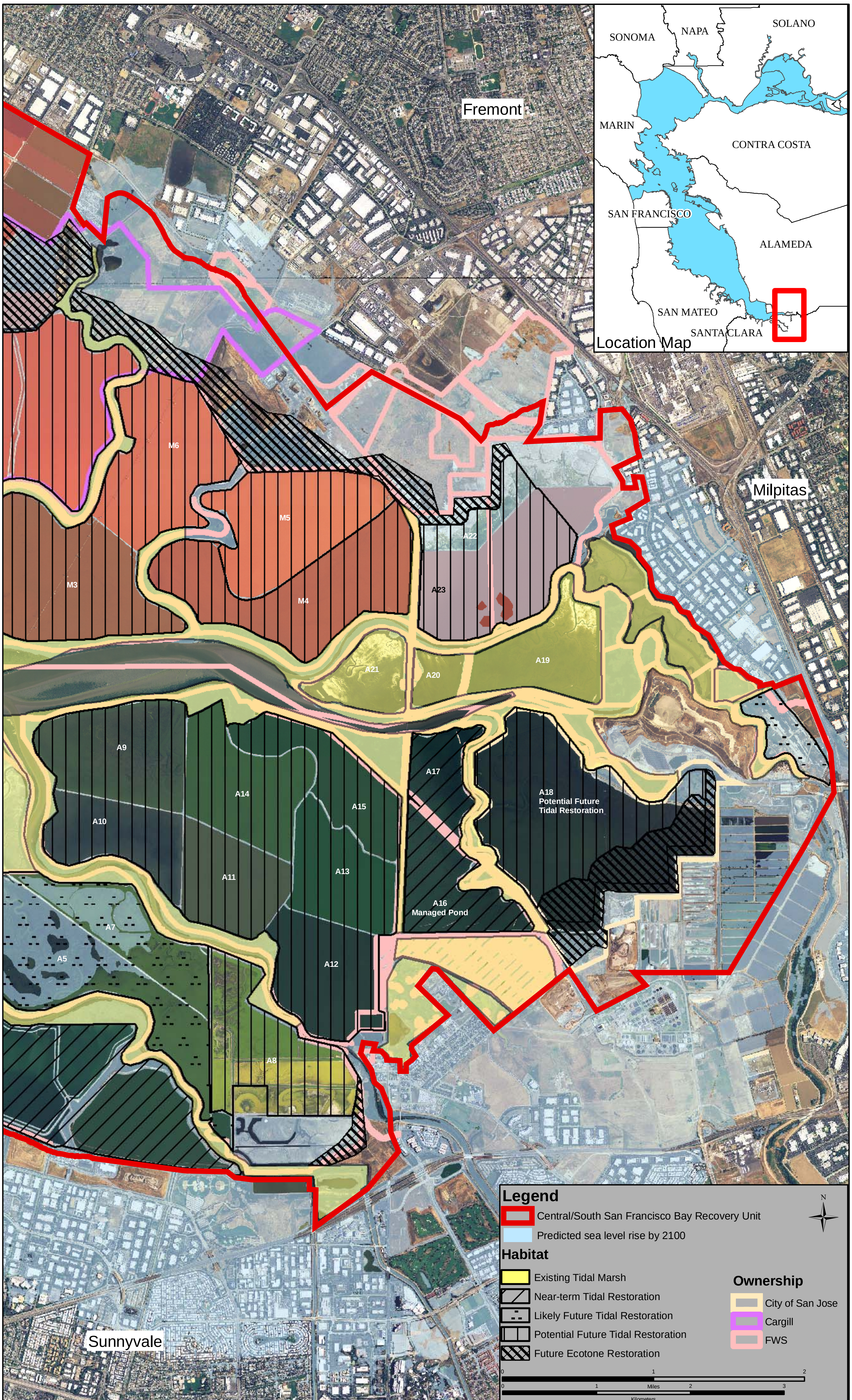
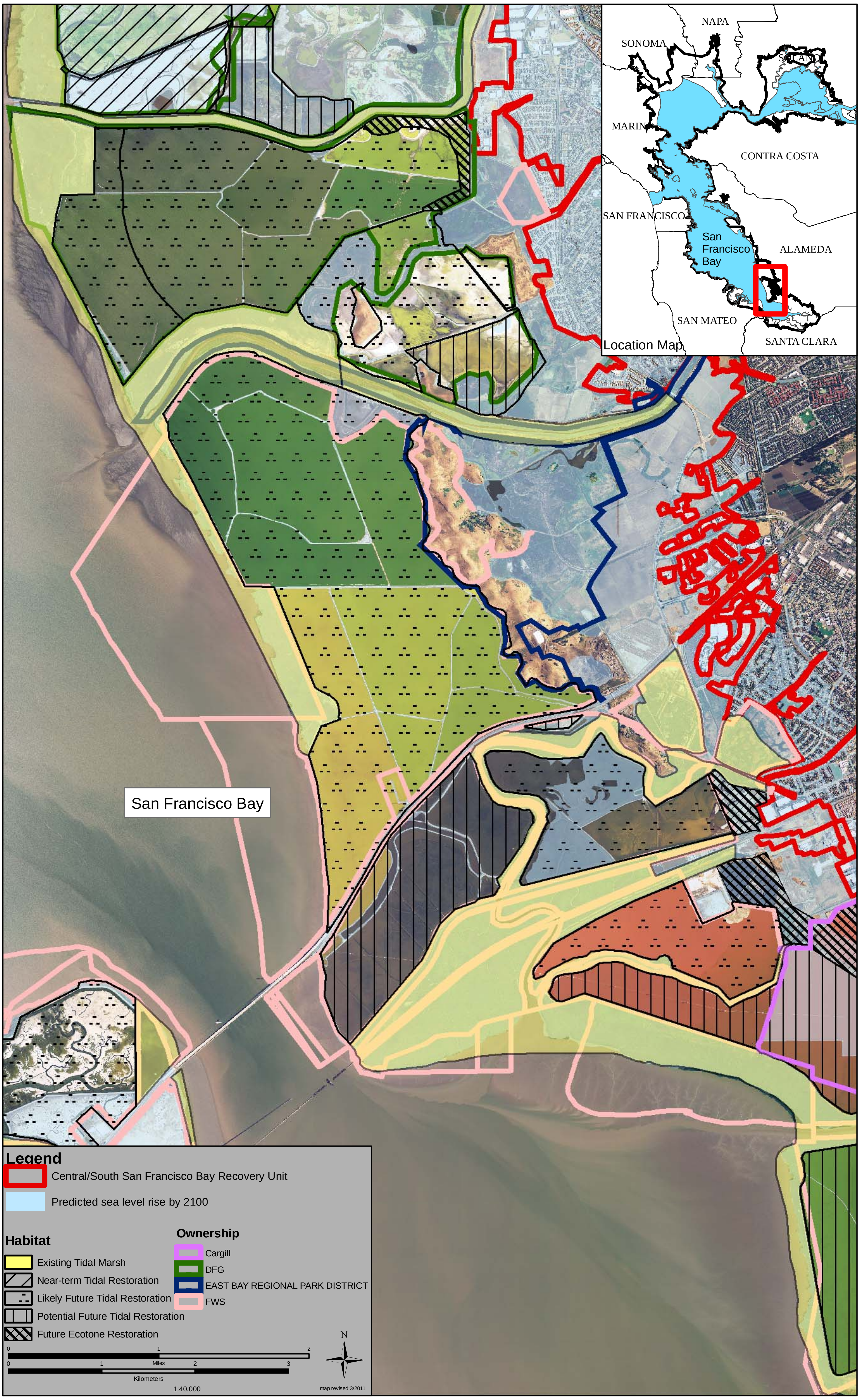


Figure III-22. Segment P

Figure III-23. Segment Q



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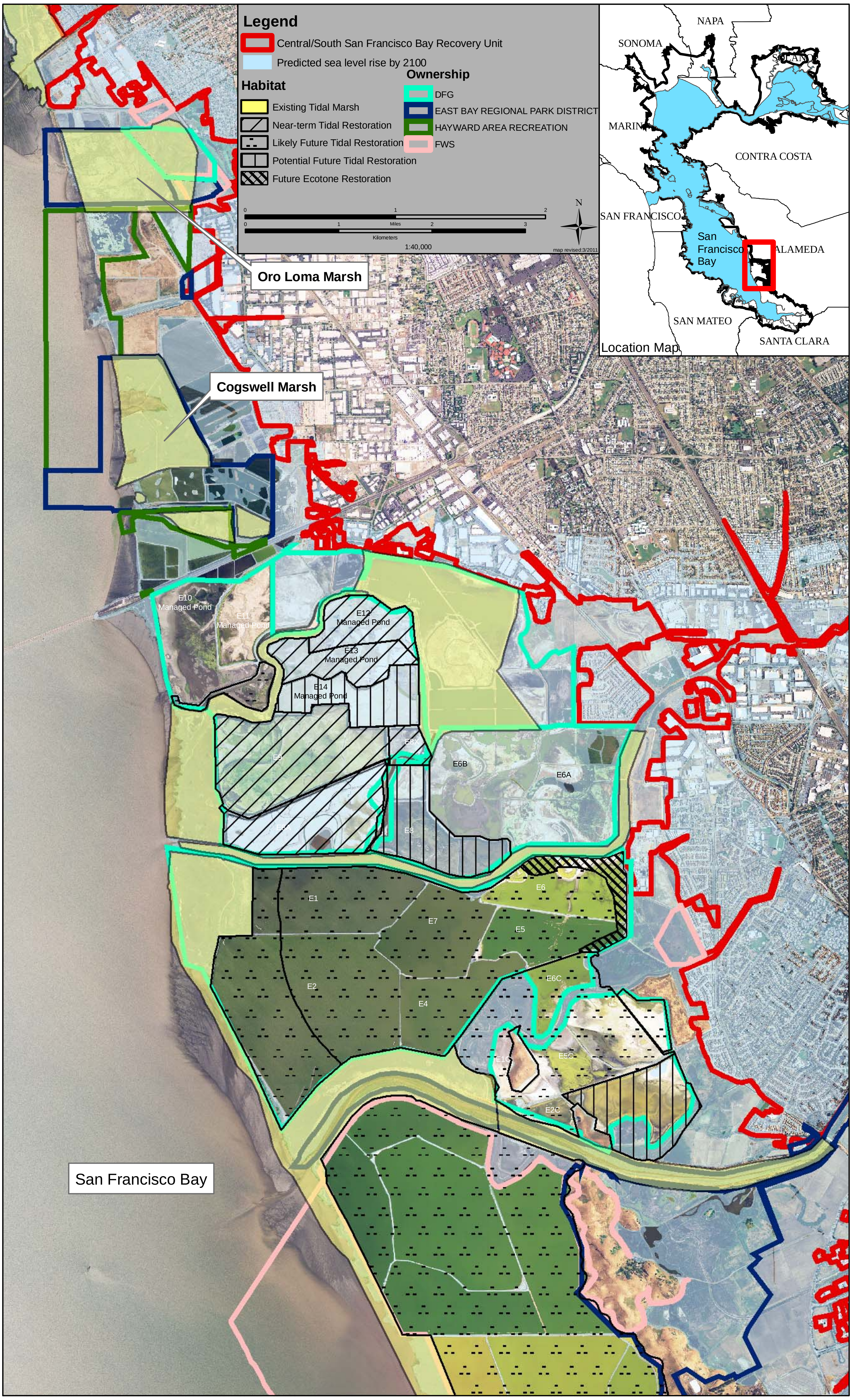

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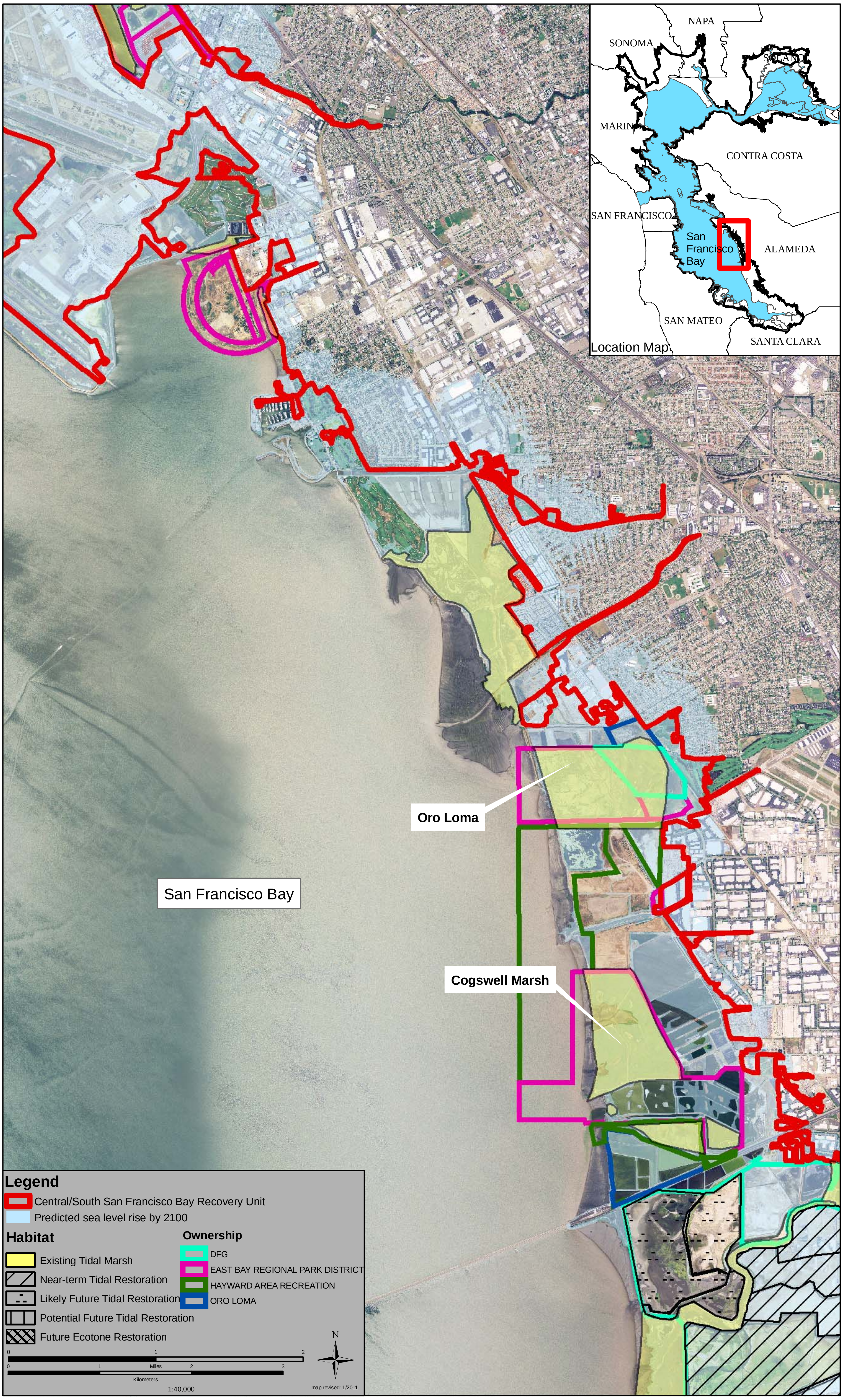

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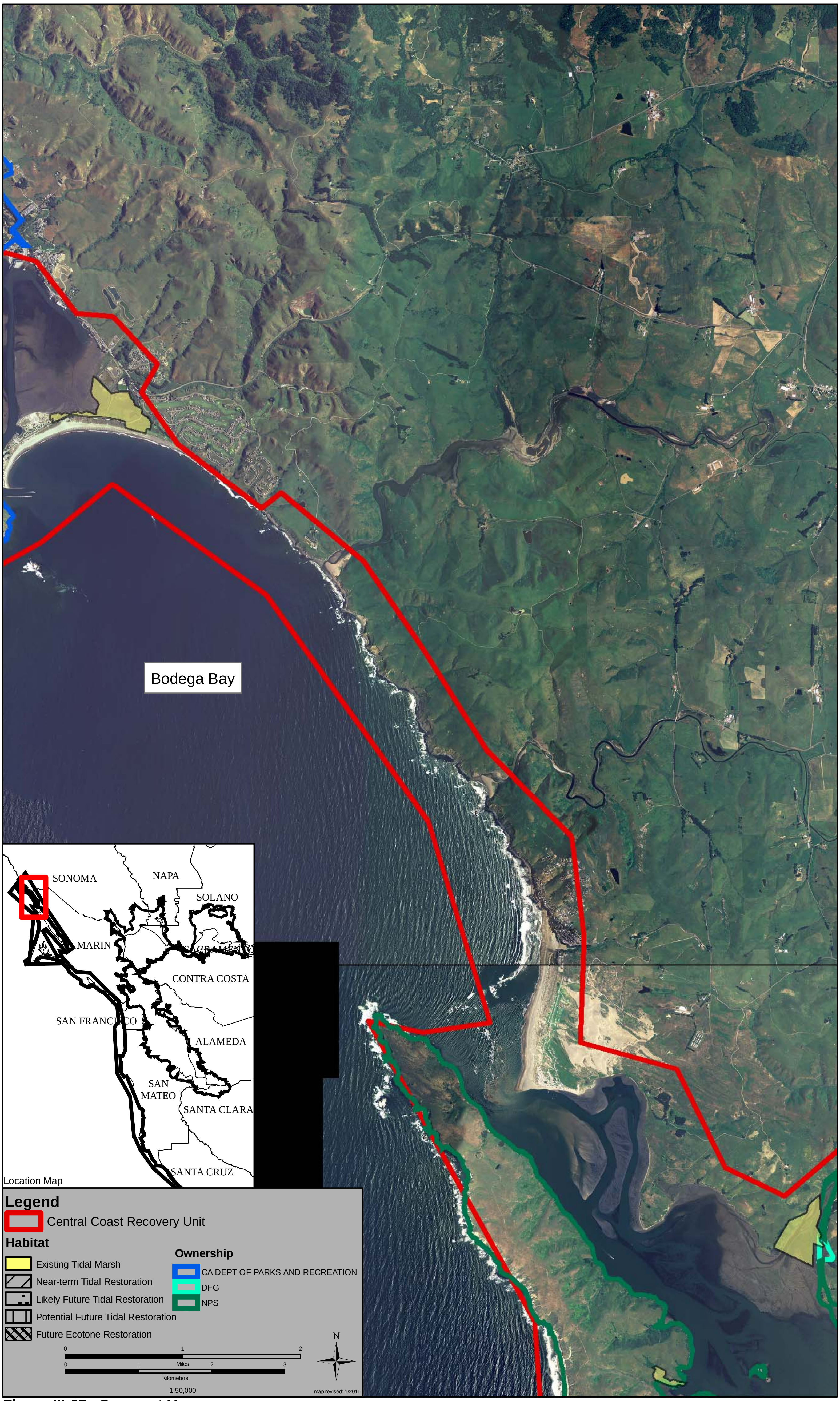

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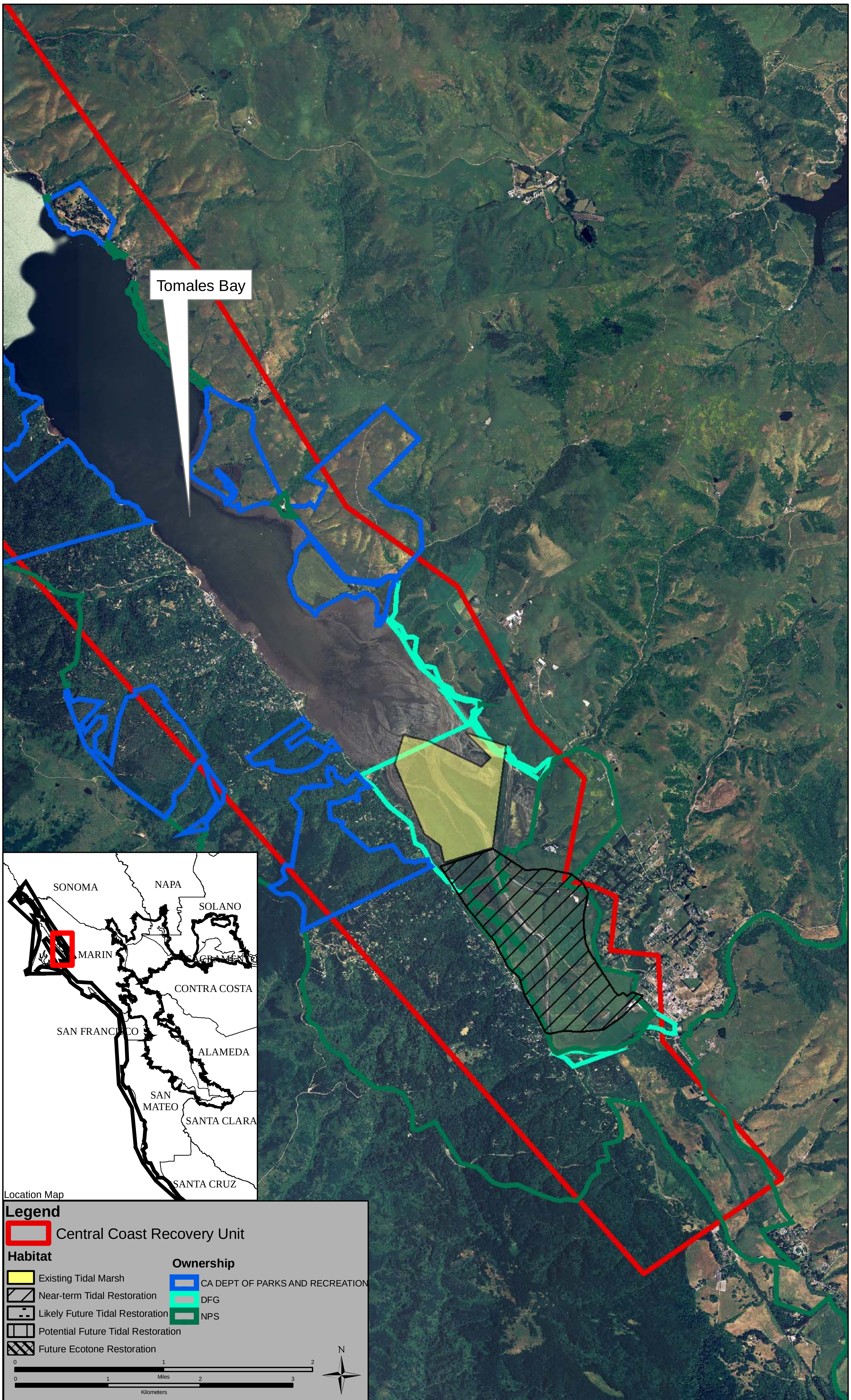

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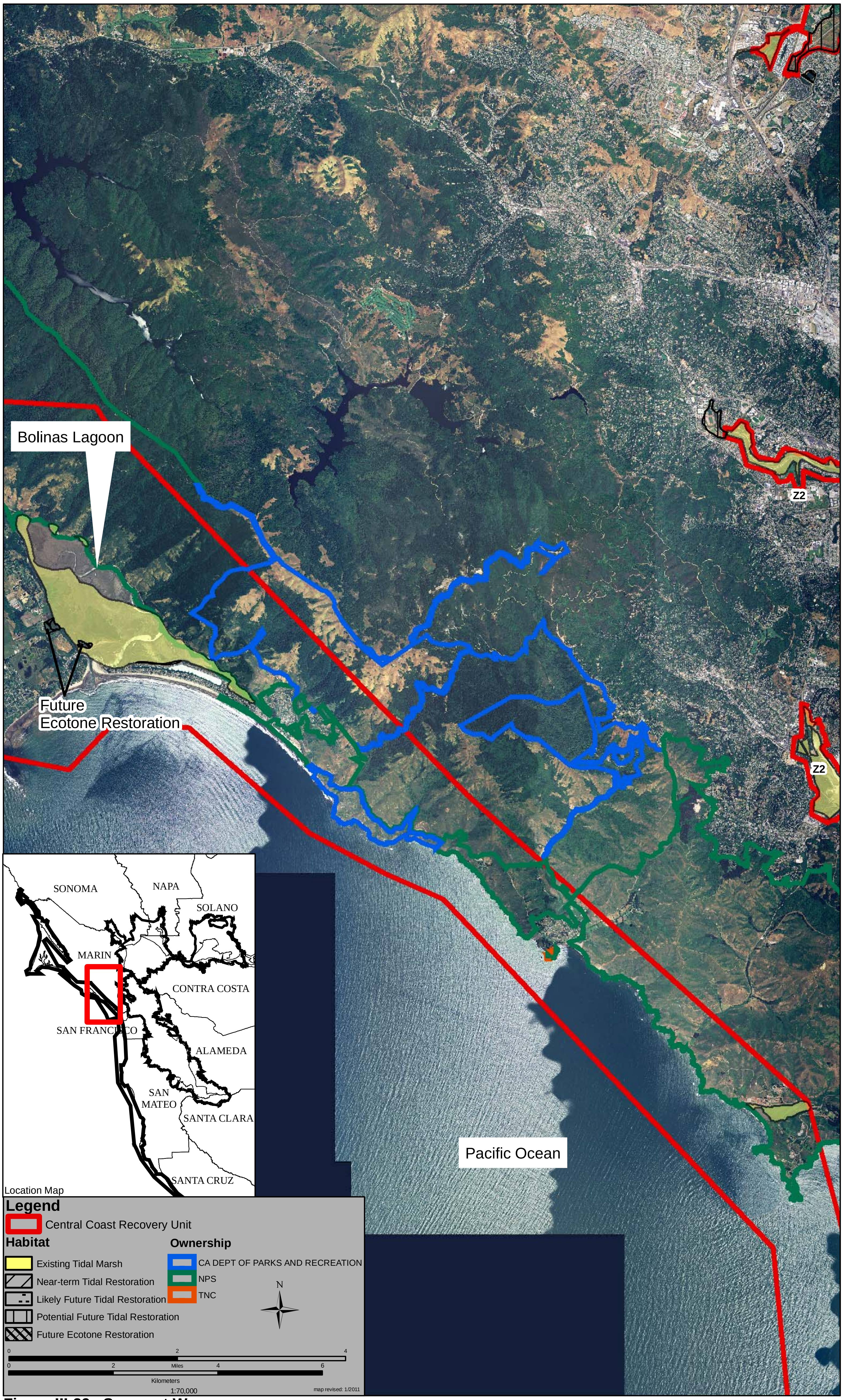

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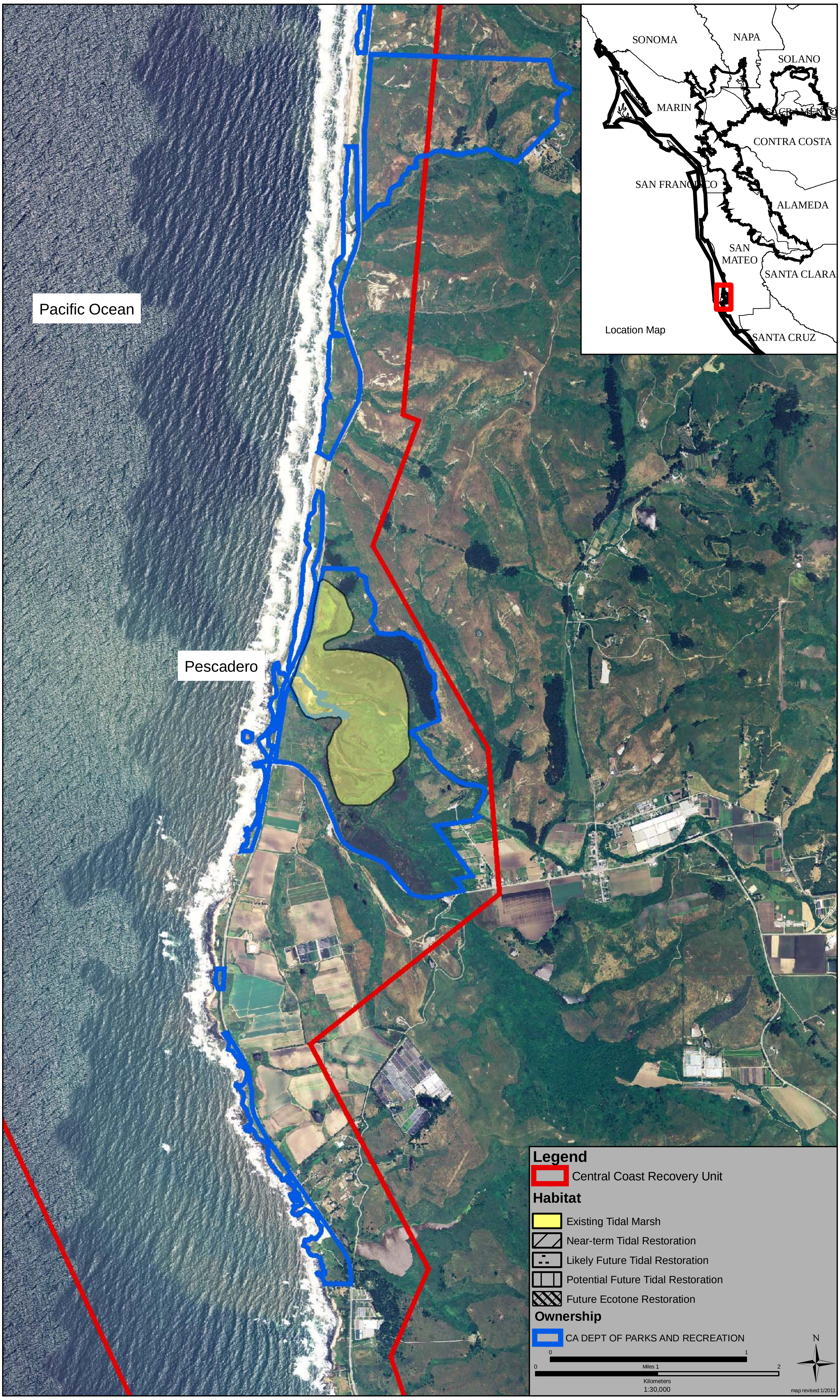

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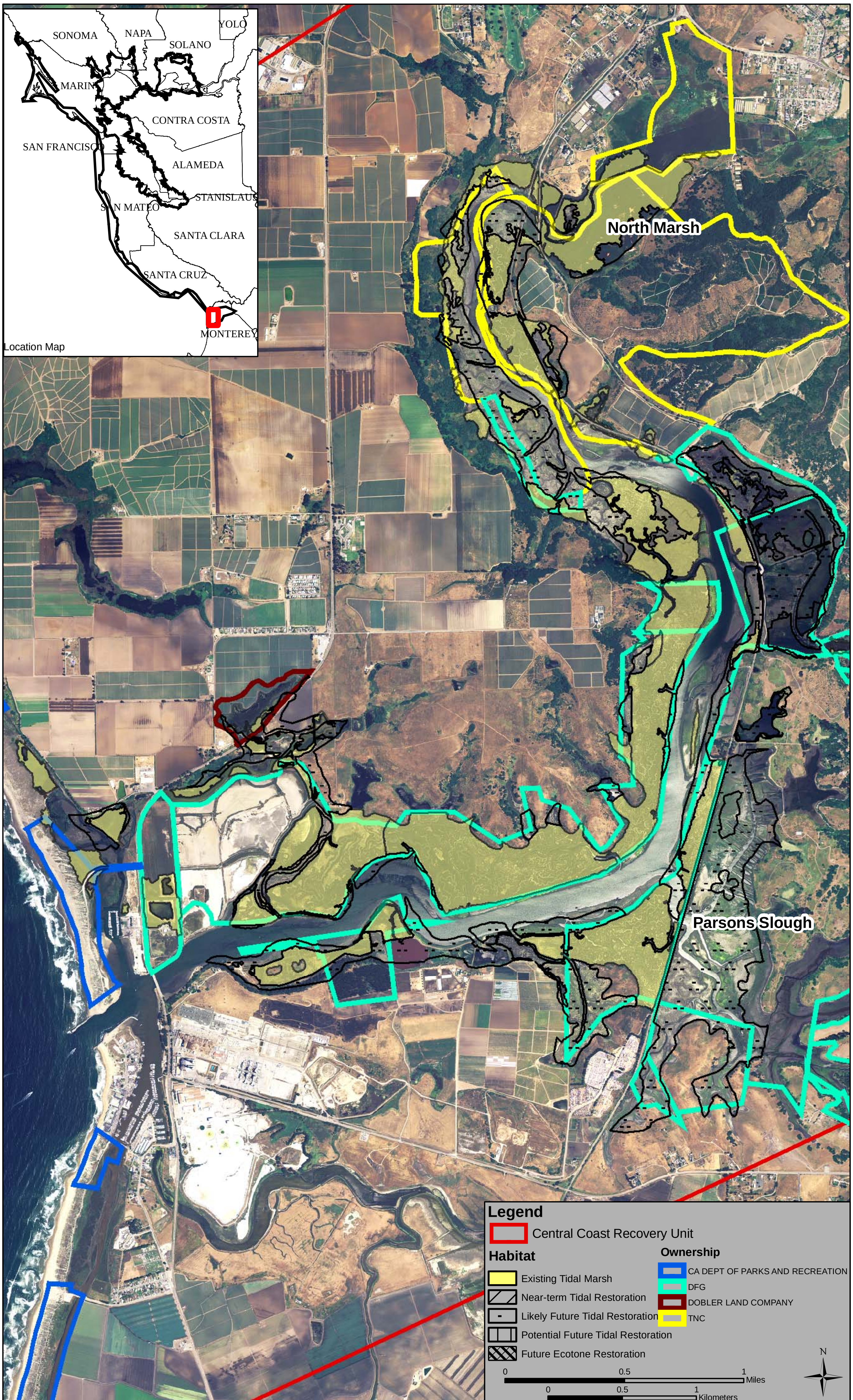

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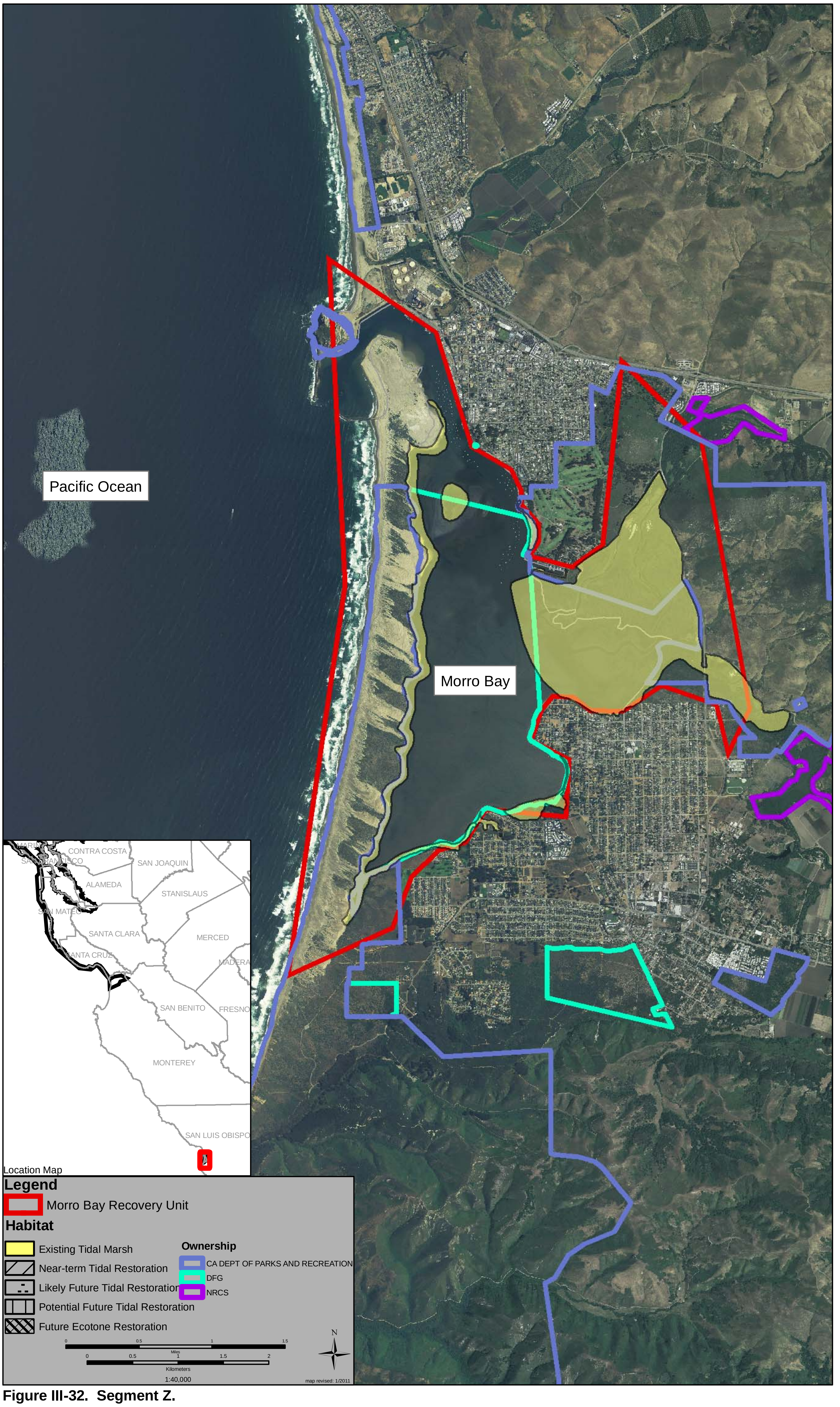

Figure III-32. Segment Z.

IV. STEPDOWN NARRATIVE

This chapter lays out the five elements of the recovery strategy, then tiers them down, from broad to specific individual recovery actions for implementation. The five elements are of the recovery strategy, as described above under Ecosystem-level recovery strategies are:

1.0 Acquire existing, historic, and restorable tidal marsh habitat to promote the recovery of listed species and the long-term conservation of species of concern and other tidal marsh species.

2.0 Manage, restore, and monitor tidal marsh habitat to promote the recovery of listed species and the long-term conservation of species of concern and other tidal marsh species.

3.0 Conduct range-wide species status surveys/monitoring and status reviews for listed species and species of concern.

4.0 Conduct research necessary for the recovery of listed species and the long-term conservation of species of concern.

6.0 Improve coordination, participation, and outreach activities to achieve recovery of listed species and long-term conservation of species of concern.

Priority numbers

The most detailed, or stepped-down, actions are assigned a priority for implementation. The priority numbers are defined as such:

Priority 1: actions that must be taken to prevent extinction or to prevent a species from declining irreversibly.

Priority 2: actions that must be taken to prevent a significant decline in the species population/habitat quality or in some other significant negative impact short of extinction.

Priority 3: all other actions necessary to provide for full recovery of the species.

The numeric recovery priority system follows that of all U.S. Fish and Wildlife Service recovery plans. Where an action involves several species, the recovery/conservation priority number reflects both the needs of the individual species and that of the broader suite of species. Because situations change over time, priority numbers must be considered in the context of past and potential future actions at all sites. Therefore, the priority numbers assigned are intended to guide, not to constrain, the allocation of limited conservation resources.

1. Acquire existing, historic, and restorable tidal marsh habitat to promote the recovery of listed species and the long-term conservation of species of concern and other tidal marsh species.

Habitat loss, which includes degradation, fragmentation, and other changes that reduce habitat quality, is the greatest threat to species covered in this recovery plan. Habitat protection requires permanent preservation of landscape, topographic, and soil features that support hydrologically and ecologically functional tidal marsh ecosystems, including space for erosional and depositional dynamics and upland transition zones. Current research suggests that in the near future global climate change and associated rise in sea level will become a serious factor in the effort to protect tidal marsh habitats.

It is necessary to retain the full range of site diversity to retain representative genetic diversity. Genetic diversity within each species increases the likelihood of species persisting through unpredictable events (e.g., drought, climate change). Since genetic composition has not been investigated for most of the covered taxa, protection of all remaining populations is prudent.

1.1 Maintain underlying ecosystem processes and functions. **(Priority 1)**

Tidal marsh species are adapted to a complex and dynamic ecosystem that includes daily, monthly, and seasonal changes in moisture and salinity due to tidal cycles, as well as specific soil and elevation characteristics. In addition, various habitats within and beyond the tidal marsh ecosystem are interrelated and interdependent, with connectivity between habitats necessary to the survival of many species.

It is crucial to maintain the full range of currently existing natural hydrology and salinity functions in the tidal marsh ecosystem. Other elements, such as soil characteristics, topography, waves and currents, nutrient cycling, water and air quality, ecotones, and corridors between habitats, must also be retained to support the species covered in this recovery plan. Where natural function of the ecosystem has essentially disappeared, especially in the high marsh, it will be necessary to expand whatever natural functions remain (*e.g.*, by creating longer, more gradual high marsh plains). Further discussion of this topic can be found below in Action 2.2.2.

1.2 Protect habitat through acquisition of fee title or development of conservation easements or other management agreements.

To protect remaining habitat, it will be desirable to acquire privately owned tidal marsh habitat, restorable areas, and adjacent buffer lands from willing sellers, in fee title or by conservation easement. Initially, willing landowners should be sought with whom to develop conservation easements. If this is not possible, valuable marsh lands and adjacent upland buffer lands should be acquired in fee title. Buffer lands will be more available for acquisition in San Pablo and Suisun Bay areas than in Central and South San Francisco Bay due to urban development in the latter.

The U.S. Fish and Wildlife Service has several programs (*e.g.*, Partners for Fish and Wildlife, Coastal Program) which provide partnership and/or funding opportunities to private entities to manage habitat to the benefit of listed species. Also, opportunities exist to provide legal assurances to private entities through habitat management agreements (*e.g*., Safe Harbor Agreement, Habitat Conservation Plans). These options, which are often more cost effective, should be pursued as ways to achieve protection of habitat and species.

Based on the imminent and severe threat of sea level rise, the most important action for preserving natural and restored marshes is to allow for the landward transgression of high marsh zones onto bordering broad, sloping plains. Therefore, special focus should be placed on acquisition/protection of these adjacent, undeveloped lands not yet serving as habitat.

In all areas, consideration should be given not only to habitat needing protection now, but also that which will fulfill species needs into the future under various possible sea level rise scenarios. Specifically, land acquisition planning should assume all lands below 140 cm elevation will be inundated by the Year 2100.

The addition of habitat to public and/or conservation ownership will enhance restoration and management options over larger areas, and increase continuity and functionality of tidal marsh habitats. Refer to **Figure III-7** through **Figure III-32** for specific parcels to be acquired or protected.

1.2.1 Acquire/protect habitat for California clapper rail and salt marsh harvest mouse by purchase in fee title or conservation easement with willing landowners.

Acquisition and protection, below, should focus on areas within the following Recovery Units, according to **Figure III-7** through **Figure III-32**:

Central/Southern San Francisco Bay: San Rafael Creek-Richardson's Bay; Bair-Greco-Ravenswood; East Palo Alto-Guadalupe Slough; Guadalupe Slough-Warm Springs; Mowry-Dumbarton; Hwy 84 to Hwy 92; Cogswell-Hayward Shoreline/Oro Loma/Robert's Landing

San Pablo Bay: China Camp to Petaluma River; Petaluma River marshes; Petaluma River to Sonoma Creek; Napa marshes; Point Pinole marsh

Suisun Bay Area: Western Suisun/Hill Slough marshes; Suisun Slough/Cutoff Slough marshes; Grizzly Island marshes and ponds; Nurse Slough/Denverton Slough marshes; Contra Costa County shoreline marshes

1.2.1.1 Acquire/protect currently unprotected tidal marsh habitat. **(Priority 2)**

1.2.1.2 Investigate opportunities to acquire/protect lands restorable to tidal marsh. **(Priority 2)**

1.2.2. Acquire/protect currently unprotected high marsh and ecotonal habitat and lands restorable to high marsh and ecotonal habitat for *Chloropyron molle* ssp. *molle*, *Cirsium hydrophilum* var. *hydrophilum*, California clapper rail, and salt marsh harvest mouse by purchase of fee title or conservation easement. **(Priority 1)**

Ecotones are vital to many of the species covered in this recovery plan. For example, pollinator species necessary to *Chloropyron maritimum* ssp. *maritimum* may require adjacent upland buffer lands, and salt marsh harvest mice require adjacent halophytic high marsh vegetation zones for escape cover during high tides. Protection may be achieved through purchase of fee title or development of conservation easement with willing landowners of *Chloropyron molle* ssp. *molle* and *Cirsium hydrophilum* var. *hydrophilum* habitat. Adjacent upland buffer lands should also be sought, in part to protect viable populations of pollinator species.

Historically, the marshes in San Francisco Bay were a complex mosaic of vegetation zones. Most of the tidal marshes around the bay have been eliminated, and those remaining have lost the upper portion of their *Sarcocornia* zones, most of the higher zone of peripheral halophytes, and almost all high marsh-grassland ecotones. It appears that populations of salt marsh harvest mice can exist in very deep (from shore to bay) tidal marshes with or without the high marsh. The populations that are in more danger are those populations found in shallow marshes; they require the extra habitat and escape cover of the high marsh much more than the populations in deep marshes.

1.2.3 Acquire/protect currently unprotected habitat for *Suaeda californica.* **(Priority 3)**

Most areas where undeveloped, suitable habitat exists are currently in conservation ownership (*i.e*., state or regional park district or National Wildlife Refuge lands). This action refers to acquisition and protection of undeveloped, suitable habitat from further encroachment or land use conflicts on land owned by local governments or private entities such as the Cities of San Francisco and San Leandro and the Ports of San Francisco and Oakland.

Protection of habitat may be accomplished by acquiring land in fee title, but should focus on protection through conservation easements or other partnerships.

Suitable habitat and upland buffer areas should be protected where future reintroduction and expansion of *Suaeda californica* populations could occur and which can accommodate the consideration of future sea level rise.

1.2.4 Acquire/protect habitat for *Chloropyron maritimum* ssp. *maritimum*. **(Priority 2)**

Any remaining undeveloped shoreline in Morro Bay should be brought under protective ownership or management. Adjacent upland buffer lands also should be sought, in part to protect viable populations of pollinator species. This may be accomplished by acquiring land in fee title, but should focus on protection through conservation easements or other partnerships.

1.2.5 Acquire/protect habitat or potential habitat for other species of concern discussed in this recovery plan. **(Priority 3)**

1.3 Strengthen legal protections by improving coordination with federal, state, and local regulatory authorities to ensure consistent, close attention to conservation of tidal marsh habitats and species. **(Priority 3)**

Coordinate with agencies, such as the U.S. Army Corps of Engineers, the California Coastal Commission, and the Bay Conservation and Development Commission, to avoid further fragmentation of habitat and other direct, indirect, and cumulative impacts to the species covered in this recovery plan, (*e.g.*, filling and dredging impacts in San Francisco Bay, San Pablo Bay, and Suisun Marsh area). Any partnership of agencies implementing this action must incorporate principles of Strategic Habitat Conservation (SHC), specifically to guide future habitat acquisition and management goals given the challenge of local sea level rise.

2. Manage, restore, and monitor tidal marsh habitat to promote the recovery of listed species and the long-term conservation of species of concern and other tidal marsh species.

Even "protected" habitat must be managed and monitored to ensure the protected habitat continues to function properly and contributes to the recovery of the listed species and the long-term conservation of species of concern. For example, fencing and signage must be maintained, non-native species controlled, and garbage removed.

Methods for effective habitat restoration, management, and monitoring in tidal marsh are continually evaluated and improved. Strategies to restore, manage, and monitor tidal marsh areas therefore must remain adaptive, and must be tied to population and ecosystem trends. Existing habitat management may be adequate where populations are currently stable or increasing, but if populations or habitats begin to decline, changes in management should be considered. Revised habitat management techniques should be based on the best available scientific data, research, or observed outcomes of management from similar situations. Planning for restoration, management, and monitoring is important, as is maintaining the flexibility to adapt plans in response to new developments or new information.

Long-term protection sometimes requires trade-offs. For example, it can be advantageous to the ecosystem to eradicate non-native *Spartina* in an existing marsh, even though it may require temporary destruction of native marsh vegetation in the short-term. However, if this course of action is taken, the cost of reduced rail numbers resulting from the loss of physical structure must be carefully considered and minimized. Stretches of high marsh will have to be sacrificed for various periods of time to allow for the creation of deep and more gradual high marshes needed by the salt marsh harvest mice, some shrews and a variety of flowering plants.

2.1 Manage tidal marsh habitat to promote the recovery/conservation of covered species and other tidal marsh species.

Appropriate management maintains habitat quality and function, correct problems, minimizes impacts, and provides benefits to species and ecosystem recovery. Many tidal marsh areas, whether existing, restored, or in the process of restoration, will need active management for some time to promote ecosystem functions and native species.

A major focus of tidal marsh management, at least in the near term, must be controlling invasive non-native species, beginning with those that actually threaten the continued existence of the native tidal marsh ecosystem. Other management issues include water quantity and quality, recreation, and maintenance of necessary roads, levees, and other features.

Habitat management, in many instances, should be conducted within an experimental context to document the effects of various factors, and should be linked with monitoring of habitat or population response.

2.1.1 Coordinate with existing agencies to develop and implement mechanisms for coordinated, long-term management of species and their habitat.

2.1.1.1 Work with Federal agencies to protect habitat and promote the recovery and conservation of the species covered in this recovery plan. **(Priority 2)**

For example, ensure adequate U.S. Fish and Wildlife Service staff and funding to coordinate recovery implementation. Interagency (section 7) consultations should contribute to the conservation of species covered in this recovery plan. Much of the large scale habitat restoration will likely rely upon U.S. Army Corps of Engineers involvement.

2.1.1.2 Work with State and local agencies that manage land to beneficially manage habitat and promote the recovery and conservation of tidal marsh ecosystems and the species covered in this recovery plan. **(Priority 2)**

2.1.1.3 Develop a web-based clearinghouse for information about managing the effects of climate change on wetland restoration. **(Priority 2)**

2.1.2 Continue to manage existing tidal marsh habitat, as shown in **Figures III-7 through III-32**. **(Priority 1)**

Protection of these lands entails continued management to maintain healthy tidal marsh habitat.

2.1.3 Conduct interim habitat management to maintain, stabilize, or enhance ecosystem function and declining populations and to monitor the effects of management.

In some cases, it will be necessary to address threats to tidal marsh species and habitats immediately while long-term, comprehensive habitat management plans are being compiled, reviewed, revised, and developed, and additional research is underway. Short-term recovery actions should be implemented concurrently with long-term habitat restoration, and should focus on managing existing habitats and populations to avoid irreversible damage to those sites and species.

2.1.3.1 Work with existing Federal, State, and local agencies, land managers and private landowners to conduct interim habitat management to promote the recovery and conservation of the species covered in this recovery plan. **(Priority 1)**

2.1.3.2 Develop and implement standardized monitoring techniques to evaluate ecosystem function and response, species response, and threat response to interim management activities. **(Priority 2)**

Standardized monitoring techniques must be developed and implemented to ensure consistency and continuity of data between observers and over time. Development of techniques should occur with input from the Recovery Implementation Team (RIT) and other interested parties. Standardized monitoring must be based on multiple criteria; no single criterion will reliably measure trends consistently over time. Standardized monitoring techniques should include criteria such as the degree of habitat fragmentation, degree of threat, shifts in vegetation type, establishment and extirpation of plant and animal occurrences, number of individuals, photopoints, estimates of acreage occupied, density, co-occurring species including non-natives, time since last disturbance, and some estimate of seed bank dynamics.

Baseline conditions of habitat, species, and threats to species should be documented before changing habitat management techniques. It may be necessary to modify interim habitat management activities according to monitoring results. This adaptive strategy is important, as new information becomes available, to the recovery and long-term conservation of tidal marsh species.

Interim habitat management activities to promote recovery and conservation should continue during the development of standardized monitoring techniques.

2.1.4 Develop, implement, and adapt habitat management plans.

Management plans are the blueprints for effective conservation and recovery activities. They ensure that a comprehensive plan is in place to guide or educate staff, and they can be passed on if ownership/management changes. Depending on objectives, plans can be developed at various scales, including comprehensive, regional, local, site-specific, or species specific. The SBSP Restoration Project and the *Suisun Marsh Habitat Restoration, Preservation, and Management Plan* exemplify two multi-faceted, multi-agency, comprehensive management plans.

Long-term comprehensive habitat management and monitoring plans should be developed and implemented to address all aspects of management activities, existing threats, species and habitat responses to habitat management activities, and incorporation of monitoring results into habitat management plans. Plans should include schedules for the completion of operations and maintenance of ongoing routine and one-time tasks.

Management plans should seek to minimize/resolve conflicts with other species. It will be important that actions are coordinated with actions identified in other recovery plans for listed species as well as other planning documents, such as the Baylands Ecosystem Habitat Goals (Goals Project 1999). Tidal marsh restoration should be designed to provide a diversity of habitats to benefit various species, such as migrating waterfowl and shorebirds. Also, any partnership of resource agencies, public landowners/managers and private landowners developing management plans should incorporate principles of Strategic Habitat Conservation (SHC), specifically to guide future habitat acquisition and management goals given the challenge of local sea level rise.

2.1.4.1 Develop management plans, where lacking, in cooperation with appropriate agencies and organizations. **(Priority 2)**

2.1.4.2 Implement existing, newly developed, or revised management plans to protect tidal marsh habitat and promote recovery and conservation of the species covered in this recovery plan. **(Priority 1)**

2.1.4.3 Revise existing management plans, if necessary. **(Priority 3)**

Revision of management plans may be appropriate in response to the results of Action 2.3.2.1 through 2.3.2.5 (monitoring).

2.1.5 Manage activities and practices that affect water and salinity in the tidal marsh.

2.1.5.1 Maintain normal tidal range. **(Priority 2)**

Natural tidal range should be maintained or restored, since their effects on vegetation and soil chemistry are important to most tidal marsh species. For example, middle to high marsh areas with periodic tidal flooding and moderate to high soil salinity, and the resulting low-stature vegetation and low abundance of non-natives or winter annuals, are vital to *Chloropyron molle* ssp. *molle*.

In particular, recent modifications to tidal fluxes at the important Hill Slough population of *Cirsium hydrophilum* var. *hydrophilum* need to be examined and any necessary fixes implemented promptly. Salinity and flow manipulations via the Montezuma salinity control gates should be evaluated in light of possible consequences for populations of *Chloropyron molle* ssp. *molle*.

2.1.5.2 Minimize or avoid over-management of estuarine salinity variation. **(Priority 2)**

Over management of estuarine salinity variation could be harmful to covered species such as salt marsh harvest mouse, *Cirsium hydrophilum* var. *hydrophilum*, and *Chloropyron molle* ssp. *molle*.

2.1.5.3 Develop and implement site-specific oil spill prevention and response plans for lands supporting known populations of any of the five listed species covered in this recovery plan. **(Priority 1)**

2.1.5.4 Manage groundwater extraction to prevent salt water intrusion in Los Osos Valley. **(Priority 2)**

Groundwater extraction and channelization or diversion of surface drainage, for example, in the Los Osos Valley area near Morro Bay, should be managed to prevent the intrusion of high-salinity water into brackish alluvial edges of tidal marsh, to maintain the brackish edge flora of the tidal marsh. This action may be accomplished through the planning efforts for the new wastewater treatment facility in Los Osos.

2.1.5.5 Modify ditching and other mosquito abatement activities in tidal marshes to avoid impacts to species covered in this recovery plan. **(Priority 3)**

2.1.5.6 Engineer and implement solutions to direct current and future urban runoff away from tidal marsh habitat at Benicia State Recreation Area. **(Priority 2)**

2.1.5.7 Avoid shoreline stabilization or development between White Point and Fairbank Point in Morro Bay. **(Priority 1)**

2.1.6 Manage non-native invasive species and predators in the tidal marsh and adjacent habitat.

Results of Action 4.5.1. will inform this Action.

2.1.6.1 Develop and implement management plans to control and/or eradicate invasive non-native plant species.

2.1.6.1.1 Continue to control non-native *Spartina* ssp. as appropriate, consistent with management of other sensitive resources, such as clapper rail.

2.1.6.1.1.1 Develop site-specific management plans, consistent with the conservation and recovery of listed species, to control non-native *Spartina* species, especially *Spartina alterniflora* and its hybrids. **(Priority 1)**

2.1.6.1.1.2 Control non-native *Spartina* species, especially *Spartina alterniflora* and its hybrids, consistent with the conservation and recovery of listed species. **(Priority 1)**

2.1.6.1.1.3 Monitor the success of control at sites where non-native *Spartina* is managed and the ability of treated sites to support California clapper rails. **(Priority 1)**

Per Action 2.1.6.1.1.1, it may be determined that some level of hybridization is acceptable. If that occurs, the definition of successful control may change.

2.1.6.1.2 Control or eradicate *Lepidium latifolium*

2.1.6.1.2.1 Prioritize possible sites at which to control or eradicate *Lepidium latifolium*. **(Priority 2)**

2.1.6.1.2.2 Develop site-specific management plans to control or eradicate *Lepidium latifolium*. **(Priority 1)**

2.1.6.1.2.3 Control or eradicate *Lepidium latifolium*. **(Priority 1)**

Particularly within rare species habitat, coordinate with and/or build off of the *L. latifolium* studies conducted by the U.S.

Department of Agriculture-ARS Exotic and Invasive Weeds Research Unit at Benicia State Recreation Area within habitat occupied by endangered *Chloropyron molle* ssp. *molle* (Grewell 2011).

2.1.6.1.2.4 Monitor the success of *Lepidium latifolium* control at the sites where it is managed. **(Priority 1)**

2.1.6.1.3 Eradicate *Carpobrotus edulis* and related non-native succulent groundcover.

Enhance the habitat quality around Morro Bay for *Suaeda californica* by eradication of *Carpobrotus edulis* (invasive nonnative iceplant) and hybrids. Restore and enhance habitat in Napa-Sonoma marshes invaded by *Carpobrotus* species and related forms.

2.1.6.1.3.1. Develop site-specific management plans to eradicate *Carpobrotus edulis*. **(Priority 2)**

2.1.6.1.3.2. Eradicate *Carpobrotus edulis*. **(Priority 2)**

2.1.6.1.3.3. Monitor the success of *Carpobrotus edulis* eradication at sites where it is managed. **(Priority 2)**

2.1.6.1.4 Develop and implement site-specific management plans for control of other invasive non-native plants. Monitor the success of control efforts. **(Priority 3)**

Control (or eradication) of other invasive non-native plant species is necessary to prevent crowding, shading, or other impacts to listed species. For example, *Arundo donax*, *Phragmites australis*, or *Tetragonia tetragonoides* may need to be controlled in the South Bay, in coordination with the San Francisco Bay National Wildlife Refuge. Although currently designated as a Priority 3 task, there may be certain species for which control later becomes a Priority 1 or 2 task if the species are allowed to expand.

2.1.6.1.5 Develop a system for early-detection and rapid response to invasive plant species. **(Priority 2)**

This system will use the Bay Area Early Detection Network, which coordinates Early Detection and Rapid Response to infestations of invasive plants, proactively dealing with new outbreaks before they can grow into large and costly environmental problems. For this task, local managers will use the early detection protocols developed by the National Park Service.

2.1.6.2 Develop and implement management plans to monitor and control non-native animals (including invertebrates) and inappropriate populations of native animals that threaten species covered in this recovery plan.

A number of predators threaten listed species and species of concern in tidal marsh ecosystems. Foremost among these is the non-native red fox, which is known to take a large toll on California clapper rail populations. Management resources should be dedicated to continued (South Bay) and expanded (San Pablo Bay and Suisun Marsh) predator control to reduce California clapper rail loss, which will facilitate efforts to increase California clapper rail numbers and expand their range.

Threats from other mammalian (e.g., Norway rats, cats, skunks, and raccoons) and invertebrate predators (e.g., non-native thistle weevils that feed upon seeds of *Cirsium hydrophilum* var. *hydrophilum*) should be monitored and, if necessary, control measures taken. Control measures may include a number of actions including removal of non-native predators, removal of predator perches, minimization of riprap slope protection, removal of trash from marsh access points, etc. Protection may also involve ensuring adequate vegetation cover and buffers to protect species from predators. Steps should be taken to reduce parasitism by brown-headed cowbirds on saltmarsh common yellowthroats.

2.1.6.2.1 Develop and implement management plans to monitor and control red fox. **(Priority 1)**

2.1.6.2.2 Develop and implement management plans to monitor and control Norway rats. **(Priority 2)**

2.1.6.2.3 Develop and implement management plans to monitor and control other animals that threaten species covered in this recovery plan. **(Priority 3)**

2.1.6.2.4 Monitor the success of, and adapt control plans for, the above non-native or native animal predators. **(Priority 3)**

2.1.7 Manage for the protection of native pollinators, insect predators, and their habitats. **(Priority 2)**

Beneficial native species of insects are part of the healthy ecosystem that supports the species covered in this recovery plan. For example, native pollinators are critical to the recovery of *Chloropyron molle* ssp. *molle*. Ground-nesting species of bumblebees and solitary bees are probably among the more effective pollinators for *Chloropyron molle* ssp. *molle* and other species mentioned in this recovery plan (*e.g., Cirsium hydrophilum* var. *hydrophilum, Chloropyron maritimus* var. *palustris, Castilleja ambiguua*). Adaptive management for, and monitoring of, ground-nesting and other native bees is needed.

Insect predators may play an important role in the recovery of species covered in this recovery plan. For example, protection of predatory wasps that feed on moth larvae (*Saphenista* spp., Tortricidae and salt marsh snout moth, *Lipographis fenestrella*, Pyralidae) that infest *Chloropyron molle* ssp. *molle inflorescences* should reduce losses of reproductive output.

2.1.8 Manage human/recreational disturbance.

Recreation, maintenance, and other human disturbance threaten tidal marsh habitat and species covered in this recovery plan. Controls should be erected and maintained to prevent illicit off-road vehicle use in tidal marsh habitat. Necessary vehicular use near habitat, such as by levee crews, mosquito abatement or wildlife personnel, and researchers is appropriate, but possible impacts to species should be considered and avoided. Similarly, planning for maintenance of levees, ditches, and other features or structures should consider and avoid impacts to the species covered in this recovery plan. Recreational and research access may need to be redirected or redesigned if impacts to species or habitats appear likely.

2.1.8.1 Protect tidal marsh habitat for *Chloropyron maritimum* ssp. *maritimum* and *Suaeda californica*, in Morro Bay, from human disturbance.

2.1.8.1.1 Route access points and trails away from sensitive *Chloropyron maritimum* ssp. *maritimum* habitat in Morro Bay. **(Priority 2)**

In particular, trampling impacts at the Los Osos locations should be eliminated. The recreational trail at Sweet Springs should be re-aligned to eliminate impacts to *Chloropyron maritimum* ssp. *maritimum*.

2.1.8.1.2 Minimize impacts from boat haulouts to *Chloropyron maritimum* ssp. *maritimum* habitat in Morro Bay. **(Priority 2)**

2.1.8.1.3 Manage dredge disposal to minimize threats to *Chloropyron maritimum* ssp. *maritimum* and *Suaeda californica* habitat in Morro Bay. **(Priority 2)**

2.1.8.2 Protect tidal marsh species and habitat from recreational disturbance, utility maintenance and other human-related disturbance.

As well as direct impacts, human disturbance includes impacts from litter and refuse which attract predators and therefore reduce habitat quality. Numerous routine human activities have the potential to adversely affect individual California clapper rails and overall population viability. These include, for example, flood control; levee, dredge lock, pipeline, and powerline maintenance; recreational uses including hiking and bird watching; human and domestic animal incursion from adjoining developments; mosquito control ditching, spraying and use of ATVs/Argos in baylands; etc.

2.1.8.2.1 Identify lands adjacent to the Bay Trail and other public access areas where human-related disturbance encourages predation that causes a threat to the California clapper rail and salt marsh harvest mouse. **(Priority 2)**

2.1.8.2.2 Develop and implement management plans for lands identified under Action 2.1.8.2.1 that reduce predation by feral or otherwise free-roaming cats and other human-related disturbance (including litter and refuse disposal) to species and habitat. **(Priority 2)**

Local governments should be encouraged to prohibit feeding of feral or otherwise free-roaming cats within their boundaries, illicit feeding stations should be located and removed, and homeowners adjacent to tidal marshlands should be notified that cat trapping may be conducted to protect endangered species. In addition, where new housing developments are planned, funds to conduct predator management should be leveraged by homeowners groups.

In regards to avian predation, Don Edwards San Francisco Bay National Wildlife Refuge should work with Pacific Gas and Electric Company to remove common raven and red-tailed hawk nests from their electrical towers.

2.1.8.2.3 Implement and enforce pet restrictions. **(Priority 2)**

Domestic animals can cause major disturbance to California clapper rails, including predation of adults and eggs. Pets should be kept out of California clapper rail marshes or restrained on leashes at all times. For example, black rails at Bodega Harbor should be protected from off-leash dogs.

2.1.8.2.4 Avoid relocation of nuisance animals in California clapper rail habitat. **(Priority 2)**

Predator release programs should avoid California clapper rail marshes when relocating nuisance animals away from adjacent urban areas.

2.1.8.2.5 Provide wardens, agents, or officers to enforce above protective measures. **(Priority 2)**

2.1.8.2.6 Improve ability to coordinate activities which occur in sensitive habitats at Rush Ranch. **(Priority 2)**

These activities include controlling access by researchers, educators, volunteers, land trust employees, and others to protect sensitive species and habitats. Research to inform management decisions should be encouraged and supported, but timing and level of permitted research in sensitive habitat should be carefully controlled. This task could be accomplished by creation of a permanent position focused on these activities.

2.1.8.2.7 Bury distribution lines from power utilities where they traverse restored tidal marshes. Avoid routing of new transmission lines through restored or protected tidal marsh. **(Priority 3)**

2.1.8.2.8 Carry out vegetation clearing, mosquito management, dredging, and other activities after the breeding season of birds covered in this recovery plan. **(Priority 2)**

Where appropriate, revegetation should occur prior to the next breeding season to ensure suitable breeding habitat.

2.1.9 Manage animal disturbance to minimize impacts to species covered in this recovery plan.

Animal management should aim to reduce trampling of species covered in this recovery plan and, for some species, to reduce breaking of haustorial connections to host plants. In addition to direct mortality, soil and plant disturbance by domestic livestock can create conditions that encourage invasion by non-native plants.

2.1.9.1 Manage black-tail deer to minimize impacts to *Suaeda californica* at Morro Bay. **(Priority 3)**

Suaeda californica must be protected from grazing and trampling at Morro Bay State Marina and the sandy shoreline between White Point and Fairbank Point. Deer population size should be managed.

2.1.9.2 Manage cattle grazing to minimize impacts to salt marsh harvest mouse, Suisun shrew, and the birds of the high tidal marsh, such as saltmarsh common yellowthroat. **(Priority 3)**

Limit grazing in riparian and uplands adjacent to marsh habitats to periods outside the saltmarsh common yellowthroat's breeding season and the growing season of vegetation in these areas. Manage grazing intensity to ensure that cover and height of wetland and upland plants are optimal for saltmarsh common yellowthroat breeding. This is particularly important in the Golden Gate National Recreation Area and at Suisun and Petaluma Marshes. Prescribed grazing should continue at the Warm Springs seasonal wetlands adjacent to marshes and vernal pools to the extent that it benefits tidal marsh and vernal pool species through non-native plant control.

2.1.9.3 Manage feral pig disturbance to minimize impacts to sensitive plants and the birds of the middle and high tidal marsh, such as saltmarsh common yellowthroat. **(Priority 3)**

Disturbance by feral pigs is similar in effects to grazing, but includes digging (rooting), and is controlled differently. A regional-scale eradication effort should be coordinated with California Department of Fish and Game (CDFW) to decrease feral pig impacts on habitat for sensitive plants in Suisun Marsh.

2.2 Enhance, restore, and create tidal marsh habitat to promote the recovery and conservation of covered species.

Habitat restoration will allow and speed the recovery and conservation of tidal marsh species. Tidal marsh restoration projects include a wide range of activities, e.g. from removing fill and planting native species at engineered elevations, to breaching levees and allowing sedimentation and natural colonization to gradually rebuild a marsh.

In all areas, consideration should be given not only to habitat needing restoration now, but also that which will fulfill species needs into the future under various possible sea level rise scenarios. Specifically, restoration planning should assume all lands below 140 cm (55 inches) elevation will be inundated by the Year 2100.

2.2.1 Create an interdisciplinary review panel or similar group to coordinate and review the design of tidal marsh restoration projects throughout San Francisco Bay. **(Priority 2)**

A review panel, including experts in salt marsh harvest mouse and California clapper rail ecology, tidal marsh vegetation, and hydrology or geomorphology of estuarine marshes, should review tidal marsh restoration designs before they are funded for construction. The USFWS acknowledges that similar agencies provide this oversight already. This focused team should ensure the coordination of restoration design review, whether via creation of a new panel or via formal incorporation of design review into existing regulatory oversight. A distinct entity from the Recovery Implementation Team (RIT) described below in Action 5.1, the review panel should be funded collaboratively by willing Federal, State, and responsible local agencies with jurisdiction over, and expertise in, the recovery of tidal marsh species.

A group to conduct such activities, named the Design Review Group, was convened in 2002 as part of the San Francisco Bay Area Wetlands Restoration Program. Due to lack of funding, the group was disbanded in 2004. The same or similar group should be brought together to maintain consistency in project design. Ideally, a member of this group would sit on the RIT to provide feedback to the U.S. Fish and Wildlife Service.

2.2.2 Create/restore tidal marsh and adjacent habitat as depicted in **Figures III-7** through **III-32**.

Restoration should focus on large blocks of habitat and must include other important features, such as high marsh/upland ecotone habitat, as discussed above in Chapter III. Restoration would occur in areas identified on **Figures III-7** through **III-32**.

2.2.2.1 Restore habitat to achieve 1,111 acres of high quality tidal marsh habitat (including high marsh/upland ecotone habitat)in each marsh complex except the San Rafael Creek-Richardsons Bay complex in the Central/So SF Bay Recovery Unit (6,666 acres total), as indicated in **Figures III-15** through **III-26**. **(Priority 1)**

2.2.2.2 Restore habitat to achieve 2,500 acres of high quality tidal marsh habitat (including high marsh/upland ecotone habitat) in each marsh complex except Point Pinole marsh, in the San Pablo Bay Recovery Unit (10,000 acres total), as indicated in **Figures III-9** through **III-14**. **(Priority 1)**

2.2.2.3 Restore habitat to achieve 400 acres of high quality tidal marsh habitat (including high marsh/upland ecotone habitat) each in the San Rafael Creek-Richardsons Bay marsh complex in the Central/South SF Bay Recovery Unit **(Figure III-15)** and the Point Pinole marsh complex in the San Pablo Bay Recovery Unit **(Figure III-14)** (800 acres total). **(Priority 1)**

2.2.2.4 Restore habitat to achieve 5,000 total acres of high quality tidal marsh habitat (including high marsh/upland ecotone habitat) in the Suisun Bay Area Recovery Unit, as indicated in **Figures III-7** and **III-8**. **(Priority 1)**

2.2.2.5 Implement *Tidal Wetland Project* in Elkhorn Slough, reversing current trend of tidal marsh loss and speeding accretion at erosion hot spots. **(Priority 3)**

This action refers to the Elkhorn Slough Foundation and Elkhorn Slough National Estuary Research Reserve's *Tidal Wetland Project*. Work should continue on the Parson's Slough sub-project to slow current erosion and preserve remaining marsh. Also, work should begin on sub-projects designed to restore/enhance marsh at North Marsh and other subsided historic marshes, possibly by the addition of layers of sediment or re-establishment of natural sediment sources to allow accretion of marshes. See **Figure III-31**.

2.2.2.6 Create/restore tidal marsh and adjacent habitat (including high marsh/upland ecotone habitat, wherever possible) beyond minimum acreage above, in each Recovery Unit, as indicated in **Figures III-7** through **III-32**. **(Priority 2)**

2.2.2.7 As deemed necessary by the U.S. Fish and Wildlife Service, with guidance from the RIT, enter into conservation agreements to restore tidal habitat on private lands ("potential restoration") as depicted in **Figures III-7** through **III-32**. **(Priority 3)**

2.2.3 Create interim reserves to protect salt marsh harvest mice until restored tidal marsh has matured.

Large-scale habitat restoration will probably take several decades to develop mature tidal marsh habitat through natural processes. Methods intended to accelerate tidal marsh development, such as placement of dredged materials, may not result in the habitats needed by a species (marsh creek bank levees derived from organic peat accumulation, upper marsh edges derived from erosion and deposition of terrestrial sediments, and complex channel networks).

An interim reserve system is needed to ensure the immediate survival of a minimum number of populations of salt marsh harvest mice. These reserves should also provide sufficient numbers and variety of founder populations to expand and colonize new habitat for recovery in the long term. Interim reserves may include both natural and artificial habitat, and must be maintained at least until large-scale tidal marsh restoration sites support well-established, resilient new populations of salt marsh harvest mice.

2.2.3.1 Protect, manage, and monitor large populations and occupied marsh complexes as interim reserves selected to represent the full range of both subspecies of salt marsh harvest mouse. **(Priority 1)**

2.2.3.2 Supplement protection of each large population with a series of smaller satellite reserves, where feasible. **(Priority 2)**

2.2.3.3 Transition from diked wetlands to restored or enhanced tidal marsh habitat, where feasible. **(Priority 3)**

Diked tidal marshes are currently considered important, at least in the short-term, for the survival of the two subspecies of the salt marsh harvest mouse. However, diked tidal marshes have numerous limitations, as stated in the salt marsh harvest mouse recovery strategy above.

Diked marshes maintained as interim reserves should be evaluated for conversion to microtidal tidal or brackish marshes and converted when 1) habitat conditions for salt marsh harvest mouse would probably be improved by restricted tidal flows; 2) adequate access to tidal sources is feasible, and installation of tidegates and inlet channels would not cause excessive environmental impacts; and 3) site elevations relative to sea level are compatible with operation of tidegates. Diked microtidal marshes in subsided baylands are not appropriate substitutes for full tidal marsh because they require perpetual maintenance of levees; ongoing tidegate adjustment, monitoring, and maintenance and repair; and cannot equilibrate with rising sea level and, consequently, are vulnerable to more severe, prolonged flooding than fully tidal marshes.

2.2.4 Restore or enhance buffer zones in existing habitat adjacent to populations of species covered in this recovery plan. **(Priority 2)**

Buffer zones can be vital for the protection of species covered in this recovery plan. For example, a buffer of 300-500 feet between development projects and wetland areas is recommended to protect saltmarsh common yellowthroats. This size should be modified to reflect the appropriate estimated dispersal distances and home ranges of the species involved.

2.2.5 Replant native dune-stabilizing vegetation in Morro Bay if excessive dune mobility threatens populations of *Chloropyron maritimum* ssp. *maritimum* and *Suaeda californica*. **(Priority 1)**

Sand dunes upwind of areas inhabited by the species may need to be managed to control factors that affect survival and regeneration of *Suaeda californica*. Dune mobility should be monitored, especially where it has been exacerbated by human actions, such as deposition of dredge spoil. If dune drift threatens to eliminate significant stands of *S. californica*, it should be reduced, for example, by extensive replanting of native dune-stabilizing vegetation during years of above-average rainfall.

2.2.6 Conduct hazardous waste cleanup of the Superfund-listed landfill in the northwestern portion of Benicia State Recreation Area and restore the site to its historic habitat for endangered species. **(Priority 3)**

2.2.7 Reintroduce species to historic habitat, if necessary.

Many of the threats facing the species listed in this recovery plan are aggravated by small population size and limited distribution. Therefore, population augmentation and establishment of new subpopulations in suitable unoccupied habitat can be beneficial. Reintroduction programs should be developed and implemented to restore species to their former distributions/ranges, and to protect species from the threat of extirpation due to random environmental and/or genetic events.

2.2.7.1 Conduct seed and clone banking, as necessary.

Collections, storage, and propagation of seeds should be conducted where necessary to preserve rare or unique genotypes, or occurrences in danger of extirpation. Plant introductions and reintroductions should use locally collected seeds whenever possible. In cases where introduction and reintroduction must be conducted using propagated individuals, the U.S. Fish and Wildlife Service's policy regarding controlled propagation must be followed (U.S. Fish and Wildlife Service 2000).

Seeds should generally be collected in years of peak abundance, but small collections should be established immediately, even during adverse population conditions. Initially, seeds should be banked from at least one population in each recovery unit in which it occurs. Seed collections should be representative of both population and species-level genetic diversity. Repeated, small collections of seed may be necessary over several years to avoid contributing to the decline of very small populations. Seed collection should follow the protocol outlined by the Center for Plant Conservation (1991) to minimize impacts to rare plant populations. Collections from each population of each taxon should be stored in at least two sites, including the National Center for Genetic Resources Preservation in Fort Collins, Colorado, and a facility certified by the Center for Plant Conservation.

2.2.7.1.1 Bank seeds of *Cirsium hydrophilum* var. *hydrophilum* during years of high seed production. **(Priority 2)**

2.2.7.1.2 Bank seeds of *Chloropyron maritimum* ssp. *maritimum* and *Chloropyron molle* ssp. *molle* during years of high seed production. **(Priority 3)**

2.2.7.1.3 Maintain a clone bank of *Suaeda californica*. **(Priority 2)**

Propagate adequate propagules of *Suaeda californica* from Morro Bay to allow for periodic translocation to San Francisco Bay. Maintain clone stock at a facility certified by the Center for Plant Conservation.

In San Francisco Bay, plants should be propagated with permanently labeled stock plants (clonal pedigrees) to prevent over-representation of a few genetic individuals. Additional individuals should be added to compensate for loss of founders, and to offset limited initial founder population size.

2.2.7.2 Augment existing populations and/or initiate new subpopulations in suitable habitat.

Work with land managers and adjacent landowners to plan and introduce new subpopulations in suitable habitat.

2.2.7.2.1 Augment existing populations and/or initiate new subpopulations in suitable habitat for *Cirsium hydrophilum* var. *hydrophilum.*

2.2.7.2.1.1 Develop an introduction and reintroduction plan for *Cirsium hydrophilum* var. *hydrophilum*. **(Priority 2)**

This action includes field reconnaissance to select appropriate introduction and reintroduction sites. Introduction and reintroduction plans must call for the submission of annual reports. Plans must be reviewed by U.S. Fish and Wildlife Service staff before being finalized.

2.2.7.2.1.2 Conduct site preparation, propagate plants, and transplant seedlings of *Cirsium hydrophilum* var. *hydrophilum* for introduction and *reintroduction*. **(Priority 2)**

2.2.7.2.1.3 Monitor and conduct maintenance around transplanted *Cirsium hydrophilum* var. *hydrophilum.* **(Priority 2)**

2.2.7.2.1.4 Assess introduction and *reintroduction* success, review reports, and adapt introduction and reintroduction plan for *Cirsium hydrophilum* var. *hydrophilum*, as necessary. **(Priority 2)**

2.2.7.2.2 Augment existing populations and/or initiate new subpopulations in suitable habitat in Morro Bay for *Chloropyron maritimum* ssp. *maritimum.*

Many of the threats facing the subspecies are aggravated by its small population size and limited distribution. If an assessment of the distribution of genetic diversity indicates that population introduction and/or reintroduction are appropriate, then population augmentation or initiation of new populations in suitable historical habitat at Morro Bay should be planned and implemented to reduce the risk of regional extirpation.

It is especially prudent to preserve and expand the Morro Bay population of *Chloropyron maritimum* ssp. *maritimum* because, as the northernmost population, it is reasonable to expect that the population has developed specific genetic adaptations suitable to climatic conditions in the northern extent of its range.

2.2.7.2.2.1 Develop introduction and reintroduction plan for *Chloropyron maritimum* ssp. *maritimum*. **(Priority 3)**

This action includes field reconnaissance to select appropriate introduction and reintroduction sites. Reintroduction and introduction plan must call for the submission of annual reports. Plans must be reviewed by

U.S. Fish and Wildlife Service staff before being finalized.

2.2.7.2.2.2 Conduct site preparation, propagate plants, and transplant seedlings of *Chloropyron maritimum* ssp. *maritimum* for introduction and reintroduction. **(Priority 3)**

2.2.7.2.2.3 Monitor and conduct maintenance around translocated *Chloropyron maritimum* ssp. *maritimum.* **(Priority 3)**

2.2.7.2.2.4 Assess introduction and reintroduction success and maintenance levels of genetic diversity, review reports, and adapt introduction and reintroduction plan for *Chloropyron maritimum* ssp. *maritimum*, as necessary. **(Priority 3)**

2.2.7.2.3 Augment existing populations and/or initiate new subpopulations in suitable habitat for *Chloropyron molle* ssp*. molle.*

Restoration of suitable tidal marsh habitat and introduction and reintroduction of *Chloropyron molle* ssp*. molle* within its historic range is critical to the recovery of the species. Introductions and reintroductions within the historic range, particularly around San Pablo Bay and associated marshes, to the westward extent of the known range, should be pursued where, and as soon as, conditions are appropriate. Introductions and reintroductions into larger or higher quality habitat areas in the Suisun Bay area will help speed recovery of the subspecies.

2.2.7.2.3.1 Develop introduction and reintroduction plan for *Chloropyron molle* ssp*. molle*. **(Priority 3)**

This action includes field reconnaissance to select appropriate introduction and reintroduction sites. Introduction and reintroduction plans must call for the submission of annual reports. Plans must be reviewed by U.S. Fish and Wildlife Service staff before being finalized.

2.2.7.2.3.2 Conduct site preparation, propagate plants, and transplant seedlings of *Chloropyron molle* ssp. *molle* for introduction and reintroduction. **(Priority 3)**

2.2.7.2.3.3 Monitor and conduct maintenance around transplanted *Chloropyron molle* ssp. *molle.* **(Priority 3)**

2.2.7.2.3.4 Assess introduction and reintroduction success, review reports, and adapt plan for *Chloropyron molle* ssp. *molle*, as necessary. **(Priority 3)**

2.2.7.2.4 Augment existing populations and/or initiate new subpopulations in suitable habitat in San Francisco Bay for *Suaeda californica.*

Augmentation and initiation of colonies in suitable unoccupied habitat should be continued to assist in local recovery following natural declines in population. Restoration of degraded habitat in Morro Bay will encourage re-expansion of *Suaeda californica* colonies there. Continued propagation and planting of *S. californica* is appropriate if monitoring indicates it remains successful and within ecologically appropriate bounds.

The introduced and reintroduced founder populations should be composed of clones or seedlings sampled throughout the Morro Bay and four existing San Francisco Bay locations to increase genetic variation. Introduced and reintroduced populations can only contribute toward recovery when multiple generations of plants can colonize the habitat without direct artificial intervention.

The *California Sea-blite Reintroduction Plan, San Francisco Bay, California* was completed in 2006 and evaluates potential reintroduction sites around San Francisco Bay based on habitat indicators.

2.2.7.2.4.1 Implement *California Sea-blite Reintroduction Plan, San Francisco Bay, California*. **(Priority 2)**

This action involves the development of site-specific reintroduction plans at the sites of highest known feasibility and highest potential conservation value, according to the *California Sea-blite Reintroduction Plan, San Francisco Bay, California*.

This action includes site preparation, propagation and transplanting of seedlings (2 years), light maintenance, monitoring (5 years) and submission of periodic reports. Reintroduction should occur at least at two sites and assumes the success of recent reintroductions since 2000 in San Francisco and Alameda Counties.

2.2.7.2.4.2 Assess reintroduction success, review reports, and adapt *California Sea-blite Reintroduction Plan, San Francisco Bay, California*, as necessary. **(Priority 2)**

2.2.7.2.5 Periodically review and assess the need for introduction and reintroduction programs for other species covered in this recovery plan. If warranted, develop and implement introduction and reintroduction programs, monitor, evaluate success, and adapt the programs, as appropriate. **(Priority 3)**

2.3 Conduct habitat monitoring.

Monitoring of habitat condition is an important component of good habitat management, to assess whether restoration or management actions are working, and to detect undesirable or unexpected conditions. In general, monitoring is done for multiple years and involves conducting standardized species and habitat surveys and assessments. Monitoring may be more intensive at first to ensure that the objectives are being met, or if progressive change in the habitat is expected, such as following restoration work. Monitoring plans should be designed so that they inform the restoration or management plans (*i.e.*, data recorded must be adequate to address the success criteria). Monitoring should always include assessment of the existing threats. If a protected area is surrounded by numerous threats, more frequent monitoring may be needed. If a location is highly protected, monitoring needs may not be as intensive.

2.3.1 Develop consistent guidelines for habitat monitoring for use throughout the geographic scope of this recovery plan. **(Priority 2)**

2.3.2 Develop and implement monitoring plans.

2.3.2.1 Develop and implement monitoring plans at a geographically representative suite of remnant mature ("pre-historical") tidal and brackish tidal marshes, as a baseline and early-warning network. **(Priority 2)**

2.3.2.2 Develop and implement habitat monitoring plans at tidal marsh restoration sites. **(Priority 2)**

2.3.2.3 Develop and implement habitat monitoring plans at species introduction and reintroduction sites. **(Priority 2)**

2.3.2.4 Develop and implement habitat monitoring plans at sites selected to observe sand dune movement. **(Priority 2)**

The sand dunes in Morro Bay should be monitored regularly for threats to populations of *Chloropyron maritimum* ssp. *maritimum* and *Suaeda californica* (see Action 2.2.5).

2.3.2.5 Prepare and implement habitat monitoring plans for other areas, as necessary. **(Priority 3)**

2.3.3 Make habitat monitoring results publically available. **(Priority 2)**

To be useful, habitat monitoring reports should be prepared promptly and made readily available to tidal marsh land managers and managing agencies, including the U.S. Fish and Wildlife Service, to help them reevaluate and adjust management activities.

2.3.4 Evaluate and improve habitat monitoring methods, as needed. **(Priority 2)**

3 Conduct range-wide species status surveys/monitoring and status reviews for listed species and species of concern covered in this recovery plan.

Generally speaking, species status surveys (one-time or limited population counts) and monitoring (typically regular and ongoing surveys) are necessary to determine progress toward achieving recovery of listed species and long-term conservation of species of concern. Unless otherwise noted, here we use the terms survey and monitor interchangeably, with the assumption of a preference for long-term monitoring over one-time surveys. Demographic monitoring, which includes trend analysis and determination of limiting factors, is one method for predicting population trends and focusing efforts on the causes of population decline at a particular site. Survey and monitoring requirements vary depending on species, as well as site location, site conditions, and time of year. Status surveys and monitoring should always include assessment of the existing threats to the species and must be adequate to determine if recovery criteria are being met.

Status surveys conducted for other species of concern will increase the understanding of these species and may lead to actions precluding the need to formally list species as threatened or endangered. Field surveys also will help to avoid or minimize impacts of projects in or near potential habitat.

Species status surveys and monitoring should follow appropriate Service and/or State guidance whenever it is available. Specific information may be available from the U.S. Fish and Wildlife Service and CDFW. Biologists monitoring certain species, such as salt marsh harvest mouse and California clapper rail, will require Endangered Species Act section 10(a)(1)(A) recovery permits.

Full reports of survey and monitoring work should be completed promptly and made publicly available so that their findings can be applied in all conservation and recovery efforts.

3.1 Conduct surveys/monitoring of known populations.

3.1.1 Develop standardized, species-specific range-wide monitoring plans for each of the species covered in this recovery plan.

A standardized, scientifically based methodology should be developed to conduct range-wide status surveys for each species. It is important to use a standardized methodology to ensure consistency and continuity of data between observers, between regions, and over time. Standardized status surveys should establish parameters that 1) evaluate population sizes to determine overall trends in species status rangewide, 2) evaluate presence at historical or potential locations, 3) evaluate threats to the species, and 4) collect additional data, as necessary, on species occurrences throughout their ranges. Standardized surveys must be based on multiple parameters, such as the degree of habitat loss or fragmentation, type and degree of threat, shifts in vegetation type, establishment and extirpation of plant and animal occurrences, number of individuals or populations, photopoints, estimates of acreage occupied, density, co-occurring species including non-natives, time since last disturbance, and some estimate of seed bank dynamics. Survey design must incorporate an estimation for probability of detection. For California clapper rail, Liu *et al*. 2009 should be used as a basis for the development of a robust and informative monitoring program.

3.1.1.1 Review existing species survey guidance to determine its adequacy. **(Priority 3)**

3.1.1.2 If necessary, revise existing guidance or develop new standardized, scientifically based, and species-specific survey guidance. **(Priority 3)**

3.1.2 Conduct long-term monitoring of all the species covered in this recovery plan to monitor population status.

3.1.2.1 Survey/monitor for *Cirsium hydrophilum* var. *hydrophilum.* **(Priority 1)**

Conduct annual population monitoring of rosettes and reproductive plants on public lands near Rush Ranch and Peytonia Slough Ecological Reserve for five consecutive years. Monitoring should include mapping of known populations, with surveys expanded in subsequent years to detect peripheral colonies or new populations (Action 3.2.1). Preliminary data from initial monitoring studies should be gathered prior to development of the long-term monitoring plan. Long-term monitoring should include sufficient demographic sampling to identify factors and life-history stages that limit regeneration or expansion of populations (e.g., non-destructive sampling of seed set, production of flower heads per plant, production of mature seed in seed heads, seedling density, juvenile survivorship, duration of juvenile phase, etc.)

3.1.2.2 Survey/monitor for *Chloropyron maritimum* ssp. *maritimum.* **(Priority 2)**

Monitor distribution and abundance annually for ten consecutive years. Attempting to count individuals is not recommended, as this may damage the fragile root connections to the host plant. Instead, surveys should be done using best estimate of logarithmic abundance class (*i.e.*, 10s, 100s, 1000s, etc.). Because population patches of this species are ephemeral, fixed monitoring grids are not recommended and new potential locations should be thoroughly surveyed.

3.1.2.3 Survey/monitor for *Chloropyron molle* ssp. *molle.* **(Priority 2)**

Monitor distribution and abundance annually for five consecutive years. Attempting to count individuals is not recommended, as this may damage the fragile root connections to the host plant. Instead, surveys should be done using best estimate of logarithmic abundance class (*i.e.,* 10s, 100s, 1000s, etc.). Because population patches of this species are ephemeral, fixed monitoring grids are not recommended and new potential locations should be thoroughly surveyed. Surveys should be delayed until after peak bloom to avoid disturbance impacts to California clapper rail (late summer-early fall).

3.1.2.4 Survey/monitor for *Suaeda californica.* **(Priority 3)**

In addition to the populations in Morro Bay, prepare and implement a long-term regional population monitoring program for populations in San Francisco Bay.

Monitor distribution and abundance of San Francisco and Morro Bay populations annually for five consecutive years.

3.1.2.5 Survey/monitor for California clapper rail.

Annual clapper rail monitoring should continue in San Francisco Bay National Wildlife Refuge, and expand to other federal and state owned lands. Monitoring provides data that are useful both in the short term for adaptive management of existing tidal marsh, and in the long term to determine success of recovery efforts. In addition to annual monitoring conducted throughout the current range of the rails, intensive monitoring should be conducted at the edges of the current range, particularly in Suisun and Tomales bays, and at sites where invasive *Spartina* control has occurred. As recovery efforts proceed, California clapper rail population distribution will expand. Intensive monitoring will be necessary to document the resulting range expansion.

3.1.2.5.1 Develop certification/training programs for California clapper rail surveyors and survey coordinators. **(Priority 3)**

3.1.2.5.2 Conduct annual California clapper rail call counts during breeding season. **(Priority 2)**

Specifically, surveying/monitoring should focus on sites previously treated to control invasive *Spartina* around San Francisco Bay. At a minimum, this research should include studies of California clapper rail abundance and habitat use at treated sites.

3.1.2.5.3 Monitor adult California clapper rail survival and mortality of adults, chicks, and eggs due to predation. **(Priority 2)**

3.1.2.5.4 Develop and maintain a database to track results from annual California clapper rail monitoring results. **(Priority 2)**

3.1.2.5.5 Examine the methodology used for call count surveys in Action 3.1.2.5.2 above, by cross validating surveys (using double observer methods) with movement studies recommended in Action 4.2.6.2. **(Priority 3)**

Use results to improve the precision of call count surveys, per Action 3.3 below.

3.1.2.6 Monitor for salt marsh harvest mouse. **(Priority 2)**

Resources for salt marsh harvest mouse monitoring should be shifted from site-specific presence/absence surveys to systematic regional surveys with replicated sampling over time. Monitoring should give special emphasis to tracking salt marsh harvest mouse (and other small tidal marsh mammal) populations before and several years after major flood events, comparing population regeneration and extinction probabilities for a range of habitat types, sizes, and landscape positions (location along sloughs or bays, distances from nearest known populations or habitats). Regional monitoring programs for both subspecies should be established and funded for a minimum of 10 years or one flood/drought cycle.

Conduct comprehensive surveys for salt marsh harvest mouse in each of the 33 viable habitat areas (VHAs, as described in III. A.3.e.). Three VHAs should be surveyed each year on an 11 year cycle. Two sites shall be selected within each viable habitat area (VHA) and at each site 100 traps should be set for 4 consecutive nights.

Appropriate salt marsh harvest mouse monitoring protocols have been developed in association with the SBSP Restoration Project and the Suisun Marsh Habitat Management, Preservation, and Restoration Plan.

3.1.2.7 Conduct surveys/monitoring of salt marsh wandering shrew and Suisun shrew. (Note that information on these species is included in **Appendix C**.) **(Priority 3)**

Develop baseline information on the distribution and abundance of endemic tidal marsh shrew species. Conduct regionwide sampling of large tidal marshes with high potential for shrew populations. Sample over multiple years to determine the annual and geographic variation of population fluctuations, including at least two years following extreme climate events (*e.g.*, drought, flood). Live trapping using methods developed by Hays (1998) is recommended.

Require focused surveys for tidal marsh shrews when regulated activities are planned or proposed within tidal marshes.

3.1.2.8 Conduct surveys/monitoring of San Pablo vole. (Note that information on the San Pablo vole is included in **Appendix C**.) **(Priority 3)**

3.1.2.9 Continue to conduct surveys/monitoring of California black rail. (Note that information on the California black rail is included in **Appendix C**.) **(Priority 3)**

Since 1996, PRBO Conservation Science has monitored tidal marsh birds, including California black rail, in the marshes of San Francisco Bay. This monitoring should continue. In addition, surveys should be conducted throughout the remainder of the range of the California black rail, including Elkhorn Slough and Pescadero Creek estuaries. If black rails are detected, management of these areas should be adapted to support them. Adaptive management actions should consider control of non-native predators if these are determined to be impediments to California black rail population viability.

3.1.2.10 Continue to conduct surveys/monitoring of song sparrow subspecies. (Note that information on these species is included in **Appendix C**.) **(Priority 3)**

Continue ongoing censuses and reproductive monitoring projects, as has been done to date by PRBO Conservation Science. Determine population sizes and productivity throughout San Francisco Bay marshes.

3.1.2.11 Conduct surveys/monitoring of saltmarsh common yellowthroat. (Note that information on the common yellowthroat is included in **Appendix C**.) **(Priority 3)**

Conduct surveys to determine baseline population size, abundance, and distribution. Monitor over a period of at least 10 years of normal, wet, and drought conditions. Monitor nests for brood parasitism by brown-headed cowbirds.

3.1.2.12 Conduct surveys/monitoring of *Cicindela senilis senilis*. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Surveys should be conducted within the San Francisco Bay Estuary, their last documented location, and also along coastal marshes to determine their presence or absence.

3.1.2.13 Conduct surveys/monitoring of *Lathyrus jepsonii* var. *jepsonii*. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Conduct surveys throughout the range of *Lathyrus jepsonii* var. *jepsonii* through both drought and high-rainfall years.

3.1.2.14 Conduct surveys/monitoring of *Spartina foliosa*. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Due to rapid hybridization with invasive *Spartina alterniflora*, surveys for this native species should occur throughout its range to enable swift protection of the species.

3.1.2.15 Survey/monitor previously documented populations of other species covered in this recovery plan. (Note that information on these species is included in **Appendix C**.) **(Priority 3)**

3.2 Search for new and relict populations of covered species (including seed bank).

Surveys of known populations are frequently conducted, yet the distribution and abundance of many of the species covered in this recovery plan are incompletely known. Therefore population status surveys need to incorporate areas not recently studied, including areas where a species is not known to occur. Surveys should be conducted in all potential habitat types. Any new populations found may increase the speed and likelihood of recovery.

3.2.1 Conduct surveys in suitable habitat for new and relict populations of species covered in this recovery plan. **(Priority 2)**

Perform field surveys for additional populations within the historical range of the species covered in this recovery plan.

3.2.2 For *Cirsium hydrophilum* var. *hydrophilum, Chloropyron maritimum* ssp. *maritimum*, *Chloropyron molle* ssp. *molle*, and *Suaeda californica* probe soil seed banks to detect presence and location of dormant viable seed. Grow out seed by cultivation or in natural protected habitat or bank seed, per Action 2.2.7.1. **(Priority 2)**

Viable seed may be present in the historical range of species such as *Cirsium hydrophilum* var. *hydrophilum*. Probes should be used in suitable subhabitats. Probe methods should include germination tests of shallow marsh soil cores, and experimentally induced small-scale vegetation gaps in unoccupied suitable habitat.

Any seedlings recruited from exhumed seed banks should be grown and protected on-site if possible, or cultivated if artificial propagation is more likely to result in survival. Resurrected populations should be utilized as founders of introduced and reintroduced populations in unoccupied or restored habitat.

3.3 Periodically review and improve methods of species monitoring. **(Priority 3)**

Any new method introduced into the species monitoring program should be cross-walked or calibrated against the old method for a period of time, to allow comparisons of data gathered with old and new methods.

3.4 Report survey results to California Natural Diversity Database and otherwise make them publically available so that findings can be applied in conservation and recovery efforts. **(Priority 2)**

3.5 Periodically review progress toward listed species recovery and long-term conservation of species of concern, and identify those species warranting a change in status (listing, delisting, uplisting, or downlisting). For listed species, status reviews are likely to be in the form of 5-year reviews required by the Endangered Species Act. **(Priority 3)**

Results of this Action will inform Action 5.1.2.

4 Conduct research necessary for the recovery of listed species and the long-term conservation of species of concern.

Research on many aspects of species biology and tidal marsh ecology will help to successfully and cost effectively meet recovery goals. Making recommendations on research needs and proposals will be part of the responsibilities of the Recovery Implementation Team (RIT) (see Action 5.1). General areas where research may benefit conservation and recovery include demography of covered species, demography in relation to environmental conditions (including presence of other species) and management factors, and studies relevant to successfully restoring tidal marsh.

Research should be seen as a tool with which to conduct adaptive management, the results of research informing management decisions and enabling progress toward recovery. Also, research only has value if the results and conclusions are disseminated so they can be widely understood and applied. Research reports should be published promptly in publicly available form, data should be properly archived, and appropriate specimens properly deposited in a public museum or other public collection. Research funded by the U.S. Fish and Wildlife Service will have reporting requirements, with final funding contingent on receipt of the completed report, and the research reports will be publicly available.

The results from research should be expressly linked to management and restoration recovery tasks and guide overall recovery and long-term conservation efforts. Recovery tasks should be modified according to research results.

4.1 Designate a research coordinator to coordinate all tidal marsh research sponsored or overseen by U.S. Fish and Wildlife Service. **(Priority 2)**

Ideally, this individual would be the U.S. Fish and Wildlife Service RIT manager (see Action 5.1). In coordination with the Sacramento Fish and Wildlife Office and the RIT, the research coordinator will determine and prioritize research needed to inform conservation and recovery actions.

4.2 Conduct research on the biology and ecology of each species, as necessary to support recovery and long-term conservation efforts. Results should be linked to adaptive management and restoration recovery tasks, and recovery tasks should be modified accordingly.

Demographic studies provide the baseline data necessary to inform decision making and recovery activities. None of the species covered in this recovery plan is completely understood. More demographic information, including population trend analyses, is necessary for a better understanding of species and ecosystem needs to better plan for conservation and recovery activities.

4.2.1. Continually update current literature base on the basic biology and ecology of the species covered in this recovery plan and develop a prioritized list of research needs for each species. **(Priority 2)**

4.2.2 Conduct biological and ecological studies on *Cirsium hydrophilum* var. *hydrophilum.*

Research is needed to determine the principal factors that affect dispersal and establishment of *C. hydrophilum* var. *hydrophilum* seedlings in brackish tidal marsh subhabitats. Research should also include requirements of seedlings in relation to variation in soil salinity, drainage/waterlogging, soil texture and density, foliar canopy shading, and soil nutrient availability. Research results should be applied to management of vegetation and salinity regimes of the Suisun Marsh.

4.2.2.1 Study reproductive ecology of *Cirsium hydrophilum* var. *hydrophilum*. **(Priority 2)**

Conduct research on regeneration of *C. hydrophilum* var. *hydrophilum* in the wild. This research should investigate seed germination and establishment in natural and artificial conditions including reproductive output, seed set, seed abortion, seed predations/predators, fungal diseases, dispersal patterns, seed bank, etc.

4.2.2..2 Study physiological ecology of *Cirsium hydrophilum* var. *hydrophilum*. **(Priority 2)**

Investigate the growth and responses of *C. hydrophilum* var. *hydrophilum* in relation to marsh soil salinity and tidal regimes, to predict the physiological and ecological limits of the species and to inform decisions regarding the operation of salinity control gates and water quality standards.

For ecologically meaningful results, this research must span more than one precipitation cycle (drought/post-drought), and include both monitoring of natural field conditions and controlled field experiments. This would take approximately 5 to 10 years.

4.2.2.3 Study community ecology of *Cirsium hydrophilum* var. *hydrophilum*. **(Priority 2)**

Research is needed on interspecies plant competition at the seedling stage, the effects of *Lepidium latifolium* on *C. hydrophilum* var. *hydrophilum*, and the microenvironments needed for seed germination and establishment.

4.2.3 Conduct biological and ecological studies on *Chloropyron maritimum* ssp. *maritimum.* **(Priority 2)**

Research should include studies of germination success of seeds resulting from self- and cross-pollination, impacts of pre- and post-dispersal seed predators, longevity of the soil seed bank, host dependency, and identification of host plants in Morro Bay.

4.2.4 Conduct biological and ecological studies on *Chloropyron molle* ssp. *molle.*

4.2.4.1 Study reproductive ecology of *Chloropyron molle* ssp. *molle*. **(Priority 2)**

Investigate aspects of reproductive ecology and demography needed for management or introduction and reintroduction success, including pollination ecology, mating systems, seed predation and disease, seed dispersal, seed germination ecology, soil seed bank demography, microhabitat conditions affecting seedling growth and establishment.

Determine proportion of seeds that die before emergence compared to those that remain dormant in the seed bank. Also, determine longevity, beyond one year, of seed bank. Quantify level of pre-dispersal seed predation within populations to determine the proportion of mature seed entering the seed bank.

Determine degree to which self-pollination is possible and reproductive output is dependent or limited by pollinators. Emphasis should be placed on factors that may limit natural persistence or establishment of populations.

4.2.4.2 Study physiological ecology of *Chloropyron molle* ssp. *molle*. **(Priority 2)**

Investigate physiological and growth responses to soil salinity and waterlogged soil conditions, and the interactive effects of these two principal environmental stresses. Investigate the growth and reproductive responses to artificial defoliation (replicating herbivory impacts.)

4.2.4.3 Study community ecology of *Chloropyron molle* ssp. *molle*. **(Priority 2)**

Investigate host-parasite relationships with emphasis on changes in fitness related to parasitism. Investigate positive and antagonistic interactions with associated vascular plants, insects, and vertebrates, with emphasis on potential key species to be targeted for management.

4.2.4.4 Study population ecology of *Chloropyron molle* ssp. *molle*. **(Priority 2)**

Study turnover of subpopulations (local extinction and new establishment of subpopulations).

4.2.5 Conduct biological and ecological studies on *Suaeda californica*. **(Priority 2)**

Determine the factors important to seed survival, germination and seedling establishment, longevity of individual plants, degree of self-compatibility, and salt tolerance. Investigate the breeding system of *Suaeda californica*. Additional management-oriented studies are needed on the relative importance of impacts of grazing, trampling and disturbance and how to prevent or ameliorate impacts.

4.2.6 Conduct biological and ecological studies on the California clapper rail.

Investigate fledge success, adult survival, subadult rail survival, subadult and adult dispersal rates, and interspecies aggression. Conduct studies on rail mortality in San Pablo Bay. Investigate response to disturbance including sensitivity to noise. This action may overlap Action 4.5.2 regarding effects of contaminants on tidal marsh ecosystems. These studies should build upon applied studies currently being conducted by the SBSP Restoration Project via U.S. Geological Survey on survival rates, factors that limit survival, movement patterns, and dispersal.

4.2.6.1 Conduct a population viability analysis of the California clapper rail. **(Priority 1)**

Study turnover of subpopulations (local extinction and new establishment of subpopulations). Assess population status (see Action 3.1.2.5.2), conduct research on population dynamics to predict recolonization rate of restored marshes, with an emphasis on necessary connectivity. Develop California clapper rail population models that incorporate *metapopulation* dynamics. Specifically, this should be an age-structured population model and should project the likelihood of population expansion or contraction, including the possibility of extinction or decline in number below specified levels.

4.2.6.2 Study effects of recent non-native *Spartina* treatment on California clapper rail movement within the ecosystem. **(Priority 1)**

Marked individuals should be used to determine the extent of mortality, displacement and redistribution of the species throughout its habitat. Results of this action will inform Action 3.1.2.5.5.

4.2.6.3 Conduct diet analyses on California clapper rail as a tool to understanding habitat use. **(Priority 2)**

4.2.7 Conduct biological and ecological studies on the salt marsh harvest mouse.

Conduct biological and ecological research with important applications to the conservation of the species.

4.2.7.1 Conduct a population viability analysis to determine desirable population sizes for long-term persistence of extant South Bay salt marsh harvest mouse populations. **(Priority 2)**

4.2.7.2 Study use of adjacent habitat, including brackish marsh, by the salt marsh harvest mouse. **(Priority 1)**

Determine extent to which salt marsh harvest mice use brackish marshes and the importance of brackish marshes to each subspecies.

The role of bulrush (*Schoenoplectus spp.)* and cattail (*Typha spp.)* in salt marsh harvest mouse biology needs to be more thoroughly examined in the South Bay, especially when such areas are lightly flooded by tides. The role of differing patch sizes of saline and brackish vegetation should be studied to ascertain if there is a patch size of brackish vegetation (such as *Schoenoplectus* spp.) at which the mouse no longer uses such vegetation.

The extent to which salt marsh harvest mice used, or would use, native grasslands is not known.

Investigate the use of suboptimal habitats to cope with interspecific competition.

4.2.7.3 Study the impact of *Spartina alterniflora* and its hybrids, and *Lepidium latifolium* on the salt marsh harvest mouse. **(Priority 2)**

It is imperative to determine the level of salt marsh harvest mouse use of both invasive species, especially of *Lepidium latifolium*, which is beginning to dominate much of the upper edges of the marshes of the southern south San Francisco bay.

4.2.7.4 Study predation impacts to the salt marsh harvest mouse. **(Priority 2)**

4.2.8 If sufficient numbers of the species are identified under Action 3.1.2.7, conduct biological and ecological studies on the salt marsh wandering shrew and the Suisun shrew. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Conduct focused studies on habitat-population relationships of tidal marsh shrews in the San Francisco Bay Estuary. Select remnant pre-historic tidal marshes (including older restored tidal marsh) to sample. Quantify variation in abundance and species composition of invertebrate prey, vegetation composition and structure, tidal flooding regimes, soil salinity, and abundance of potential predators and competitor species. Apply results to habitat prescriptions for restoration and management of tidal marshes.

Study natural and artificial dispersal of tidal marsh shrews. Investigate natural dispersal and experimental translocation to unoccupied habitat, and determine conditions by which founder populations establish.

4.2.9 If sufficient numbers of the species are identified under Action 3.1.2.8, conduct biological and ecological studies on the San Pablo vole. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

4.2.10 Conduct biological and ecological studies on the California black rail. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Investigate foraging behavior and diet, and collect incubation data.

4.2.11 Conduct biological and ecological studies on the song sparrow subspecies of the San Francisco Bay Estuary. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Determine the extent to which diked habitats affect reproductive success and survival.

4.2.12 Conduct biological and ecological studies on salt marsh common yellowthroat. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Research including assessment of the limiting factors affecting population sizes, distribution, habitat use, and interactions among local populations. In addition, migration and dispersal should be monitored via long-term banding and recapture studies to define home ranges and determine adequate buffer sizes between breeding and foraging habitats and developments. Effectiveness of buffer zones should be monitored to determine optimum widths and placements.

4.2.13 Conduct biological and ecological studies on *Cicindela senilis senilis*. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

4.2.14 Conduct biological and ecological studies on *Lathyrus jepsonii* var. *jepsonii*. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Study the persistence of *Lathyrus jepsonii* var. *jepsonii* through years of high salinity conditions.

4.2.15 Conduct biological and ecological studies on *Spartina foliosa*. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

4.2.16 Conduct biological and ecological studies on other species covered in this recovery plan. **(Priority 3)**

4.3 Conduct genetic research on species covered in this recovery plan.

4.3.1 Conduct a salt marsh harvest mouse population genetic analysis to determine:

- the genetic effective population size
- the genetic relationships among presumed populations
- the magnitude of gene exchange between marshes and subpopulations within marshes
- the extent of inbreeding occurring within populations **(Priority 1)**

4.3.2 If sufficient numbers of the species are identified under Action 3.1.2.7, conduct research to assess genetic diversity within and among populations of salt marsh wandering shrew and Suisun shrew. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Assess levels of genetic diversity within and among populations of resident tidal marsh shrews. Determine whether inbreeding is occurring and if it is, determine whether population genetics may significantly constrain long-term growth and persistence of viable populations.

4.3.3 If sufficient numbers of the species are identified under Action 3.1.2.8, build upon research conducted by Conroy and Neuwald (2008) to reassess the genetic identity of San Pablo vole, given recent finding of two phylogeographic groups of California vole. (Note that information on this species is included in **Appendix C**.) **(Priority 2)**

Perform genetic analysis for a better understanding of the subspecies, given recent studies that indicate a possible split of California vole into two species.

4.3.4 Conduct research to resolve taxonomic uncertainties regarding other species covered in this recovery plan. **(Priority 3)**

4.3.5 Conduct genetic studies on *Cirsium hydrophilum* var. *hydrophilum.* **(Priority 2)**

Investigate the possible hybridization of *C. hydrophilum* var. *hydrophilum* and *C. vulgare*.

4.3.6 Conduct genetic studies on *Chloropyron molle ssp. molle.* **(Priority 3)**

Investigate the genetic structure of populations, comparing levels of genetic diversity in large and small populations, and potential differences in fitness between samples from large and small populations.

4.3.7 Conduct genetic studies on song sparrow subspecies. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Conduct research to determine the genetic differentiation among the three song sparrow subspecies and upland song sparrows.

4.3.8 Conduct genetic studies on saltmarsh common yellowthroat. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

Study genetic differentiation between the saltmarsh common yellowthroat and western yellowthroat (*Geothlypis trichas occidentalis*). Determine races in the zones of overlap to define exact range and genetic differences.

4.3.9 Continue to refine genetic analysis to verify pure *Spartina foliosa* stands in San Francisco Bay. (Note that information on this species is included in **Appendix C**.) **(Priority 3)**

As part of this Action, it should be determined what degree of hybridization between *S. alterniflora* and *S. foliosa* is acceptable.

4.4 Conduct research into environmental/habitat factors affecting the recovery and long-term conservation of tidal marsh species.

4.4.1 Conduct studies on the efficacy of various habitat restoration techniques. **(Priority 2)**

Studies and evaluation of various habitat restoration techniques will help to inform on-the-ground restoration activities (Action 2.2.2). This feedback between restoration and applied research should help to increase the efficiency and efficacy of tidal marsh restoration. These studies should build upon habitat development rate studies currently being conducted by the SBSP Restoration Project.

4.4.2 Study natural sedimentation rates in marshes throughout the bay. **(Priority 1)**

A key question for habitat restoration is whether there is enough sediment to not only create tidal marshes, but also to create them in a suitable time frame (*i.e.,* 20 years or less). The threat of sea level rise will require even greater amounts of sedimentation to maintain marsh elevation. Sedimentation studies can be used as a tool to predict marsh restoration outcome and time to reach effective elevations, especially to support deep enough bands of *Sarcocornia pacifica* to be useful to salt marsh harvest mice. These studies should build upon sedimentation rate studies currently being conducted by the SBSP Restoration Project. Studies should also be performed to determine if controlled growth of invasive *Spartina* in select locations may hasten marsh accretion in the face of sea level rise. This action may overlap with Action 4.4.7.

4.4.3 Study the impacts of large-volume, human-caused, freshwater discharges into tidal marshes. **(Priority 2)**

Freshening of South Bay marshes resulting from large volume freshwater discharges has been documented, but the impacts of this change on benthic invertebrates, the food base of California clapper rails, have not been evaluated.

4.4.4 Investigate the effects of salinity fluctuation and altered tidal datum on species covered in this recovery plan. **(Priority 2)**

4.4.5 Study the time lag between habitat restoration and recolonization by species covered in this recovery plan. **(Priority 2)**

These studies should build upon studies currently being conducted by the SBSP Restoration Project.

4.4.6 Conduct research on the physical processes (geomorphic and hydrologic) that maintain the structure and function of suitable habitats for tidal marsh species. **(Priority 2)**

This research should include investigation into the role of channel structure (*i.e*., sinuosity, channel width) in the ecosystem.

4.4.7 Study the effects of global climate change and resulting sea level rise on tidal marsh ecosystems. **(Priority 1)**

Study is needed to understand the changes that could occur to tidal marsh species and ecosystems due to global climate change. Some of the changes anticipated include increased storm severity, increased wave heights, gradual increase in salinity up the estuary, changes in sediment supply, changes in species composition and location. Studies are needed to determine the amount and extent of habitat change. Studies on effects of sea level rise should include determining whether controlled growth of invasive *Spartina* in select locations may hasten marsh accretion in the face of sea level rise. This action may overlap with Action 4.4.2.

4.4.8 Conduct research on management conflicts between tidal marsh species. **(Priority 2)**

For example, at Pescadero marsh, adjustment of hydrology in diked brackish marshes (or portions of them) managed principally for California red-legged frogs (*Rana aurora draytonii*) should be investigated to determine if it can be managed without conflicts to California black rails.

4.5 Conduct research related to threats to tidal marsh species and ecosystems.

4.5.1 Conduct research on invasive species that impact tidal marsh species and ecosystems.

Invasive species are a major threat to tidal marsh ecosystems. Research is needed on a number of fronts to mitigate these threats, including studies on the invasive species and their effects on the ecosystem, methods of control, and restoration of degraded habitats. These studies should build upon studies currently being conducted on invasive species by the SBSP Restoration Project.

4.5.1.1 Determine the effects of non-native species on tidal marsh ecosystems. **(Priority 1)**

Conduct studies to determine the direct and indirect effects of invasive species, including tidal invertebrates, on tidal marsh species and habitats.

4.5.1.2 Investigate methods for controlling invasive species in tidal marsh ecosystems. **(Priority 1)**

Conduct studies on various methods of control, including their effect on non-target organisms. Results of this Action will inform Action 2.1.6.

4.5.1.3 Investigate methods of restoring tidal marsh ecosystems that have been degraded by invasive species. **(Priority 1)**

4.5.2 Conduct research on effects of contaminants on the species covered in this recovery plan.

Conduct research on bioaccumulation of toxic estuarine contaminants on tidal marsh species and its effects on reproductive success and development. Investigate the toxic effects of newer contaminants (*e.g.,* pharmaceuticals, plasticizers, flame retardants, detergent additives, etc). Apply results of this research to water quality standards to protect sensitive wildlife of the San Francisco Bay Estuary.

4.5.2.1 Conduct research into mercury exposure pathways for California clapper rails and potential means to interrupt those pathways. **(Priority 2)**

This research should build upon mercury analyses recently conducted by the U.S. Geological Survey and those currently ongoing by the SBSP Restoration Project relative to the opening of Pond A8.

4.5.2.2 Conduct other necessary research on bioaccumulation and effects, including reproductive success and development, of toxic estuarine contaminants on tidal marsh species. **(Priority 2)**

Specifically, future research investigating the proportion of eggs within a population with increased mercury levels that negatively affects a population's viability will help refine this criterion. Investigate the toxic effects of pesticides (*e.g.*, pyrethroids) and emerging contaminants (*e.g.*, pharmaceuticals, plasticizers, flame retardants, detergent additives, *etc*).

One study that must be conducted is further assessment of the accumulation of PCBs in clapper rails. Of particular importance is the role of dioxins, furans, dioxin-like PCBs and their associated toxic impacts. Past data have focused on total PCBs. Future work should be done to assess these past data using a toxic-equivalent concentration approach. Baseline concentrations of these compounds in rails and their prey should be established.

4.5.2.3 Apply results of research in Action 4.5.2.2 to re-evaluate suitability of delisting criterion E/5 for the California clapper rail and revise, if appropriate. **(Priority 3)**

4.5.2.4 Apply results of research in Actions 4.2.4.2.1 and 4.2.4.2.2 to sediment and water quality standards to protect sensitive wildlife of the San Francisco Bay Estuary. **(Priority 3)**

4.5.2.5 Conduct studies to establish contaminant levels in biosentinels that are "acceptable" or "not acceptable", then measure compounds in these biosentinels directly or via a non-invasive surrogate, such as feathers, if possible. **(Priority 1)**

4.5.3 Conduct studies on pollinators that affect the long-term conservation and recovery of species covered in this recovery plan.

Pollinators may be a limiting factor for species covered in this recovery plan. In some cases, such as with *Chloropyron molle ssp. molle*, the pollinators are unknown. Studies are needed on the pollinators and their ecological needs.

4.5.3.1 Determine if pollination is a limiting factor for any population of a plant species covered in this recovery plan. **(Priority 2)**

4.5.3.2 If Action 4.2.5.1 reveals pollination limitations, identify pollinators, their efficacy, and their ecological needs. **(Priority 2)**

4.5.4 Conduct predator/prey and parasite/host studies for species covered in this recovery plan.

4.5.4.1 Conduct research into whether an elevated or unnaturally high predation level is experienced by salt marsh harvest mice at narrow marshes where the species is concentrated, especially during flooding events. If unacceptable impacts are discovered, develop and implement methods to reduce such predation. **(Priority 2)**

4.5.4.2 Conduct research into the extent of seed predation by the non-native thistle weevil (*Rhinocyllus conicus*). If unacceptable impacts are discovered, develop and implement methods to reduce such seed predation. **(Priority 1)**

4.5.4.3 Conduct other research on predator/prey and parasite/host relationships. **(Priority 3)**

Complex parasite-host relationships may exist that affect species covered in this recovery plan. For example, predatory wasps that feed on moth larvae that infest inflorescences may benefit *Chloropyron molle ssp. molle*. Data on the nesting and feeding habits of these species will be important in determining appropriate management. Another type of predation/parasitism is exemplified by brown-headed cowbird parasitism and predation of saltmarsh common yellowthroats.

4.6 Establish cultivated populations of plants for research purposes, where necessary. **(Priority 3)**

Cultivated populations can provide seed to be used for research in basic biology, management, and propagation of the species, and thus avoid conflicts with conservation goals for wild populations. Cultivated population should be established with founders sampled according to the same guidelines as seed banks and should be managed to minimize artificial selection and genetic drift in cultivation (Guerrant 1996).

Products of this Action may feedback to Action 2.2.7.2.

4.7 Establish research protocols, where necessary, and as determined by the RIT, described below. **(Priority 3)**

For example, establish protocols for handling sick, injured, oiled, and dead California clapper rails or salvaged eggs.

4.8 Conduct additional research identified as necessary by the Recovery Implementation Team that address changing conditions and are supportive of highest priority recovery tasks. **(Priority 2)**

4.9 Apply the results of all studies to conservation and recovery efforts. **(Priority 2)**

5 Improve coordination, participation, and outreach activities to achieve recovery of listed species and long-term conservation of species of concern covered in this recovery plan.

Public participation is vital to ecosystem recovery efforts. The recovery plan intends to coordinate and pull together landowners, managers, and other stakeholders, both public and private, to achieve conservation and recovery needs and to form lasting partnerships. Because a substantial proportion of tidal marsh or restorable areas is under public ownership, working with public lands agencies to form beneficial relationships is key to the recovery strategy. Partnerships with private landowners are extremely important, because of the need to maximize tidal marsh area, whether public or private, for recovery and to link fragmented tidal marshes with appropriate species dispersal corridors and refugia. Many private landowners, local agencies, organizations and citizens are willing participants in recovery efforts but may not have the information necessary to make fully informed decisions. Outreach to develop working relationships with all interested parties is important. Education is a key component in increasing both the public's general awareness of tidal marsh ecosystems and their participation in tidal marsh restoration and recovery. Outreach and educational programs will be developed in cooperation with schools, agencies, conservation organizations, and stakeholder groups.

5.1 Appoint and regularly convene a RIT to advise the Regional Director on implementation of tidal marsh species recovery actions.

Because recovery needs and knowledge of the best ways to achieve them are expected to evolve over time, the U.S. Fish and Wildlife Service will appoint a team to advise the Regional Director on implementation of tidal marsh ecosystem recovery actions. Communication among the community of tidal marsh researchers, regulators, and managers is important for efficient adaptive management. This RIT will help coordinate, refine, and expedite recovery actions and will advise the Service on desirable adaptations of the recovery plan strategies and tasks.

This RIT will:

- Include selected experts with considerable experience in California tidal marsh recovery issues. The RIT may convene one or more Technical Advisory Committees for input on scientific and technical needs and priorities.

- Determine a periodic meeting schedule.

- Establish a forum for data exchange, *e.g.* publication, website, annual meeting.

Full reports of survey and monitoring work, and research results should be made available to the public and researchers.

5.1.1 Appoint the RIT. **(Priority 2)**

5.1.2 Periodically convene the RIT to guide the implementation of the recovery plan. **(Priority 2)**

Using the results from Action 3.5, the RIT will help coordinate, refine, and expedite recovery actions and advise the U.S. Fish and Wildlife Service on desirable adaptations of the recovery plan strategies and actions. The RIT will also make recommendations on research proposals and additional research needs.

5.2 Conduct outreach to partners in tidal marsh species recovery, including public and private landowners, and appropriate Federal, State, and local agencies. **(Priority 2)**

Building upon Action 2.1.1, coordination and cooperation must occur between landowners, regulatory and non-regulatory agencies, and other stakeholders to achieve recovery and conservation needs covered in this recovery plan.

5.3 Develop outreach, education, and action programs in cooperation with schools, agencies, conservation organizations, stakeholder groups, and the public, to further the goals of this recovery plan.

Education will be a key component in increasing both the public's general awareness of tidal marsh ecosystems and their participation in tidal marsh ecosystem restoration and recovery.

5.3.1 Develop general educational programs for public schools within the geographic scope of this recovery plan. **(Priority 2)**

5.3.2 Develop, maintain, and distribute updated information and educational materials related to recovery and conservation of species covered in this recovery plan. **(Priority 2)**

5.3.3 Coordinate with local news media to promote local public interest in the recovery and conservation of species covered in this recovery plan. **(Priority 2)**

V. IMPLEMENTATION SCHEDULE

The following implementation schedule outlines actions and estimated costs for this recovery plan. It is a guide for meeting the objectives discussed in Chapter III. This schedule describes and prioritizes actions, provides an estimated timetable for performance of actions, indicates the responsible parties, and estimates costs of performing actions. These actions, when accomplished, should further the recovery and conservation of the covered species.

Key to terms and acronyms used in the Implementation Schedule:

Definition of Action Durations:
Continual: An action that will be implemented on a routine basis once begun.
Ongoing: An action that is currently being implemented and will continue until action is no longer necessary.
Unknown: Either action duration or associated costs are not known at this time.
TBD: to be determined

Definition of Species Benefitting:
CLRA: California clapper rail
CHMO: *Chloropyron molle* ssp. *molle*
SUCA: *Suaeda californica*
SMHM: Salt marsh harvest mouse
CIHY: *Cirsium hydrophilum* var. *hydrophilum*
Other: other sensitive species addressed in plan
All: The five listed species, plus all other sensitive species addressed in plan

Responsible Parties:

ALL-	All Responsible Parties
AUD-	Audubon Society
CCC-	California Coastal Conservancy
CDFW -	California Department of Fish and Wildlife
CDPR-	California Department of Parks and Recreation
CNPS -	California Native Plant Society
DOD -	Department of Defense (Includes U.S. Army Corps of Engineers)
DWR -	Department of Water Resources
EBRPD-	East Bay Regional Park District
ESNERR -	Elkhorn Slough National Estuary Research Reserve
GGNRA-	Golden Gate National Recreation Area
ISP-	Invasive Spartina Project
LOC-	County, City or Other Local Government
MAD-	Mosquito Abatement District
MAS	Marin Audubon Society
MBNEP-	Morro Bay National Estuary Program
OWN -	Agency or organization that administers or owns each site
PORT O-	Port of Oakland
PORT SF-	Port of San Francisco
PRBO-	PRBO Conservation Science
PVT-	Private Contractor
RWQCB-	Regional Water Quality Control Board

SFBNWR-	San Francisco Bay National Wildlife Refuge
SFBO-	San Francisco Bird Observatory
SFEI-	San Francisco Estuary Institute
SLT-	Solano Land Trust
STO -	Organization to Store/Propagate Seeds or Cysts (*e.g*., Rancho Santa Ana Botanic Garden)
TEAM-	Tidal Marsh Recovery Team
UFID-	Utility, Flood or Irrigation District
UNIV -	University
USFWS-	U.S. Fish and Wildlife Service
USGS-	U.S. Geological Survey

Responsible parties are those agencies who may voluntarily participate in any aspect of implementation of particular tasks listed within this recovery plan. Responsible parties may willingly participate in project planning, funding, staff time, or any other means of implementation. The most likely lead responsible party appears in bolded text in the table below.

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
1	1.1	Maintain underlying ecosystem processes and functions.	All	Ongoing	ALL	TBD	-	-	-	-	-	
2	1.2.1.1	Acquire/protect currently unprotected tidal marsh habitat.	All	Until recovery criteria are met	AUD, CCC, CDFW, CDPR, DOD, DWR, EBRPD, GGNRA, LOC, PORT O, PORT SF, SFBNWR, SLT, UTID, USFWS	380,000	-	-	-	-	-	Maximum cost, based on fee title acquisition of approximately 38K acres of unprotected tidal marsh multiplied by $10K/acre (average price paid over last 10 years for salt ponds in San Francisco Bay)
2	1.2.1.2	Investigate opportunities to acquire/protect lands restorable to tidal marsh ("potential restoration" in **Figures III-7-III-32**).	All	Until recovery criteria are met	AUD, CCC, CDFW, CDPR, DOD, DWR, EBRPD, GGNRA, LOC, PORT O, PORT SF, SFBNWR, SLT, UTID, **USFWS**	TBD	-	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
1	1.2.2	Acquire/protect currently unprotected high marsh and ecotonal habitat and land restorable to high marsh and ecotonal habitat for *Chloropyron molle ssp. molle*, *Cirsium hydrophilum* var. *hydrophilum*, California clapper rail, and salt marsh harvest mouse by purchase of fee title or conservation easement.	CLRA, SMHM, CIHY, CHMO, Other	Until recovery criteria are met	AUD, CCC, CDFW, CDPR, DOD, DWR, EBRPD, GGNRA, LOC, PORT O, PORT SF, SFBNWR, SLT, UTID, **USFWS**	46,940	-	-	-	-	-	Maximum cost, based on fee title acquisition of approximately 4,694 acres of unprotected high marsh/ecotonal habitat multiplied by $10K/acre (average price paid over last 10 years for salt ponds in San Francisco Bay)
3	1.2.3	Acquire/protect currently unprotected habitat for *Suaeda californica.*	SUCA	Ongoing	AUD, CCC, CDFW, CDPR, DOD, DWR, EBRPD, GGNRA, LOC, MBNEP, PORT O, PORT SF, SFBNWR, SLT, UTID, **USFWS**	0	-	-	-	-	-	No cost if accomplished through management partnerships.

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units)						Comments
						Total	FY14	FY15	FY16	FY17	FY18	
2	1.2.4	Acquire/protect habitat for *Chloropyron maritimum* ssp. *maritimum.*	CHMO	Until recovery criteria are met	AUD, CCC, CDFW, CDPR, DOD, DWR, EBRPD, GGNRA, LOC, MBNEP, PORT O, PORT SF, SFBNWR, SLT, UTID, **USFWS**	0	-	-	-	-	-	No cost if accomplished through management partnerships.
3	1.2.5	Acquire/protect habitat or potential habitat for other species of concern discussed in this recovery plan.	Other	Until recovery criteria are met	AUD, CCC, CDFW, CDPR, DOD, DWR, EBRPD, GGNRA, LOC, MBNEP, PORT O, PORT SF, SFBNWR, SLT, UTID, **USFWS**	0	-	-	-	-	-	No cost if accomplished through management partnerships.
3	1.3	Strengthen regulatory and legal protections by improving coordination with federal, state, and	All	Ongoing	CCC, CDFW, CDPR, DOD, DWR, EBRPD,	263.1	52.6	52.6	52.6	52.6	52.6	Assumes 10 hrs/wk x 50 wks/yr @ $842/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
		local regulatory authorities to ensure consistent, close attention to preservation of tidal marsh habitats and species.			GGNRA, LOC, MBNEP, SFBNWR, USGS, **USFWS**							
2	2.1.1.1	Work with Federal agencies to protect habitat and promote the recovery and conservation of the species covered in this recovery plan.	All	Ongoing	ALL	2,021+	404.16	404.16	404.16	404.16	404.16	2 FWS biologists FT @ $842/d x 20 d/mo x 12 mo; To implement section 7(a)(1) and 7(a)(2) and other obligations
2	2.1.1.2	Work with State and local agencies that manage land to beneficially manage habitat and promote the recovery and conservation of tidal marsh ecosystems and the species covered in this recovery plan.	All	Ongoing	ALL	2,880+	576	576	576	576	576	4 DFG biologists FT @ $600/d x 20 d/mo x 12 mo/yr; To implement section 10 and other obligations
2	2.1.1.3	Develop and maintain a web-based clearinghouse for information about managing the effects of climate change on wetland restoration.	All	Ongoing	CCC, **CDFW**, GGNRA, ISP, MBNEP, OWN, PRBO, SFBNWR, SFBO,	216+	72	36	36	36	36	60d to develop and 5d/mo x 12 mo/yr @ $600/d x 50 yrs.

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units)						Comments
						Total	FY14	FY15	FY16	FY17	FY18	
					SFEI, USFWS, USGS							
1	2.1.2	Continue to manage existing tidal marsh habitat, as shown in **Figures III-7 through III-32**.	All	Ongoing	**OWN**, MAS	TBD	-	-	-	-	-	48,604 acres
1	2.1.3.1	Work with existing Federal, State, local agencies, and land managers and private landowners to use their authorities to conduct interim habitat management to promote the recovery and conservation of the species covered in this recovery plan.	All	Ongoing	ALL	TBD	-	-	-	-	-	
2	2.1.3.2	Develop and implement standardized monitoring techniques to evaluate ecosystem, species, and threat response to interim habitat management activities.	All	1 yr	**USFWS,** CDFW, CCC, CNPS	32.2	32.2	-	-	-	-	38.25 d @ $842/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
2	2.1.4.1	Develop management plans, where lacking, in cooperation with appropriate agencies and organizations.	All	Ongoing	USFWS, CDFW, LOC, **OWN**	TBD	-	-	-	-	-	
1	2.1.4.2	Implement existing, newly developed, or revised management plans to protect tidal marsh habitat and promote recovery and conservation of the species covered in this recovery plan.	All	Ongoing	USFWS, CDFW, LOC, **OWN**	TBD	-	-	-	-	-	
3	2.1.4.3	Revise existing management plans, if necessary.	All	Ongoing	USFWS, CDFW, LOC, **OWN**	TBD	-	-	-	-	-	
2	2.1.5.1	Maintain normal tidal range.	All	Until recovery criteria are met	**OWN**	TBD	-	-	-	-	-	
2	2.1.5.2	Minimize or avoid over-management of estuarine salinity variation.	All	Continual	CDFW, DWR, **OWN**	0	-	-	-	-	-	
1	2.1.5.3	Develop and implement site-specific oil spill prevention and	All	Continual	**OWN**	TBD	-	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units)						Comments
						Total	FY14	FY15	FY16	FY17	FY18	
		response plans for lands supporting known populations of any of the listed species covered in this recovery plan.										
2	2.1.5.4	Manage groundwater extraction to prevent salt water intrusion in Los Osos Valley.	SUCA, Other	Ongoing	DWR, **LOC**, OWN, RWQCB	TBD	-	-	-	-	-	
3	2.1.5.5	Modify ditching and other mosquito abatement activities in tidal marshes to avoid impacts to species covered in this recovery plan.	All	Ongoing	**MAD**	0	-	-	-	-	-	
2	2.1.5.6	Engineer and implement solutions to direct current and future urban runoff away from tidal marsh habitat at BSRA.	CLRA, SMHM, CHMO, SUCA, Other	6 mo	CDPR, **LOC,** RWQCB	48	48	-	-	-	-	20 d/mo x 6 mo @ $400/d
1	2.1.5.7	Avoid shoreline stabilization or development between White Point and Fairbank Point in Morro Bay.	SUCA, Other	Ongoing	**LOC,** MBNEP	0	-	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
1	2.1.6.1.1.1	Develop site-specific management plans, consistent with the conservation and recovery of listed species, to control non-native *Spartina* species, especially *Spartina alterniflora* and its hybrids.	All	5 yrs	CCC, CDFW, **ISP,** SFBNWR	140	80	20	20	10	10	Per Director, SF Invasive Spartina Project (pers com 2006), $80K so far, but doesn't include revised plans (for follow up treat.)+ any new sites
1	2.1.6.1.1.2	Control non-native *Spartina* species, especially *Spartina alterniflora* and its hybrids, consistent with the conservation and recovery of listed species.	All	5 yrs	CCC, CDFW, **ISP,** SFBNWR	3,603	1,000	1,000	853	500	250	Per SF Invasive Spartina Project (pers com 2007).
1	2.1.6.1.1.3	Monitor the success of non-native *Spartina* control sites and the ability of treated sites to support California clapper rail.	All	Ongoing	CCC, CDFW, **ISP,** SFBNWR USGS	895	495	100	100	100	100	Assumes 2 surveys/site/yr; Includes admin, environmental compliance, inventory monitoring, efficacy monitoring, and CLRA monitoring
2	2.1.6.1.2.1	Prioritize possible sites to control or eradicate *Lepidium*	All	3 d	CDFW, CDPR, DWR,	3	3	-	-	-	-	3 sites@ 1d/site@ $1K/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
		latifolium.			**OWN**, SLT, UNIV							
1	2.1.6.1.2.2	Develop site-specific management plans to control or eradicate *L. latifolium.*	All	15 d	CDFW, CDPR, DWR, **OWN**, PVT, SLT, UNIV	15	15	-	-	-	-	3 sites@ 5 d/site@ $1K/d
1	2.1.6.1.2.3	Control or eradicate *L. latifolium.*	All	15 d	CDFW, CDPR, DWR, **OWN**, PVT, SLT	15	15	-	-	-	-	4 sites@ 5 d/site@ $1K/d
1	2.1.6.1.2.4	Monitor the success of *L. latifolium* control sites.	All	3 yrs	CDFW, CDPR, DWR, **OWN**, PVT, SLT, UNIV	24	8	8	8	-	-	3 sites@ 2 d/site@ $1K/d@ 3 yrs + 2 d/yr for report of all sites
2	2.1.6.1.3.1	Develop site-specific management plans to eradicate *Carpobrotus edulis.*	SUCA, Other	15 d	CDFW, CDPR, DWR, MBNEP, **OWN**, PVT, SLT, UNIV	15	15	-	-	-	-	3 sites@ 5d/site@ $1K/d
2	2.1.6.1.3.2	Eradicate *C. edulis.*	SUCA, Other	15 d	CDFW, CDPR, DWR, MBNEP, **OWN**, PVT, SLT	20	20	-	-	-	-	4 sites@ 5d/site@ $1K/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
2	2.1.6.1.3.3	Monitor the success of *C. edulis* eradication sites.	SUCA, Other	3 yrs	CDFW, CDPR, DWR, MBNEP, **OWN**, PVT, SLT, UNIV	24	8	8	8	-	-	3 sites@ 2 d/site@ $1K/d@ 3 yrs + 2 d/yr for report of all sites
2	2.1.6.1.5	Develop a system for early detection of and rapid response to invasive plant species.	All	6 mo	CNPS, CDFW, **SFBNWR**	72	72	-	-	-	-	20 d/mo x 6 mo @ $600/d
1	2.1.6.2.1	Develop and implement management plans to monitor and control red fox.	CLRA, SMHM, Other	5 yrs	CCC, CDFW, CDPR, LOC, **OWN**, SFBNWR, USFWS,	126.3	25.26	25.26	25.26	25.26	25.26	30d/yr @ $842/d
2	2.1.6.2.2	Develop and implement management plans to monitor and control Norway rats.	CLRA, Other	5 yrs	CCC, CDFW, CDPR, LOC, **OWN**, SFBNWR, USFWS	126.3	25.26	25.26	25.26	25.26	25.26	30d/yr @ $842/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
3	2.1.6.2.3	Develop and implement management plans to monitor and control other animals that threaten species covered in this recovery plan.	CLRA, SMHM, Other	5 yrs	CCC, CDFW, CDPR, LOC, **OWN**, SFBNWR, USFWS	126.3	25.26	25.26	25.26	25.26	25.26	30d/yr @ $842/d
3	2.1.6.2.4	Monitor the success of, and adapt control plans for, the above non-native or native animal predators.	CLRA, SMHM, Other	5 yrs	CCC, CDFW, CDPR, LOC, **OWN**, SFBNWR, USFWS	21.05	4.21	4.21	4.21	4.21	4.21	5 d/yr @ $842/d
2	2.1.7	Manage for the protection of native pollinators, insect predators, and their habitats.	All	Ongoing	SLT, LOC, **OWN,** SFBNWR	0	-	-	-	-	-	
2	2.1.8.1.1	Route access points and trails away from sensitive *Chloropyron maritimum* ssp. *maritimum* habitat in Morro Bay.	CHMA, SUCA, Other	2 wks	CDPR, MBNEP, LOC**, OWN**	4	4	-	-	-	-	10 d (re-routing & signage) @ $400/d
2	2.1.8.1.2	Minimize impacts from boat haulouts to *Chloropyron maritimum* ssp. *maritimum* habitat in Morro Bay.	CHMA, SUCA, Other	5 d	CDPR, MBNEP, **LOC**	2	2	-	-	-	-	5 d (signage) @ $400/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan													
						Cost Estimate (in $1,000 units)							
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
2	2.1.8.1.3	Manage dredge disposal to minimize threats to *Chloropyron maritimum* ssp. *maritimum* and *Suaeda californica* habitat in Morro Bay.	CHMA, SUCA, Other	Ongoing	UFID, OWN, **LOC**	0	-	-	-	-	-	
2	2.1.8.2.1	Identify lands adjacent to the Bay Trail and other public access areas where human-related disturbance encourages predation that causes a threat to the California clapper rail and salt marsh harvest mouse.	CLRA, SMHM, Other	5 d	**LOC,** OWN	5	5	-	-	-	-	5 d @$1K/d
2	2.1.8.2.2	Develop and implement a management plan for lands adjacent to the Bay Trail and other public access areas that reduces predation by feral or otherwise free-roaming cats and other human-related disturbance to	CLRA, SMHM, Other	Ongoing	**LOC,** OWN	0	-	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Cost Estimate (in $1,000 units)**						**Comments**
						Total	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	
		species and habitat.										
2	2.1.8.2.3	Implement and enforce pet restrictions.	CLRA, SMHM, Other	Ongoing	**LOC,** OWN	0	-	-	-	-	-	
2	2.1.8.2.4	Avoid relocation of nuisance animals to California clapper rail habitat.	CLRA, SMHM, Other	Ongoing	**LOC,** OWN	0	-	-	-	-	-	
2	2.1. 8.2.5	Provide wardens, agents, or officers to enforce above protective measures.	CLRA, SMHM, Other	Ongoing	CDPR, USFWS, CDFW, **LOC**	1,440	28.8	28.8	28.8	28.8	28.8	1 warden x 4d/mo x 12 mo/yr @ $600/d x 50 yrs
2	2.1.8.2.6	Improve ability to coordinate activities which occur in sensitive habitat at Rush Ranch.	CLRA, SMHM, CHMO, CIHY, Other	5 days	USFWS, CDFW, **SLT**	2	2	-	-	-	-	5 days at $400/day. Assumes time to develop a plan for coordinating activities at Rush Ranch.
3	2.1.8.2.7	Bury distribution lines from power utilities where they traverse restored tidal marshes and prevent routing of new transmission lines through restored or protected tidal marsh.	All	Ongoing	LOC, **UFID**	5,000	5,000	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan													
						Cost Estimate (in $1,000 units)							
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
2	2.1.8.2.8	Carry out vegetation clearing, mosquito management, dredging, and other activities after the breeding season of birds covered in this recovery plan.	CLRA, Other	Ongoing	OWN, LOC, **MAD**	0	-	-	-	-	-	
3	2.1.9.1	Manage black-tailed deer to minimize impacts to *Suaeda californica* at Morro Bay.	SUCA, Other	1 mo.	**OWN**	5	5	-	-	-	-	Based on fencing/repair costs.
3	2.1.9.2	Manage cattle grazing to minimize impacts to salt marsh harvest mouse, Suisun shrew, and the birds of the high tidal marsh, such as saltmarsh common yellowthroat.	CLRA, SMHM, Other	Ongoing	CDFW, GGNRA, SLT, SRCD, **OWN**	TBD	-	-	-	-	-	
3	2.1.9.3	Manage feral pig disturbance to minimize impacts to sensitive plants and the birds of the middle and high tidal marsh, such as saltmarsh common yellowthroat.	CLRA, CHMO, CIHY, SUCA, Other	Ongoing	CDFW, GGNRA, SLT, SRCD, **OWN**	TBD	-	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units) Total	FY14	FY15	FY16	FY17	FY18	Comments
2	2.2.1	Create an interdisciplinary review panel, or similar group to coordinate and review the design of tidal marsh restoration projects throughout San Francisco Bay.	All	5 yrs	**USFWS,** CDFW, UNIV, USGS	95.5	19.1	19.1	19.1	19.1	19.1	Creation and administration of panel only- not review. 4 Feds+ 5 state/private X 3 days/yr.
1	2.2.2.1	Restore habitat to achieve 1,111 acres of high quality tidal marsh habitat (including high marsh/upland ecotone habitat) in each marsh complex except San Rafael Creek-Richardsons Bay, in the Central/Southern SF Bay Recovery Unit (RU) (6,666 acres total), as indicated in **Figures III-15** through **III-26.**	CLRA, SMHM, SUCA, Other	Until recovery criteria are met	CDFW, **OWN**, USFWS	233,310	-	-	-	-	-	Maximum cost, assuming no existing marsh currently meets criteria. Timing of restoration is unknown and will likely be opportunistic based on available funding. Based on average restoration cost of $35,000/acre.

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
1	2.2.2.2	Restore habitat to achieve 2,500 acres of high quality tidal marsh habitat (including high marsh/upland ecotone habitat) in each marsh complex except Point Pinole marsh, in the San Pablo Bay RU (10,000 acres total), as indicated in **Figures III-9** through **III-14.**	CLRA, SMHM, SUCA, CHMO, Other	Until recovery criteria are met	CDFW, **OWN**, USFWS, MAS	350,000	-	-	-	-	-	Maximum cost, assuming no existing marsh currently meets criteria. Timing of restoration is unknown and will likely be opportunistic based on available funding. Based on average restoration cost of $35,000/acre.
1	2.2.2.3	Restore habitat to achieve 400 acres of high quality tidal marsh habitat (including high marsh/upland ecotone habitat)each in the San Rafael Creek-Richardsons Bay marsh complex in the Central/South SF Bay RU **(Figure III-15)** and the Point Pinole marsh complex in the San Pablo Bay RU **(Figure III-14)** (800 acres total).	CLRA, SMHM, SUCA, Other	Until recovery criteria are met	CDFW, **OWN**, USFWS, MAS	28,000	-	-	-	-	-	Maximum cost, assuming no existing marsh currently meets criteria. Timing of restoration is unknown and will likely be opportunistic based on available funding. Based on average restoration cost of $35,000/acre.

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Cost Estimate (in $1,000 units)**						**Comments**
						Total	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	
1	2.2.2.4	Restore habitat to achieve 5,000 total acres of high quality tidal marsh habitat (including high marsh/upland ecotone habitat) in the Suisun Bay Area RU, as indicated in **Figures III-7** and **III-8.**	CLRA, SMHM, CHMO, CIHY, Other	Until recovery criteria are met	CDFW, **OWN**, USFWS	175,000	-	-	-	-	-	Maximum cost, assuming no existing marsh currently meets criteria. Timing of restoration is unknown and will likely be opportunistic based on available funding. Based on average restoration cost of $35,000/acre.
3	2.2.2.5	Implement *Tidal Wetland Project* in Elkhorn Slough, reversing trend of tidal marsh loss and speeding accretion at erosion hot spots.	SUCA, CHMA, Other	TBD	**ESNERR,** MBNEP	TBD						Further planning, engineering, and regulatory compliance required.
2	2.2.2.6	Create/restore tidal marsh and adjacent habitat (including high marsh/upland ecotone habitat, wherever possible), beyond minimum acreage above, in each RU, as indicated in **Figures III-7** through **III-32**.	All	Until recovery criteria are met	CDFW, **OWN**, USFWS, MAS	TBD	-	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units)						Comments
						Total	FY14	FY15	FY16	FY17	FY18	
3	2.2.2.7	As deemed necessary by the Service, with guidance from the RIT, enter into conservation easements to restore tidal habitat on private lands ("potential restoration"), as indicated in **Figures III-7** through **III-32**.	All	Until recovery criteria are met	CDFW, **USFWS,** SLT	TBD	-	-	-	-	-	
1	2.2.3.1	Protect, manage, and monitor large populations and occupied marsh complexes as interim reserves selected to represent the full range of both subspecies of salt marsh harvest mouse.	All	10 yrs	CDFW, **OWN,** USFWS	2,595.6	259.6	259.6	259.6	259.6	259.6	1 FWS, 1 DFG x 20 d x 9 mo; To be maintained at least until large-scale restoration sites can support SMHM.
2	2.2.3.2	Supplement protection of each large population with a series of smaller satellite reserves, where feasible.	All	10 yrs	CDFW, **OWN**, USFWS	TBD	-	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units)						Comments
						Total	FY14	FY15	FY16	FY17	FY18	
3	2.2.3.3	Transition from diked wetlands to restored or enhanced tidal marsh habitat, where feasible.	All	30 yrs	CDFW, SRCD, **USFWS**	TBD	-	-	-	-	-	
2	2.2.4	Restore or enhance buffer zones in existing habitat adjacent to populations of species covered in this recovery plan.	All	10 yrs	**USFWS,** CDFW	TBD	-	-	-	-	-	
1	2.2.5	Replant native dune-stabilizing vegetation in Morro Bay if excessive dune mobility threatens populations of *Chloropyron maritimum* ssp. *maritimum* and *Suaeda californica*.	SUCA, CHMA, Other	2 yrs	CNPS, MBNEP, OWN, **UNIV**	4	2	2	-	-	-	If dune mobility threatens populations, then 2 yrs @ 5d/yr @ $400/d
3	2.2.6	Conduct hazardous waste cleanup of the Superfund-listed landfill in the northwestern portion of BSRA and restore the site to its historic habitat for endangered species.	CLRA, SMHM, CHMO, SUCA, Other	TBD	CDPR, LOC, **OWN**, USFWS	TBD	-	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
2	2.2.7.1.1	Bank seeds of *Cirsium hydrophilum* var. *hydrophilum* during years of high seed production.	CIHY	3 yrs	CDFW, SLT, STO**,** **UNIV**	5.3	5.3	-	-	-	-	Per Rancho Santa Ana Bot. Gardens, $2500 flat rate + $150, per population; 2 pops/species X 1 species; 3 yrs (no charge for multiple yr sampling)
3	2.2.7.1.2	Bank seeds of *Chloropyron maritimum* ssp. *maritimum* and *Chloropyron molle ssp. molle* during years of high seed production.	CHMA, CIHY	3 yrs	CDFW, SLT, MBNEP, STO, **UNIV**	10.6	10.6	-	-	-	-	Same as above, but for two species.
2	2.2.7.1.3	Maintain a clone bank of *Suaeda californica.*	SUCA	10 yrs	CDFW, MBNEP, PVT, STO, **USFWS**	10	1	1	1	1	1	UCB estimated $50/yr per individual, 20 individuals
2	2.2.7.2.1.1	Develop introduction/ reintroduction plan for *Cirsium hydrophilum* var. *hydrophilum*.	CIHY	10 d	CDFW, **PVT,** SLT, UNIV, USFWS	10	10	-	-	-	-	10 days x $1K/d
2	2.2.7.2.1.2	Conduct site preparation, propagate plants, and transplant seedlings for *Cirsium*	CIHY	2 yrs	CDFW, **PVT,** SLT, UNIV, USFWS	10	6	4	-	-	-	$1K/d; 2 d for site prep, 2 d/yr-propagation, 2 d/yr-transplanting, assuming 2-3 sites

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units)						Comments
						Total	FY14	FY15	FY16	FY17	FY18	
		hydrophilum var. *hydrophilum* introduction/ reintroduction.										
2	2.2.7.2.1.3	Monitor and conduct maintenance of transplanted *Cirsium hydrophilum* var. *hydrophilum.*	CIHY	5 yrs	CDFW, **PVT,** SLT, UNIV, USFWS	25	5	5	5	5	5	5 d/yr @ $1K/d
2	2.2.7.2.1.4	Assess introduction/ reintroduction success, review reports, and adapt introduction/ reintroduction plan for *Cirsium hydrophilum* var. *hydrophilum*, as necessary.	CIHY	5 yrs	CDFW, **USFWS,**	4.2	0.84	0.84	0.84	0.84	0.84	1 d/yr @ $842/d
3	2.2.7.2.2.1.	Develop introduction/ reintroduction plan for *Chloropyron maritimum* ssp. *maritimum.*	CHMA	10 d	CDFW, MBNEP, **PVT,** UNIV, USFWS	10	10	-	-	-	-	10d x $1K/d
3	2.2.7.2.2.2.	Conduct site preparation, propagate plants, and transplant seedlings for *Chloropyron*	CHMA	2 yrs	CDFW, MBNEP, **PVT,** UNIV, USFWS	10	6	4	-	-	-	$1K/d; 2 d site prep, 2 d/yr-propagation, 2 d/yr-transplanting, assuming 2-3 sites

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
		maritimum ssp. *maritimum* introduction/ reintroduction.										
3	2.2.7.2.2.3	Monitor and conduct maintenance of transplanted *Chloropyron maritimum* ssp. *maritimum.*	CHMA	5 yrs	CDFW, MBNEP, **PVT,** UNIV, USFWS	25	5	5	5	5	5	5 d/yr @$1K/d
3	2.2.7.2.2.4	Assess introduction/ reintroduction success and maintenance levels of genetic diversity, review reports, and adapt introduction/ reintroduction plan for *Chloropyron maritimum* ssp. *maritimum*, as necessary.	CHMA	5 yrs	**CDFW, USFWS,**	4.2	0.842	0.842	0.842	0.842	0.842	1 d/yr @$842/d
3	2.2.7.2.3.1	Develop introduction/ reintroduction plan for *Chloropyron molle ssp. molle.*	CHMO	20 d	CDFW, **PVT,** SLT, UNIV, USFWS	20	20	-	-	-	-	$1K/d
3	2.2.7.2.3.2	Conduct site preparation, propagate plants, transplant seedlings for *Chloropyron molle ssp. molle*	CHMO	2 yrs	CDFW, **PVT,** SLT, UNIV, USFWS	24	14	10	-	-	-	$1K/d; 4 d site prep, 2 d/yr-propagation, 8 d/yr-transplanting, assuming 4 sites

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units)						Comments
						Total	FY14	FY15	FY16	FY17	FY18	
		introduction/ reintroduction.										
3	2.2.7.2.3.3	Monitor and conduct maintenance of transplanted *Chloropyron molle ssp. molle.*	CHMO	5 yrs	CDFW, **PVT,** SLT, UNIV, USFWS	100	20	20	20	20	20	20d/yr @ $1K/d
3	2.2.7.2.3.4	Assess introduction/ reintroduction success, review reports, and adapt introduction/ reintroduction plan for *Chloropyron molle ssp. molle*, as necessary.	CHMO	5 yrs	**CDFW, USFWS,**	8.42	1.684	1.684	1.684	1.684	1.684	2 d/yr @ $842/d
2	2.2.7.2.4.1	Implement *California Sea-blite Reintroduction Plan, San Francisco Bay, California*.	SUCA	5 yrs	AUD, CNPS, **PVT,** USFWS	60	16	14	10	10	10	Assumes 2 sites (assumes success of recent reintroduction); 2 d site prep, 2 d/yr prop & 2 d/yr transplant for 2 years, 10 d/yr maint & monitor for 5 yrs@$1K/d
2	2.2.7.2.4.2	Assess reintroduction success, review reports, and adapt	SUCA	5 yrs	**USFWS**	8.42	1.68	1.68	1.68	1.68	1.68	2 d/yr @ $842/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
		reintroduction plan for *Suaeda californica*, as necessary.										
3	2.2.7.2.5	Periodically review and assess the need for reintroduction programs for species covered in this recovery plan. If warranted, develop and implement reintroduction programs, monitor, evaluate success, and adapt the programs, as appropriate.	SUCA, CHMO, CIHY, CHMA	Continual	**USFWS**	TBD	-	-	-	-	-	
2	2.3.1	Develop consistent guidelines for habitat monitoring for use throughout the geographic scope of this recovery plan.	All	20 d	**USFWS,** CDFW	16.84	16.84	-	-	-	-	20d @ $842/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
2	2.3.2.1	Develop and implement habitat monitoring plans at a geographically representative suite of remnant mature ("pre-historical") tidal and brackish tidal marshes, as a baseline and early-warning network.	All	30 yrs	**USFWS,** CDFW, OWN	47.16	13.48	6.74	6.74	6.74	6.74	Once per 5 yrs; 4 sites @ 2d/site. Assumes using results of Action 2.3.1 as a base for plan, then making specific to sites; devel. of plan= 2d/site (=$6,736)
2	2.3.2.2	Develop and implement habitat monitoring plans at tidal marsh restoration sites.	All	Ongoing	**USFWS,** CDFW, OWN	TBD	-	-	-	-	-	
2	2.3.2.3	Develop and implement habitat monitoring plans at species reintroduction sites.	All	Ongoing	**USFWS,** CDFW, OWN	TBD	-	-	-	-	-	
2	2.3.2.4	Develop and implement habitat monitoring plans at sites selected to observe sand dune movement.	SUCA, CHMA, Other	Continual	USFWS, CDFW, MBNEP, **CDPR,** OWN	14.4	7.2	3.6	3.6	-	-	3 sites at Morro Bay; 2d/site/yr.+ devel. of plan= 2d/site
3	2.3.2.5	Prepare and implement habitat monitoring plans for other areas, as necessary.	All	TBD	USFWS, CDFW, **OWN**	TBD	-	-	-	-	-	
2	2.3.3	Make habitat monitoring results	All	30 yrs	**USFWS**	50.52	1.68	1.68	1.68	1.68	1.68	2 d/yr @ $842/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Cost Estimate (in $1,000 units)**						**Comments**
						Total	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	
		publically available.										
2	2.3.4	Evaluate and improve habitat monitoring methods, as needed.	All	3 yrs	**USFWS,** CDFW	7.58	2.53	2.53	2.53	-	-	3 d/yr @ $842/d
3	3.1.1.1	Review existing species survey guidance to determine its adequacy.	All	3 d	**USFWS**	2.53	2.53	-	-	-	-	
3	3.1.1.2	If necessary, revise existing guidance or develop new standardized, scientifically based, and species-specific survey guidance.	All	0.05 yr	**USFWS**	TBD	-	-	-	-	-	
1	3.1.2.1	Survey/monitor for *Cirsium hydrophilum* var. *hydrophilum.*	CIHY	5 yrs	CDFW, PVT, SLT, **UNIV**	10	2	2	2	2	2	Rank abundance estimates only. 3 d/yr + report (2d/yr) @$400/d
2	3.1.2.2	Survey/monitor for *Chloropyron maritimum* ssp. *maritimum.*	CHMA	5 yrs	CDFW, MBNEP, PVT, **UNIV**	10	2	2	2	2	2	Rank abundance estimates only. 3 d/yr + report (2d/yr) @$400/d
2	3.1.2.3	Survey/monitor for *Chloropyron molle ssp. molle.*	CHMO	5 yrs	CDFW, PVT, SLT, **UNIV**	26	5.2	5.2	5.2	5.2	5.2	Rank abundance estimates only. 10 d/yr + report (3d/yr) @$400/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units) Total	FY14	FY15	FY16	FY17	FY18	Comments
3	3.1.2.4	Survey/monitor for *Suaeda californica.*	SUCA	5 yrs	CDFW, MBNEP, PVT, **UNIV**	12	2.4	2.4	2.4	2.4	2.4	Rank abundance estimates only. 4 d/yr + report (2d/yr) @$400/d ; If initial SF Bay reintro plan unsuccessful, only half these costs/yr.
3	3.1.2.5.1	Develop certification/training programs for California clapper rail surveyors and survey coordinators.	CLRA	10 d	USFWS, **PRBO, SFBO**, PVT	6	6	-	-	-	-	Calculated at $600/d
2	3.1.2.5.2	Conduct annual California clapper rail call counts during breeding season.	CLRA	8 yrs	USFWS, **PRBO, SFBO**	57.6	7.2	7.2	7.2	7.2	7.2	12 d/yr (8 d surveys+ 4 d reporting)@$600/d
2	3.1.2.5.3	Monitor adult California clapper rail survival and mortality of adults, chicks, and eggs due to predation.	CLRA	3 yrs	USFWS, **PRBO, SFBO**	21.6	7.2	7.2	7.2	-	-	12 d/yr (8 d surveys+ 4 d reporting) @ $600/d
2	3.1.2.5.4	Develop and maintain a database to track annual California clapper rail monitoring results.	CLRA	5 yrs +	**USFWS,** PRBO, SFBO	TBD	20	20	5	5	5	Initial setup 2 yrs, maintenance until recovery

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
3	3.1.2.5.5	Examine the methodology used for call count surveys in Action 3.1.2.5.2 above, by cross validating surveys (using double observer methods) with movement studies recommended in Action 4.2.6.2.	CLRA	5 d	USFWS, **PRBO, SFBO**	3	3	-	-	-	-	At $600/d
2	3.1.2.6	Monitor for salt marsh harvest mouse.	SMHM	9 yrs	**USFWS, CDFW, DWR, PVT**, UNIV	663.1	73.68	73.68	73.68	73.68	73.68	30 VHAs; Survey one third ea yr on 3 yr cycle. Two 100 trap grids/area=20 grids/yr x 4 nts ea= 80 nts (days)/yr; 15 d DFG+ 63 d PVT+ 2 d USFWS
3	3.1.2.7	Conduct surveys/monitoring of salt marsh wandering shrew and Suisun shrew.	Other	3 yrs	UNIV, **PVT**	181	61	60	60	-	-	4 nts x 5 areas/RU x 3 Rus @$1K/day + $1K in FY1 for trap modification materials
3	3.1.2.8	Conduct surveys/monitoring of San Pablo vole.	Other	1 yr	UNIV, **PVT**	20	20	-	-	-	-	4 nts x 10 areas (doing 2 areas concurrently)@$1K/day

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units) Total	FY14	FY15	FY16	FY17	FY18	Comments
3	3.1.2.9	Continue to conduct surveys/monitoring of California black rail.	Other	20 yrs	**PRBO, SFBO**, UNIV, PVT	28.8	7.2	-	-	-	-	2 visits/season/site; 6 sites @$600/d; Survey once every 5 yrs for 20 yrs
3	3.1.2.10	Conduct surveys/monitoring of song sparrow subspecies.	Other	20 yrs	**PRBO, SFBO**, UNIV, PVT	28.8	7.2	-	-	-	-	2 visits/season/site; 6 sites @$600/d; Survey once every 5 yrs for 20 yrs
3	3.1.2.11	Conduct surveys/monitoring of saltmarsh common yellowthroat.	Other	20 yrs	**PRBO, SFBO**, UNIV, PVT	28.8	7.2	-	-	-	-	2 visits/season/site; 6 sites @$600/d; Survey once every 5 yrs for 20 yrs
3	3.1.2.12	Conduct surveys/monitoring of *Cicindela senilis senilis.*	Other	1 yr	**USFWS,** UNIV, PVT	33.68	33.68	-	-	-	-	Surveys in Feb, Apr, May, June, Jul, Aug, Sept, & Oct @ 5 d ea (3 field + 2 reporting) at $842/d
3	3.1.2.13	Conduct surveys/monitoring of *Lathyrus jepsonii* var. *jepsonii.*	Other	20 yrs	CNPS, **UNIV,** PVT	16	4	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
3	3.1.2.14	Conduct surveys/monitoring of *Spartina foliosa.*	Other	20 yrs	CNPS, **UNIV,** PVT	6	6	-	-	-	-	12 d surveying+ 3 days reporting
3	3.1.2.15	Conduct surveys/ monitoring of previously documented populations of other species covered in this recovery plan.	All	1 yr	**UNIV**, PVT	TBD	-	-	-	-	-	
2	3.2.1	Conduct surveys in suitable habitat for new and relict populations of species covered in this recovery plan.	All	1 yr	**UNIV**, PVT	TBD	-	-	-	-	-	
2	3.2.2	For *Cirsium hydrophilum* var. *hydrophilum, Chloropyron maritimum* ssp. *maritimum*, and *Chloropyron molle ssp. molle*, probe soil seed banks to detect presence and location of dormant viable seed. Grow out seed by cultivation or in natural protected habitat or bank seed, per Action 2.2.7.1.	CIHY, CHMA, CHMO	5 yrs	USFWS, CDFW, **UNIV**	20	4	4	4	4	4	10 d/yr

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
3	3.3	Periodically review and improve methods of species monitoring.	All	3 yrs	**USFWS,** CDFW	7.58	2.53	2.53	2.53	-	-	3 d/yr
2	3.4	Report survey results to California Natural Diversity Database and otherwise make them publically available so that findings can be applied in conservation and recovery efforts.	All	Continual	ALL	TBD	1.8	1.8	1.8	1.8	1.8	3 d/yr @ $600/d
3	3.5	Periodically review progress toward listed species recovery and long-term conservation of species of concern and identify those species warranting a change in status (listing, delisting, uplisting, downlisting).	All	Continual	USFWS	TBD	4.21	4.21	4.21	4.21	4.21	5 d/yr @ $842/yr
2	4.1	Designate a research coordinator to coordinate all research sponsored or overseen by USFWS.	All	1 d	**USFWS**	0.84	0.84	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
2	4.2.1	Continually update current literature base on the basic biology and ecology of the species covered in this recovery plan and develop a prioritized list of research needs for each species.	All	10 d	**USFWS,** CDFW	8.42	8.42	-	-	-	-	
2	4.2.2.1	Study reproductive ecology of *Cirsium hydrophilum* var. *hydrophilum.*	CIHY	3 yrs	USFWS, SLT, CDFW, **UNIV**, PVT	100	40	30	30	-	-	
2	4.2.2.2	Study physiological ecology of *Cirsium hydrophilum* var. *hydrophilum.*	CIHY	6 yrs	USFWS, SLT, CDFW, **UNIV**, PVT	125	25	25	25	25	25	
2	4.2.2.3	Study community ecology of *Cirsium hydrophilum* var. *hydrophilum.*	CIHY	3 yrs	USFWS, SLT, CDFW, **UNIV**, PVT	150	75	50	25	-	-	
2	4.2.3	Conduct biological and ecological studies on *Chloropyron maritimum* ssp. *maritimum.*	CHMA	5 yrs	**UNIV**, PVT, MBNEP	200	40	40	40	40	40	
2	4.2.4.1	Study reproductive ecology of *Chloropyron molle ssp. molle.*	CHMO	3 yrs	SLT, **UNIV**, PVT	100	40	30	30	-	-	same as *C. H.* var. *hydrophilum*

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Cost Estimate (in $1,000 units)**						**Comments**
						Total	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	
2	4.2.4.2	Study physiological ecology of *Chloropyron molle ssp. molle.*	CHMO	6 yrs	SLT, **UNIV**, PVT	150	25	25	25	25	25	same as *C. H.* var. *hydrophilum*
2	4.2.4.3	Study community ecology of *Chloropyron molle ssp. molle.*	CHMO	3 yrs	SLT, **UNIV**, PVT	150	75	50	25	-	-	same as *C. H.* var. *hydrophilum*
2	4.2.4.4	Study population ecology of *Chloropyron molle ssp. molle.*	CHMO	3 yrs	SLT, **UNIV**, PVT	150	75	50	25	-	-	
2	4.2.5	Conduct biological and ecological studies on *Suaeda californica.*	SUCA	5 yrs	**UNIV**, PVT	200	40	40	40	40	40	
1	4.2.6.1	Conduct a population viability analysis of the California clapper rail.	CLRA	5 yrs	**PRBO**, SFBO, UNIV, PVT	60	12	12	12	12	12	20 d/yr $600/d x 5 yrs
1	4.2.6.2	Study effects of recent non-native *Spartina* treatment on California clapper rail survival and movement within the ecosystem.	CLRA	3 yrs	PRBO, SFBO, ISP, UNIV, **USGS**	119.81	41.63	41.63	36.55	-	-	Per 5/06 USGS proposal (SSP grant); inc. salary, transmitters, vehicle, telemetry supp., trapping equip, travel, contingency, & overhd rate of 23.894%

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
2	4.2.6.3	Conduct diet analyses on California clapper rail as a tool to understanding habitat use.	CLRA	1 yr	PRBO, SFBO, ISP, UNIV, **USGS**	12	12	-	-	-	-	Used population ecology action costs.
2	4.2.7.1	Conduct a population viability analysis to determine desirable population sizes for long-term persistence of extant South Bay salt marsh harvest mouse populations.	SMHM	3 yrs	**UNIV**, PVT	200	100	50	50	-	-	FY1= development of microsatellite DNA probe. FY2 & 3= analyzing hair samples; If add'l trapping required then extra $50K required in FY2& 3.
1	4.2.7.2	Study use of adjacent habitat, including brackish marsh, by the salt marsh harvest mouse.	SMHM	1 yr	**UNIV**, PVT	100	100	-	-	-	-	Can be folded into movement study for salt marsh harvest mouse (Action 4.2.1.2.6.1.).
2	4.2.7.3	Study the impact of *Spartina alterniflora* and its hybrids, and *Lepidium latifolium* on the salt marsh harvest mouse.	SMHM	1 yr	UNIV, PVT, **SLT**	70	70	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Cost Estimate (in $1,000 units)**						**Comments**
						Total	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	
2	4.2.7.4	Study predation impacts to the salt marsh harvest mouse.	SMHM	2 yrs	UNIV, PVT	140	70	70	-	-	-	Trapping before and after predator access is prevented at several marshes
3	4.2.8	If sufficient numbers of the species are identified under Action 3.1.2.7, conduct biological and ecological studies on the salt marsh wandering shrew and the Suisun shrew.	Other	2 yrs	UNIV, **PVT**	250	200	50	-	-	-	
3	4.2.9	If sufficient numbers of the species are identified under Action 3.1.2.8, conduct biological & ecological studies on the San Pablo vole.	Other	1 yr	UNIV, **PVT**	70	70	-	-	-	-	
3	4.2.10	Conduct biological & ecological studies on the California black rail.	Other	2 yrs	**PRBO, SFBO**, UNIV, PVT	TBD	-	-	-	-	-	
3	4.2.11	Conduct biological and ecological studies on the song sparrow subspecies of the San Francisco estuary.	Other	2 yrs	**PRBO, SFBO,** UNIV, PVT	TBD	-	-	-	-	-	

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
3	4.2.12	Conduct biological and ecological studies on saltmarsh common yellowthroat.	Other	2 yrs	**PRBO, SFBO**, UNIV, PVT	TBD	-	-	-	-	-	
3	4.2.13	Conduct biological and ecological studies on *Cicindela senilis senilis.*	Other	1 yr	UNIV, **PVT**	420	105	105	105	105	-	7 mo @ 10 field + 5 reporting d/mo @1K/d
3	4.2.14	Conduct biological and ecological studies on *Lathyrus jepsonii* var. *jepsonii.*	Other	2 yrs	**UNIV,** PVT, CNPS	TBD	-	-	-	-	-	
3	4.2.15	Conduct biological and ecological studies on *Spartina foliosa.*	Other	1 yr	**UNIV,** PVT, CNPS	TBD	-	-	-	-	-	
3	4.2.16	Conduct biological and ecological studies on other species covered in this recovery plan.	All	TBD	**UNIV**, PVT, CNPS	TBD	-	-	-	-	-	
1	4.3.1	Conduct a salt marsh harvest mouse population genetic analysis.	SMHM	2 yrs	**UNIV**, PVT	100	50	50	-	-	-	
3	4.3.2	If sufficient numbers of the species are identified under Action 3.1.2.7., conduct research to assess genetic	Other	3 yrs	**UNIV**, PVT	300	100	100	100	-	-	FY1= development of microsatellite DNA probe. FY2 & 3= analyzing hair samples and conducting add'l trapping

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
		diversity within and among populations of salt marsh wandering shrew and Suisun shrew.										
2	4.3.3	If sufficient numbers of the species are identified under Action 3.1.2.8, build upon research conducted by Conroy and Neuwald to reassess the genetic identity of San Pablo vole, given recent finding of two phylogeographic groups of California vole.	Other	3 yrs	**UNIV**, PVT	300	100	100	100	-	-	FY1= development of microsatellite DNA probe. FY2 & 3= analyzing hair samples and conducting add'l trapping
3	4.3.4	Conduct research to resolve taxonomic uncertainties regarding other species covered in this recovery plan.	All	TBD	**UNIV**, PVT	TBD	-	-	-	-	-	
2	4.3.5	Conduct genetic studies on *Cirsium hydrophilum* var. *hydrophilum.*	CIHY	2 yrs	**UNIV,** PVT, SLT	50	25	25	-	-	-	This is for taxonomy work, not just population genetics/diversity.

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan													
						Cost Estimate (in $1,000 units)							
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
3	4.3.6	Conduct genetic studies on *Chloropyron molle ssp. molle.*	CHMO	2 yrs	**UNIV,** PVT, SLT	50	25	25	-	-	-	62.5 d/yr @ $400/d
3	4.3.7	Conduct genetic studies on song sparrow subspecies.	Other	3 yrs	**PRBO, SFBO**, UNIV, PVT	150	50	50	50	-	-	50 d/yr @ $1000/d
3	4.3.8	Conduct genetic studies on salt marsh common yellowthroat.	Other	3 yrs	**PRBO, SFBO**, UNIV, PVT	150	50	50	50	-	-	50 d/yr @ $1000/d
3	4.3.9	Continue to refine genetic analysis to verify pure *Spartina foliosa* stands in San Francisco Bay	Other	4 yrs	**UNIV,** PVT, CNPS	100	25	25	25	25	-	62.5 d/yr @ $400/d
2	4.4.1	Conduct studies on the efficacy of various habitat restoration techniques.	All	5 yrs	UNIV, **PVT**	125	25	25	25	25	25	Studies to happen much later than FY5; 25 d/yr @ $1K/d
1	4.4.2	Study natural sedimentation rates in marshes throughout the bay.	All	20 yrs	UNIV, **PVT,** USACE	TBD	-	-	-	-	-	Studies to happen much later than FY5
2	4.4.3	Study the impacts of large-volume, human-caused freshwater discharges into tidal marshes.	All	2 yrs	UNIV, PVT, **RWQCB**	96	48	48	-	-	-	80 d/yr @ $600/d
2	4.4.4	Investigate the effects of salinity fluctuation and	All	2 yrs	UNIV, PVT, **DWR**	96	48	48	-	-	-	80 d/yr @ $600/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
		altered tidal datum on species covered in this recovery plan.										
2	4.4.5	Study the time lag between habitat restoration and recolonization by species covered in this recovery plan.	All	20 yrs	**UNIV**, PVT	TBD	-	-	-	-	-	Studies to happen much later than FY5
2	4.4.6	Conduct research on the physical processes (geomorphic and hydrologic) that maintain the structure and function of suitable habitats for tidal marsh species.	All	2 yrs	UNIV, **PVT**, USACE	100	50	50	-	-	-	50 d/yr @ $1K/d
1	4.4.7	Study the effects of global climate change and resulting sea level rise on tidal marsh ecosystems.	All	20 yrs	UNIV, **PVT**, USGS	TBD	-	-	-	-	-	
2	4.4.8	Conduct research on management conflicts between listed species.	All	20 d	**USFWS**	16.84	16.84	-	-	-	-	20 d@ $842/d
1	4.5.1.1	Determine the effects of non-native species on tidal marsh	All	3 yrs	USFWS, CDFW, UNIV, **PVT**	75	25	25	25	-	-	25 d/yr @ $1K/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan													
Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units)							Comments
						Total	FY14	FY15	FY16	FY17	FY18		
		ecosystems.											
1	4.5.1.2	Investigate methods for controlling invasive species in tidal marsh ecosystems.	All	2 yrs	USFWS, CDFW, UNIV, **PVT**	100	50	50	-	-	-		50 d/yr @ $1K/d
1	4.5.1.3	Investigate methods of restoring tidal marsh ecosystems that have been degraded by invasive species.	All	2 yrs	USFWS, CDFW, UNIV, **PVT**	150	75	75	-	-	-		75 d/yr @ $1K/d
2	4.5.2.1	Conduct research into mercury exposure pathways for California clapper rails and potential means to interrupt those pathways.	CLRA, SMHM, Other	Ongoing (3 yrs)	**USFWS**, USGS, SFPBO, RWQCB	500	500	-	-	-	-		Cost does not reflect funds spent during first two years (fieldwork). 2 staff @ 250 d @ $1K/day (USFWS contaminants rate).
2	4.5.2.2	Conduct other necessary research on bioaccumulation and effects, including reproductive success and development, of toxic estuarine contaminants on tidal marsh species.	CLRA, SMHM, Other	5 yrs	**USFWS**, SFPBO, RWQCB	1,250	250	250	250	250	250		3 yrs fieldwork + 2 yrs reporting; 5 yrs @ 250 d/yr @ $1K/d (USFWS contaminants rate)

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units) Total	FY14	FY15	FY16	FY17	FY18	Comments
3	4.5.2.3	Apply results of research in Action 4.5.2.2 to re-evaluate suitability of delisting criterion E/5 for the California clapper rail and revise, if appropriate.	CLRA	40 d	**USFWS**	33.68	33.68					40 d @ $842/d
3	4.5.2.4	Apply results of research in Actions 4.2.4.2.1 and 4.2.4.2.2 to sediment and water quality standards to protect sensitive wildlife of the San Francisco estuary.	CLRA, SMHM, Other	40 d	**RWQCB**, CCC	24	-	-	-	-	24	Pending results of Actions 4.2.4.2.1 and 4.2.4.2.2; 40d @ $600/d
1	4.5.2.5	Conduct studies to establish contaminant levels in biosentinels that are "acceptable" or "not acceptable", then measure compounds in these biosentinels directly or via a non-invasive surrogate, such as feathers, if possible	All	TBD	**USGS**	TBD	-	-	-	-	-	
2	4.5.3.1	Determine if pollination is a limiting factor for	CHMO, CIHY, SUCA,	3 yrs	**UNIV**, PVT, SLT, CNPS	48	16	16	16	-	-	40 d/yr @ $400/d @ 3 yrs

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units)						Comments
						Total	FY14	FY15	FY16	FY17	FY18	
		any population of a plant species covered in this recovery plan.	CHMA, Others									
2	4.5.3.2	If Action 4.2.4.3.1 reveals pollination limitations, identify pollinators, their efficacy, and their ecological needs.	CHMO, CIHY, SUCA, CHMA, Others	3 yrs	**UNIV**, PVT, SLT, CNPS	72	-	-	-	24	24	Dependant on results of Action 4.2.4.3.1; 60d/yr @ $400/d @ 3 yrs
2	4.5.4.1	Conduct research into whether an elevated or unnaturally high predation level is experienced by salt marsh harvest mice at narrow marshes where the species is concentrated, especially during flooding events. If unacceptable impacts are discovered, develop and implement methods to reduce such predation.	SMHM	5 yrs	**UNIV,** PVT, SLT, CDFW, USFWS	40	8	8	8	8	8	$400/d @ 5 d/mo @ 4 mo/yr @ 5 yrs

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units) Total	FY14	FY15	FY16	FY17	FY18	Comments
1	4.5.4.2	Conduct research into the extent of seed predation by the non-native thistle weevil (*Rhinocyllus conicus*). If unacceptable impacts are discovered, develop and implement methods to reduce such seed predation.	CIHY	3 yrs	**UNIV**, PVT, SLT	18	6	6	6	-	-	$400/d @ 15 d/yr @ 3 yrs
3	4.5.4.3	Conduct other research on predator/prey and parasite/host relationships.	All	TBD	**UNIV**, PVT	TBD	TBD	TBD	TBD	TBD	TBD	
3	4.6	Establish cultivated populations for research purposes, where necessary.	All	3 yrs	**UNIV,** PVT, SLT, CNPS	48	16	16	16	-	-	Based on 4 species @ 10 d/species/yr
3	4.7	Establish research protocols, where necessary, and as determined by the RIT.	All	20 d	**USFWS,** CDFW, UNIV, PVT	16.84	16.84	-	-	-	-	20 d @ $842/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan

Action Priority	Action Number	Action Description	Species Benefitting	Action Duration	Responsible Parties	Cost Estimate (in $1,000 units)						Comments
						Total	FY14	FY15	FY16	FY17	FY18	
2	4.8	Conduct additional research identified as necessary by the RIT that address changing conditions and are supportive of highest priority recovery tasks.	All	TBD	**UNIV**, PVT	TBD	TBD	TBD	TBD	TBD	TBD	
2	4.9	Apply the results of all studies to conservation and recovery efforts.	All	Ongoing	ALL	TBD	TBD	TBD	TBD	TBD	TBD	
2	5.1.1	Establish the RIT.	All	10 d	**USFWS**	8.42	8.42	-	-	-	-	10 d @$842/d
2	5.1.2	Periodically convene the RIT to guide the implementation of this recovery plan.	All	Continual	**TEAM**	240	4.8	4.8	4.8	4.8	4.8	8 d/yr @$600/d for 50 yrs
2	5.2	Conduct outreach to partners in tidal marsh species recovery, including public and private landowners, and appropriate Federal, State, and local agencies.	All	Continual	**USFWS**	421	8.42	8.42	8.42	8.42	8.42	Calculated at 10 d/yr for 50 yrs
2	5.3.1	Develop general educational programs for public schools within the geographic scope of this recovery plan.	All	15 d	**USFWS,** UNIV, PVT	12.63	12.63	-	-	-	-	15 d @$842/d

Implementation Schedule for Tidal Marsh Ecosystem Recovery Plan												
						Cost Estimate (in $1,000 units)						
Action Priority	**Action Number**	**Action Description**	**Species Benefitting**	**Action Duration**	**Responsible Parties**	**Total**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**Comments**
2	5.3.2	Develop, maintain, and distribute updated information and educational materials to target audiences related to recovery and conservation of species covered in this recovery plan.	All	Continual	**USFWS**	70.18	4.21	-	-	4.21	-	Revisions and updates every 5 yrs (5 d every 3 yrs for 50 yrs)
2	5.3.3	Coordinate with local news media to promote local public interest in the recovery and conservation of species covered in this recovery plan.	All	Continual	**USFWS**	210.5	4.21	4.21	4.21	4.21	4.21	Calculated at 5 d/yr @$842 for 50 yrs

Priority 1 actions subtotal: $841,400,710

Priority 2 actions subtotal: $393,486,550

Priority 3 actions: subtotal: $7,614,380

Total Estimated Cost of Recovery through 2063: $1,242,501,640 + additional costs that could not be estimated at this time

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