CHAPTER 1

Introduction

Beginning some two hundred years ago, the San Francisco Bay Area started to undergo major changes. At first, these changes were small and localized. Then, in the 1850s, they accelerated and spread across the landscape. In less than two centuries, this region of remarkable beauty and biological diversity became an intensively urbanized center for industry, agriculture, and commerce. Today, the San Francisco Bay-Delta estuary is one of the most modified estuaries in the United States.

The development of the Bay Area has adversely affected nearly all the region's natural habitats, from the deep channels of the Bay to the forests of the coastal canyons. Perhaps most severely affected by these changes over the years have been the wetlands and lands closest to the Bay — the baylands.

The baylands and associated habitats are important for many reasons. They provide critical support for a diverse array of fish and wildlife, such as crab, salmon, seals, egrets, and ducks that many Bay Area residents associate with this rich and beautiful environment. Some bayland habitats also are home to species that are in danger of extinction, such as the salt marsh harvest mouse and California clapper rail. The wetlands within the baylands are important in many ways besides providing fish and wildlife habitat. For example, they help to improve water quality, protect lands from flooding, provide energy to the estuarine food web, and help stabilize shorelines against erosion.

Recognizing the importance of bayland habitats and considering the historical destruction of these limited resources, nine state and federal agencies and dozens of concerned scientists came together several years ago to develop a picture of needed habitat change. This effort was called the San Francisco Bay Area Wetlands Ecosystem Goals Project (hereinafter referred to as the Goals Project or Project), and this report presents the Project's recommendations.

The baylands provide some form of food, shelter, or other benefits to over 500 species of fish, amphibians, reptiles, birds, and mammals. In addition, there are almost as many species of invertebrates in the ecosystem as all the other animals combined. This brings to over one thousand the total number of animal species that use or call the baylands ecosystem home.

Project Purpose

The Goals Project was undertaken in June 1995 to establish a long-term vision for a healthy and sustainable baylands ecosystem. Shortly after the Goals Project began, the interagency group directing the effort — the Resource Managers Group (RMG) — developed this statement of purpose:

> The San Francisco Bay Area Wetlands Ecosystem Goals Project will use available scientific knowledge to identify the types, amounts, and distribution of wetlands and related habitats needed to sustain diverse and healthy communities of fish and wildlife resources in the San Francisco Bay Area. The Project will provide a biological basis to guide a regional wetlands planning process for public and private interests seeking to preserve, enhance, and restore the ecological integrity of wetland communities.

In keeping with this statement of purpose, the RMG prepared the recommendations presented in this report. It was the RMG's hope that this document would help guide future wetlands planning and improvement activities throughout much of the Bay Area.

Scope

The geographic scope of the Goals Project included the portion of the San Francisco Bay-Delta estuary[1] downstream of the Sacramento-San Joaquin Delta (**Figure 1.1**). Within this area, the Project designated four primary subregions: Suisun, North Bay, Central Bay, and South Bay. The box on page 4 describes the boundaries of each of these subregions.

Within these subregions, the Project focused on the baylands and the baylands ecosystem. The *baylands* are the lands that lie between the elevations of the high and low tides, including those areas that would be covered by the tides in the absence of levees or other structures. The *baylands ecosystem*, as defined by the Goals Project, includes the baylands and their adjacent waters and lands, and their associated communities of plants and animals. The baylands boundary is shown in **Figure 1.1**. The baylands ecosystem boundary, however, cannot be so clearly drawn, as the ecosystem extends into the adjacent areas, encompassing oak woodlands, grasslands, riparian areas, and other habitats.

For clarification, as used in this report, the term "Bay" refers to the estuarine waters within the Project's four subregions. The term "Bay Area" refers to those waters and the adjacent lands in the immediate Bay watershed.

Background

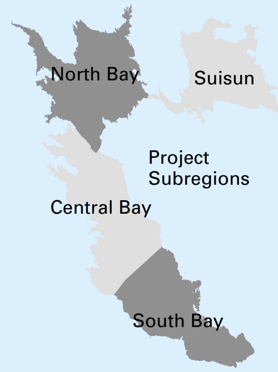
The need to establish a long-term vision for the Bay Area's wetlands arose initially during discussions among participants of the San Francisco Estuary Project

[1] Hereinafter referred to as the San Francisco Estuary.

FIGURE 1.1 **Project Area**

Project Subregions

To facilitate developing habitat goals, the Resource Managers Group defined four Project subregions. Each subregion has unique features and presents special opportunities and constraints to habitat enhancement and restoration. These subregions include Suisun, North Bay, Central Bay, and South Bay:



Suisun
The Suisun subregion is furthest upstream in the Project area. It extends from near Chipps Island on the Sacramento River downstream to the Carquinez Bridge. On its northern side is Suisun Marsh, and on its southern side is the Contra Costa shoreline. Its major streams include Green Valley Creek, Sacramento River, Suisun Creek, and Walnut Creek. This subregion lies within Contra Costa and Solano counties. It includes about 75,000 acres of baylands.

North Bay
The North Bay subregion encompasses the baylands and adjacent habitats of San Pablo Bay. Its boundary with the upstream Suisun subregion is the Carquinez Bridge. Downstream it abuts Central Bay on the western shore at Point San Pedro and on the eastern shore at Point San Pablo. Its larger streams include the Napa River, Sonoma Creek, Petaluma River, Novato Creek, and Gallinas Creek. Lands within this subregion are in Contra Costa, Marin, Napa, Solano, and Sonoma counties. It includes about 80,000 acres of baylands.

Central Bay
The Central Bay subregion includes the main body of San Francisco Bay. It extends along the western shore from Point San Pedro to Coyote Point, and along the eastern shore from Point San Pablo to the San Leandro Marina. Its major streams, all relatively small, include Codornices, Corte Madera, Temescal, and Wildcat creeks. Lands within this subregion are in Alameda, Contra Costa, Marin, San Francisco, and San Mateo counties. It includes about 33,000 acres of baylands.

South Bay
The South Bay subregion includes the southern-most portion of San Francisco Bay. It abuts the Central Bay subregion on the western side at Coyote Point, and on the eastern side at the San Leandro Marina. It has few major streams, and the larger of these include Alameda, Coyote, San Francisquito, San Mateo, and Stevens creeks. It includes lands in Alameda, Santa Clara, and San Mateo counties. It includes about 75,000 acres of baylands.

(Estuary Project). Established by the U.S. Environmental Protection Agency in 1987 as a part of its National Estuary Program, the Estuary Project was a seven-year collaborative effort involving the environmental community, private sector, and government. It focused much-needed attention on the San Francisco Estuary.

The Estuary Project identified the Estuary's most critical environmental problems and described them in a series of status and trends reports. In 1992, the *State of the Estuary* report summarized the status and trends reports and presented additional material. The Estuary Project then prepared its final major product, a *Comprehensive Conservation and Management Plan* (CCMP), which was signed in 1993 by the Governor of California and the Administrator of the U.S. Environmental Protection Agency.

The CCMP identified 145 actions necessary to "restore and maintain the estuary's chemical, physical, and biological integrity" (SFEP 1993). Its main wetlands recommendation called for the creation of a comprehensive, Estuary-wide plan to "protect, enhance, restore, and create wetlands in the Estuary." The CCMP specified that this plan be based on habitat goals designed to protect wildlife.

In 1994, the San Francisco Estuary Institute (Estuary Institute), a non-profit organization established by the Estuary Project, began developing and gaining agency support for a process to establish regional wetland habitat goals. At the same time, staff from the California Department of Fish and Game, National Marine Fisheries Service, and U.S. Fish and Wildlife Service, spurred by disagreements over the best way to approach tidal marsh restoration efforts, engaged in discussions aimed at improving consistency between the agencies and developing a "shared vision" for wildlife within the Estuary.

By early 1995, a group of agency biologists, the predecessor to the Project's RMG, had joined with the Estuary Institute and enlisted the help of the San Francisco Bay Regional Water Quality Control Board to organize and initiate a larger effort. The list of potential RMG members was expanded to include other state and federal resource agencies, and an Administrative Core Team was formed to administer the Project, to procure funding, and to provide public outreach. In June 1995, the San Francisco Bay Regional Water Quality Control Board and the Estuary Institute sponsored a workshop, initiating the process to establish wetland habitat goals.

"In the early 1990's, the agencies reviewed several proposals to dispose of dredged material on diked baylands. Interagency discussions regarding these projects were often rife with conflict, largely because we were trying to solve region-wide habitat issues on a project-by-project basis."

– RMG Member

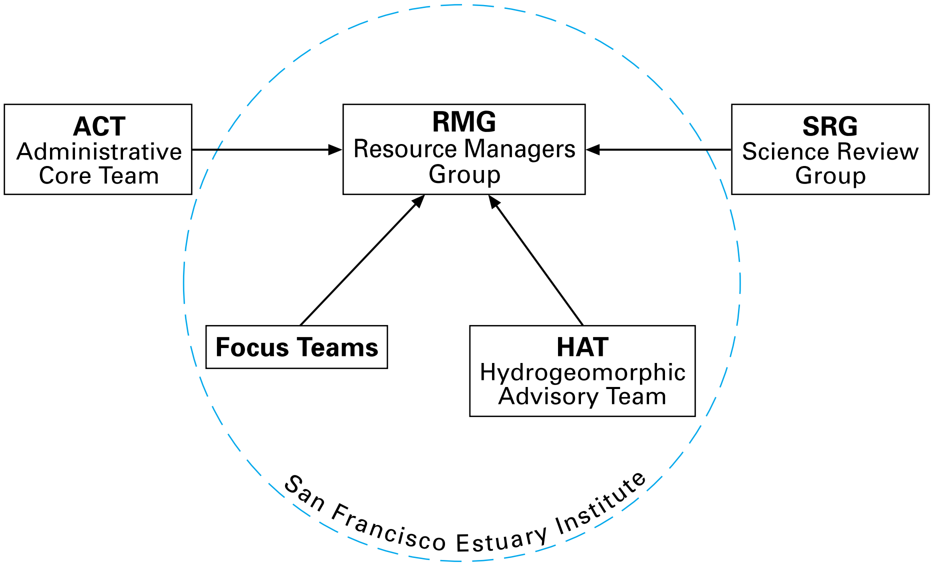
Participants and Project Organization

Goals Project participants included representatives from local, state, and federal agencies, academia, and the private sector. Participants were organized into several groups, and each group had a unique role. **Figure 1.2** illustrates the relationship among the groups. Public resource or regulatory agencies sponsored many of the Goals Project's participants. However, because the Goals Project sought to develop recommendations based on science, the RMG asked participants to engage as scientists rather than as agency representatives. *It is important to recognize that an agency's participation in the Goals Project does not necessarily mean that the recommendations in this report comply with the agency's mandates or policies.*

Resource Managers Group

The Resource Managers Group (RMG), composed of senior agency ecologists, biologists, and managers, oversaw all technical aspects of the Project. They met often during the course of the Project and directed workshops and focus team activities. The RMG had final responsibility for the content of the Goals. Members of the RMG included representatives from the California Coastal Conservancy, California Department of Fish and Game, California Department of Water Resources, National Marine Fisheries Service, San Francisco Bay Conservation and Development Commission, San Francisco Bay Regional Water Quality Control Board, U.S. Environmental Protection Agency, and U.S. Fish and Wildlife Service.

FIGURE 1.2 Project Structure



Focus Teams

Five focus teams of scientists with recognized expertise in populations of plants, fish, and wildlife made recommendations to the RMG regarding the needs of their target plant and animal groups. RMG members served as the leaders of the focus teams and were responsible for relaying information between the teams and the RMG. The focus teams included a broad representation of scientists from local, state, and federal agencies, local districts, private consulting firms, universities, and other interests.

Hydrogeomorphic Advisory Team

The Hydrogeomorphic Advisory Team (HAT) included hydrologists, geologists, and engineers from state and federal agencies, universities, and private consulting firms. It assisted the focus teams by responding to general questions about hydrological, geological, and infrastructure constraints on wetland enhancement and restoration. The RMG did not ask the HAT to comment on individual or site-specific recommendations.

Science Review Group

The RMG established a Science Review Group (SRG) to provide critical review of the Project's process and products. The members of the SRG were carefully selected to assure a strong panel of scientists with expertise in disciplines such as ecosystem analysis, integrated resource planning, and conservation biology. The RMG considered this sort of "big picture" critiquing an essential complement to the scientific peer review provided by the focus team scientists. SRG members included:

- Dr. Steven Beissinger, Associate Professor of Conservation Biology, University of California, Berkeley

- Dr. Theodore Foin, Professor of Agronomy and Range Science, University of California, Davis
- Mr. David Hulse, Professor of Landscape Architecture, University of Oregon, Eugene
- Dr. Luna Leopold, Emeritus Professor of Landscape Architecture, Geology, and Geophysics, University of California, Berkeley
- Dr. Charles Simenstad, Coordinator of the Wetland Ecosystem Team, School of Fisheries, University of Washington, Seattle
- Dr. Joy Zedler, Aldo Leopold Professor of Restoration Ecology, University of Wisconsin, Madison

Dr. Leopold chaired the SRG, which was convened in February 1997.

Administrative Core Team

An Administrative Core Team (ACT) provided Project administration and public outreach and helped procure funding. ACT members included representatives from the California Department of Fish and Game, California Resources Agency, San Francisco Bay Conservation and Development Commission, San Francisco Bay Joint Venture, San Francisco Bay Regional Water Quality Control Board, San Francisco Estuary Institute, San Francisco Estuary Project, and U.S. Environmental Protection Agency. The San Francisco Bay Regional Water Quality Control Board and U.S. Environmental Protection Agency provided Project management.

San Francisco Estuary Institute

The Estuary Institute developed the original process adapted by the RMG to establish habitat goals and provided science coordination and technical support. One of the Estuary Institute's main roles was helping Project participants to understand and visualize habitat distribution and change through time. To do this, Estuary Institute staff compiled maps and other data requested by the focus teams in a computerized Geographic Information System (GIS) called the Bay Area EcoAtlas. The EcoAtlas represents the most detailed documentation of the historical and modern distribution of baylands habitats. All the maps and acreage estimates of past and present conditions in this report were produced by the Institute staff using the EcoAtlas.

The Estuary Institute also helped the focus teams and the RMG to visualize and quantify their habitat recommendations using the EcoAtlas. Appendix A contains additional information on the EcoAtlas, which may be viewed on the Estuary Institute's website at http://www.sfei.org.

Public Outreach

The Administrative Core Team developed an outreach program to inform the public about the Project. Outreach efforts included workshops, meetings, informational brochures, periodic reports, and news releases. Public outreach began immediately upon Project initiation and continued throughout its life span. Chapter 3 describes the major components of this outreach.

Funding

Funding for the Goals Project began in 1994, in preparation for the first RMG meeting. Most of the early funding supported the Estuary Institute's background scientific work and development of the EcoAtlas. Some agencies paid for parts of the EcoAtlas for use in planning and management efforts unrelated to the Goals Project. Throughout the Project, several agencies continued to provide funds for additional science support, public outreach, administration, and report production. Without this generous support, the Goals Project would not have been possible.

The agencies and groups providing funding that directly or indirectly helped support preparation of the habitat goals included the CALFED Bay-Delta Program, California Coastal Conservancy, California Department of Fish and Game, California Resources Agency, City of San Jose, San Francisco Bay Conservation and Development Commission, San Francisco Bay Regional Water Quality Control Board, Sausalito-Marin City Sanitation District, Shell Oil Spill Litigation Settlement Trustees, State Office of Oil Spill Prevention and Response, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and others.

The Baylands Past and Present

A report on the effort to establish habitat goals for San Francisco Bay and the surrounding landscape would be incomplete without an overview of the baylands. This chapter describes the baylands and the main factors that influence their evolution. It also describes how the baylands have changed since the arrival of Europeans. Finally, it describes the effects of these changes on several species of plants, fish, and wildlife.

Definition of the Baylands

The baylands consist of the shallow water habitats around the San Francisco Bay between the maximum and minimum elevations of the tides (BCDC 1982, Bay Institute 1987). They are the lands that are touched by the tides, plus the lands that would be tidal in the absence of any levees, sea walls, or other man-made structures that block the tides (**Figure 1.1**). Landward of the baylands are their watersheds. Bayward are the shallow and deep waters of the open bays and straits.

The baylands include tidal and diked habitats. Tidal baylands are subject to the daily action of the tides. Diked baylands are areas of historical tidal habitats that have been isolated from the usual action of the tides by the construction of levees, tide gates, or other water control structures. These two major kinds of habitats contain other kinds that are smaller, such that the baylands as a whole consist of many levels of ecological organization.

The term "ecosystem" refers to the abiotic environment plus its communities of plants and animals. An ecosystem can be viewed as the product of three basic characteristics: ecological structure of the communities, physical structure of the environment, and the functions of the ecosystem, such as nutrient cycling and food production.

The Baylands Ecosystem

The baylands ecosystem includes the baylands, adjacent habitats, and their associated plants and animals. The boundaries of the ecosystem vary with the bayward and landward movements of fish and wildlife that depend upon the baylands for survival. For example, several species of fish, such as Pacific herring and Chinook salmon, rely on the baylands, but also utilize local streams or deeper portions of the Bay at certain times in their life cycles. Schools of Pacific herring mobilize in deep channels of the Bay and then move toward the shoreline to lay their eggs in shallow water. Adult Chinook salmon migrate upstream through the deeper channels of the bays to spawn in the watersheds of the Estuary, and young salmon forage in shallow water habitats on their way to the ocean. Marine mammals, such as the harbor seal and California sea lion, use the baylands at certain times for resting and feeding. Smaller mammals, such as the salt marsh harvest mouse, take refuge on levees and in the adjacent uplands to avoid the highest tides. Great blue herons forage in the baylands, but may roost in the

What is a Wetland?

Many of the habitats of the bayland ecosystem are wetlands. Given the Project's emphasis on establishing prescriptions for the amounts and distribution of wetlands, it is appropriate to briefly review some common wetland definitions.

In general, the term "wetland" refers to areas that are covered with shallow and sometimes temporary or intermittent waters. Smith (1980) described wetlands as halfway worlds between terrestrial and aquatic ecosystems that exhibit some of the characteristics of each. Wetlands occur along gradients between well-defined aquatic conditions and uplands, exhibit a wide range of hydrology, and vary considerably in size, location, and appearance.

After years of review, the U.S. Fish and Wildlife Service developed perhaps the most comprehensive definition of wetlands. This definition was first presented in a report entitled *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al. 1979) and is commonly referred to as the Cowardin definition. According to this definition:

> "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."

Today, the U.S. Fish and Wildlife Service and the California Department of Fish and Game both use the Cowardin definition in their efforts to protect and manage wetlands. The U.S. Army Corps of Engineers (Corps) and the U.S. Environmental Protection Agency (EPA) use another definition of wetlands when regulating the discharge of dredged or fill material to waters of the United States under Section 404 of the Clean Water Act. This definition reads:

> "The term "wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." (33 CFR 328.3(b); 1984)

In using this definition for regulatory purposes, the Corps and EPA require that a wetland have *all three* parameters: appropriate soils, hydrology, and vegetation. Thus, this definition is much stricter than the Cowardin definition, which defines a wetland as having *one or more* of these parameters.

For purposes of establishing habitat goals, Project participants used the more expansive Cowardin definition of wetlands, as it is more inclusive and appropriate for ecological planning purposes. Using this definition, most of the baylands are considered to be wetlands.

adjacent uplands. Some songbirds, such as the salt marsh common yellowthroat, move up and down local streams, from the brackish zones of tidal reaches to the riparian forests.

Chapter 3 lists the key species of the baylands ecosystem. Chapter 4 describes the ecosystem's key habitats and the ways in which they support some of the key species.

Evolution of the Baylands

The evolution of the baylands is closely related to the history of changes in sea level. At the end of the last glacial period, some 15,000 to 18,000 years ago, the seas began their most recent rise, and about 10,000 years ago, ocean waters began to flood the valleys now occupied by the Estuary. Sea level rise slowed over time, from an initial rate of about 0.8 inch per year (Atwater 1979), to the current rate of about 0.1 inch per year, beginning about 6,000 years ago. (Atwater 1979, Hutchinson 1992, Byrne 1997). Between about 2,000 and 3,000 years ago, mudflats and tidal marshes began to form around the edges of western Suisun, North Bay, Central Bay, and South Bay.

The decreased rate of sea level rise helps explain the older marshes in the eastern part of the Estuary, towards the Delta. The marshes of the Delta are older than the marshes of the Bay Area. The Delta marshes of the ancient Sacramento and San Joaquin rivers formed behind the narrow passage now called Carquinez Strait, before the sea rose through the Golden Gate. After the rapidly rising sea passed through the Strait into Suisun, it slowed. Some of the marshes in the far western part of Suisun were drowned by the rapidly rising sea, but the marshes further east survived. This partly explains why there are very large open bays downstream of Carquinez Strait, small bays in western Suisun, and no large natural open bays in the Delta (Collins and Foin 1993).

Some of the current global climate change models predict future rates of sea level rise that exceed the early rates for the Estuary (Gleick et al. 1999). How the baylands might respond to such a rapid increase in sea level is unknown. Their response will depend on the supplies of sediment and runoff, which may increase or decrease with climate change, depending partly on how the land is managed.

Natural Habitat Controls

There are several major factors that influence the form and function of the baylands ecosystem. Some, such as climate and sea level rise, are global in nature and have affected the formation of the Estuary over the millennia. Others are more local, and these include topography; the ebb and flow of the tides; the volume, timing, and location of freshwater inflow; and the availability and types of sediments. This section describes these natural habitat controls.

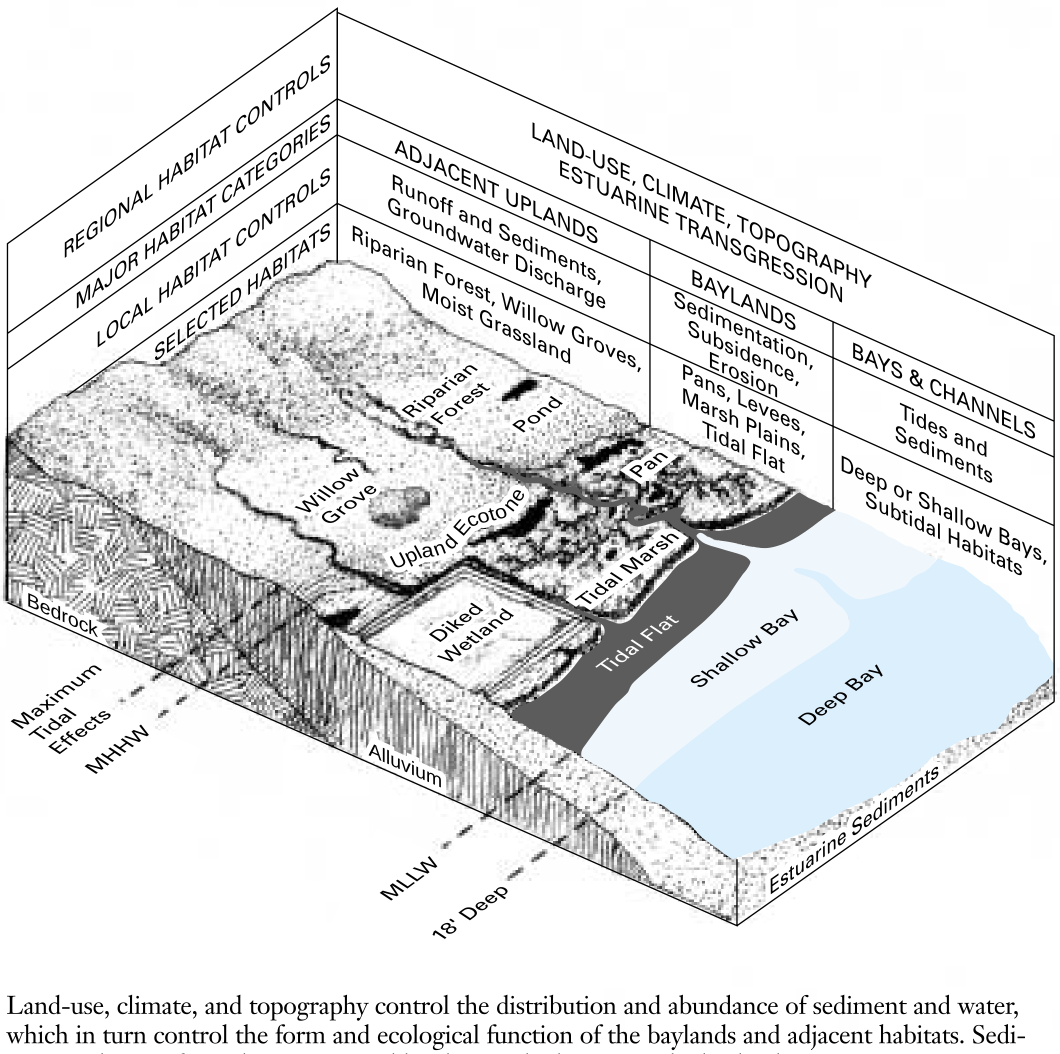
Many different models may be used to study the relationships of habitat controls and their effects on the baylands ecosystem. Several useful models are described in recent work done for the CALFED Bay-Delta Program's Comprehensive Monitoring and Research Program (CALFED 1998a). **Figure 2.1** illustrates some of the ways habitat controls may interact to influence the baylands.

The interactions among the baylands' natural habitat controls are complex and powerful; the baylands are constantly responding to the ebb and flow of the tides and to changes in water and sediment supplies. The natural biological diversity of the baylands ecosystem is critically dependent on this dynamic environment.

Climate

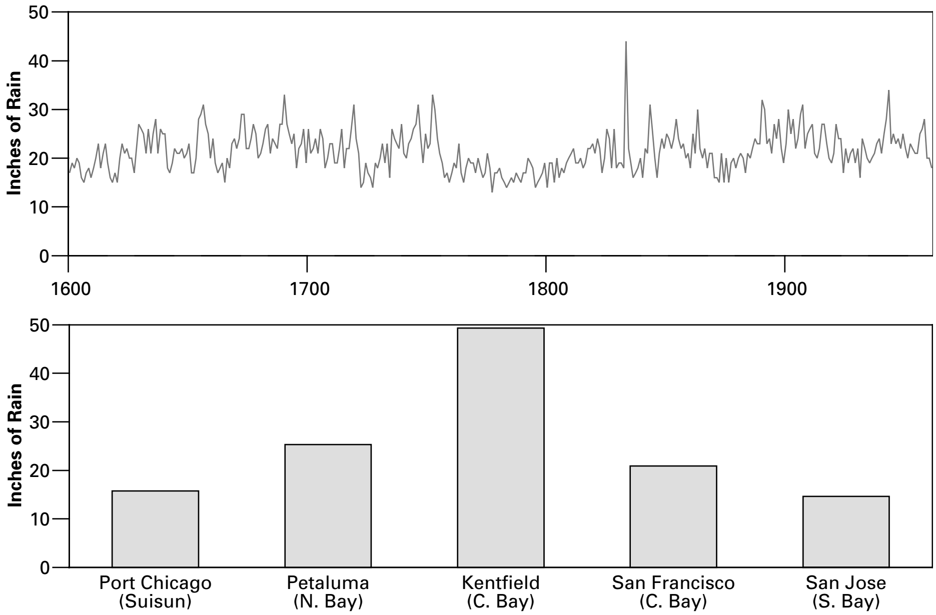
The climate of a region is defined by the seasonal and year-to-year patterns of air temperature and rainfall. Climate is forever operating on the baylands; it ultimately controls the *amount* of water and sediment that is available to create and maintain

FIGURE 2.1 Relation of Local and Regional Factors that Control Baylands and Adjacent Habitats



Land-use, climate, and topography control the distribution and abundance of sediment and water, which in turn control the form and ecological function of the baylands and adjacent habitats. Sediment and water from the Estuary and local watersheds meet at the baylands. Estuarine transgression means that the Estuary and its baylands move inland as sea level rises. Figure is modified from Helley et al. 1979.

FIGURE 2.2 **Rainfall Patterns**



The tree ring index of rainfall since 1600 (Fritts and Gordon 1980) shows little change in the annual average amount of rain for northern California, despite large differences between some years, and despite differences between subregions of the baylands ecosystem (NCDC 1998). The data suggest that the restored baylands would be subject to similar climatic controls as the historical baylands.

the baylands. For example, during winter storms and strong winds, erosion in the uplands and waves in the bays increase the availability of sediment (Krone 1979). The timing and amount of rainfall affect the salinity of the tides and soil. Temperature affects the potential rate of evaporation, which in turn affects the timing and amount of ponding in diked baylands (SFEI 1994).

Climatic conditions change slowly. For example, the long-term, average annual values for rainfall have not changed significantly for any of the four subregions of the Bay Area in the past two hundred years, despite obvious differences among the subregions, and despite seasonal and year-to-year variations everywhere (**Figure 2.2**).

Topography

Topography controls the *distribution* of water and sediment. The topography of tidal baylands determines the frequency and duration of tidal inundation and where the tides go. The topography of diked baylands and adjacent uplands affects runoff and groundwater recharge. Slight variations in topography can have ecologically significant effects on the distribution of water on the ground surface. Like climate, topography changes slowly, except for the local effects of floods, landslides, earthquakes, and people.

The slope of the terrain near the Estuary strongly influences the width of local baylands. In areas where the shoreline is steep, as in many parts of Central Bay and along the Carquinez Strait, the baylands are restricted to narrow fringes bordering deeper water. In areas where the terrain is flatter, as in much of South Bay, North Bay, and Suisun, the baylands are broader.

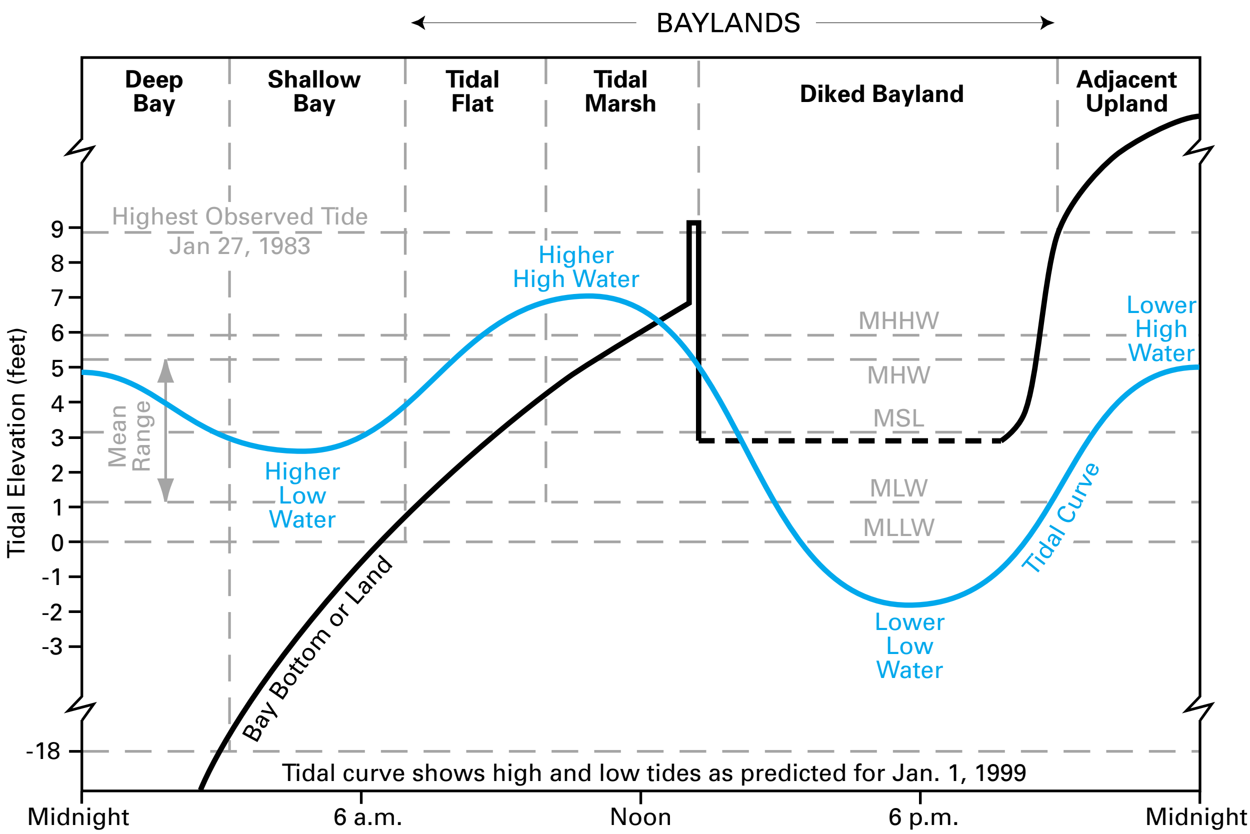
Water

The major sources of water for the baylands are the tides and freshwater runoff from watersheds. The characteristics of these sources have changed significantly over time. The tides have changed naturally throughout the Estuary for centuries as a result of sea level rise. Runoff has also changed substantially, but mostly as a result of land use changes rather than natural causes. It has decreased in some areas and has increased in others.

Tides and Sea Level

The tides are the major source of water for tidal baylands. They are also an important water source for many diked habitats, particularly managed marsh during droughts. In the Estuary, there is a mixed-diurnal type of tide (**Figure 2.3**). This means that there are two high tides and two low tides almost every day. The range of the tide is greatest around the new moon and full moon of each month. These are called spring tides. The tides that correspond to the quarter phases of the moon are called neap tides. The highest spring tides tend to occur in January and June.

FIGURE 2.3 Tidal Datums



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.

What is a Tidal Datum?

The word "tides" most commonly refers to the alternating rise and fall of the oceans. The National Ocean Survey (NOS) measures every tide almost continuously at two tide stations in the San Francisco Estuary. These measurements are used to estimate average heights of the tides for each tidal epoch, which is the 19-year interval between alignments of the moon, the sun, and the earth. If the moon is full today, then it will be full again on this date in 19 years.

The average local heights of the tides are called tidal datums. The average height of the higher of the two high tides is called local Mean Higher High Water (MHHW). The average of all the high tides is called local Mean High Water (MHW). There are many other datums, including Mean Lower Low Water (MLLW), Mean Low Water (MLW), and Mean Tide Level (MTL), which is midway between MHW and MLW. Mean Sea Level (MSL) is the average of all the tide measurements for a tidal epoch. Local MLLW is the zero datum of the tides, or zero tidal elevation. "Minus tides" are below MLLW.

Many things affect local water levels of the Estuary. Besides the sun and moon, there is wind, barometric pressure, shape of the Estuary, and distance from the Golden Gate. Water levels vary within tidal marshes because of friction in tidal channels.

Tidal datums have also been used to measure land elevations. Values for Mean Sea Level in 1929 were adopted as the National Geodetic Vertical Datum (NGVD 29), or zero elevation for measuring land height. Benchmarks were established throughout the United States marking local elevations relative to NGVD 29. Since then, disturbance and loss of many benchmarks has warranted a new datum. The NGVD 29 is being replaced by the North American Vertical Datum of 1988 (NAVD 88), and new geodetic datums are being planned to make use of improved surveying technology.

Tidal datums must be recalculated periodically because sea level is changing. During the last few thousand years, sea level in the San Francisco Estuary has been rising at an average rate slightly greater than about 0.1 inch per year, or about 1 foot per century. Tidal datums are recalculated for each new tidal epoch, beginning in 1929.

The tides influence the baylands in three basic ways. They carry nutrients, sediments, salts, and other materials to and from the baylands; they create gradients of decreasing moisture and amount of tidal action from lower to higher tidal elevations; and they provide the physical means for fish and other aquatic organisms to move across tidal flats and marshes at high tide.

Sea level affects the elevation of the tides. As sea level rises, so do the elevations of the tides, relative to the uplands. As noted above, rising sea level started to form the Estuary some 10,000 years ago. The rising sea will continue to exert a strong effect on the baylands in the future. One of the most obvious effects will be the increased flooding associated with higher tides. It has been predicted that a one foot rise in sea level could double the average number of floods of Delta islands (Logan 1990). Rising sea level will necessitate adding or improving bank stabilization and flood protection features throughout the baylands; levees will need to be raised, and other similar features strengthened.

On flatter lands around the Estuary, primarily in Suisun, North Bay, and South Bay, rising sea level will make it possible for tidal marshes to expand and

The Mixing Zone

Estuaries are places where fresh water runoff from the land meets with salt water from the ocean. Fresh water is less dense and tends to flow over the salt water. The two layers of water mix along their interface, creating a brackish salinity regime. The brackish mixing zone varies in length depending on the range of the tide and the amount of freshwater.

Suspended sediment and nutrient particles tend to accumulate in the mixing zone (Arthur and Ball 1979). Terms such as "null zone," "entrapment zone," " zone of maximum turbidity," and "X2" (Kimmerer 1998) have been used to describe some of the particular characteristics of this zone.

In the San Francisco Estuary, fresh water from the Delta usually meets ocean water in the vicinity of Suisun Bay. Here, the mixing zone may be several miles long and is most prominent when Delta outflow is high (Conomos 1979, Arthur et al. 1985). Similar but smaller zones occur along every river and creek that flows into the Estuary.

The mixing zones can be the Estuary's most productive areas. Here is where the production of tiny plants called phytoplankton is greatest. Small zooplankton feed on these phytoplankton, and these in turn are fed upon by fishes, such as Pacific herring, Delta smelt, and young striped bass and salmon (SFEP 1992). The mixing zones are therefore considered to be of critical importance to the aquatic food web of the Estuary.

Restoring tidal marshes and tidal flats around Suisun Bay and along the local rivers and creeks would increase the amount of nursery, resting, and escape habitat for many aquatic species that are associated with these highly productive portions of the Estuary.

move landward, provided there is an adequate supply of sediment to maintain the marsh plain. However, given the likelihood that the owners of lands adjacent to the baylands will seek to protect their properties from the rising sea, there may be little undeveloped land available for new tidal marshes.

The rising sea will also change the salinity regime of the brackish baylands. As the sea rises and saline water moves further inland, salinity gradients will shift upstream. The salinity of Delta channels will become more like that of Suisun today, and the vegetation influenced by the tides will become more brackish. Likewise, as Suisun Marsh becomes more saline, its vegetation will become more like the vegetation that now exists around North Bay. The inland movement of the Estuary is called estuarine transgression (**Figure 2.1**). It has been an ongoing process since the last ice age.

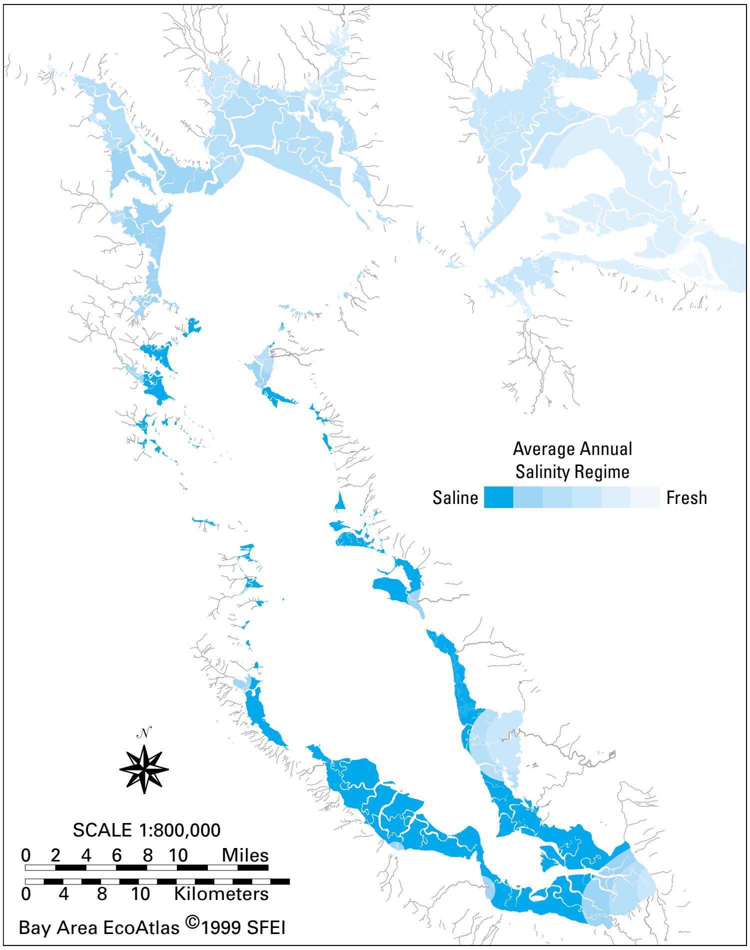
To preserve the natural diversity of the baylands, tidal marshes must be restored along the salinity gradients of the Estuary, such that fresh and brackish species of plants and animals have someplace to go as sea level rises and the Estuary moves inland.

Freshwater Flows

Fresh water naturally reaches the baylands through rivers and creeks and, to a much lesser extent, as surface and subsurface runoff. Unnatural sources of fresh water include storm drains and the discharge pipes from sewage treatment facilities.

Fresh water affects salinity conditions and many physical and biological processes throughout much of the Estuary. These effects occur at various geographic scales. For example, the flows of the Sacramento and San Joaquin river system influence the large salinity gradient from the Delta to Central Bay and even South Bay. The flows of smaller creeks and streams affect local salinity gradients (**Figure 2.4**).

FIGURE 2.4 **Regional Map of Salinity Gradients**



Under natural conditions, the seasonal timing of freshwater flows would differ between the Sacramento and San Joaquin river system and the local watersheds of the Bay Area. For the Sacramento and San Joaquin rivers, flows would generally increase in late fall, with the onset of the wet season, and continue to increase throughout the winter, peaking in spring during snowmelt, then declining to annual low levels during late summer. For the local watersheds that do not get snow, the freshwater flows would peak in winter, rather than in spring. Many of the native species of fish and wildlife are adapted to these different flow regimes.

Sedimentation

Sediment exerts an important control on tidal baylands. Without an adequate supply of sediment and an environment that promotes sediment deposition, tidal marshes and tidal flats erode or will not form. There are two main sources of sediment for the baylands: inorganic silts and clays that are generated by freshwater flows, tidal currents, and wind-driven waves; and organic sediments that are created by the growth of plants within the baylands.

FIGURE 2.5 Suspended Sediment Downstream of the Delta

In this photograph, the lighter shades of bay and river water represent large amounts of suspended sediment provided by the Sacramento River after heavy winter storms in the Sacramento Valley. The rising tide is moving sediment-laden surface water into the baylands of Suisun and North Bay.

USACE 1974

More than six million cubic yards of inorganic sediment enter the Estuary annually from watersheds, mostly from the Sacramento and San Joaquin river system, and local watersheds supply the remainder (**Figure 2.5**). Only a small proportion of this sediment is transported to the baylands. The rest settles out on the bottom of the Estuary or is carried to the ocean (Krone 1979 and 1985, Ogden Beeman and Associates 1992).

Within the tidal marshes, inorganic sediments mostly occur within the channels and along their immediate margins (Leopold et al. 1993). Plant production and the accumulation of organic sediments account for most of the sedimentation on the tidal marsh plains (Collins et al. 1987). This pattern varies with marsh elevation, such that lower marshes receive more inorganic sediments.

A key question regarding large-scale tidal marsh restoration is whether there will be an adequate supply of sediment in the long term to restore and maintain the baylands. Although it is difficult to answer this question with a high degree of certainty, a couple of factors indicate that sediment availability will likely decline in the coming decades. First, as the large amount of sediment from Gold Rush hydraulic mining continues to pass through the Estuary, the volume of re-suspended sediment will decline (Jaffe et al. 1998). Second, recent research indicates that the volume of sediment provided to the Estuary by the Sacramento River has declined by about one-half since 1960, mostly as a result of dams (Krone 1979 and 1985). Assuming that existing and perhaps additional dams continue to trap sediments, it is reasonable to also assume that there will be less material coming into the Estuary through the Delta in the future. This suggests that large-scale tidal marsh restoration will probably need to occur over a period of many decades, and that the rate of restoration will need to be closely linked to sediment availability. As described in Chapter 6, the limited use of dredged material may be appropriate in certain circumstances to augment the natural sediment supply for purposes of restoring and enhancing the bayland habitats.

The rate of sedimentation affects the evolution of tidal habitats. In subsided areas of the Bay, tidal marsh restoration will proceed primarily by deposition of suspended sediment. Although deposition rates vary around the Bay, tidal marshes eventually reach intertidal heights suitable for plants, and later, with the addition of organic sediments that the plants provide, the marshes reach equilibrium with sea level rise. Initial accretion rates of more than two feet per year are common in deeply subsided sites, but these rates decrease as the marsh plain rises. This means that the upward building of a marsh gets slower as the marsh gets higher. Mature tidal marshes have plains above the average high tide.

Tidal marsh restoration projects underway at several sites in the Estuary indicate that substantial accretion and re-colonization by marsh vegetation can occur quickly. For example, the Petaluma River Marsh has accreted sediment at a rate of about 1.5 feet per year since the site was opened to tidal action in 1996, and marsh vegetation is becoming well-established (Siegel 1998). Marsh vegetation began to colonize Pond 2A in the Napa Marsh within six months after it was opened to tidal action in 1993 (Swanson, pers. comm.). At Pond B-1 in South Bay, the site of a wetlands mitigation project, sedimentation rates greatly exceed the rates required by the U.S. Army Corps of Engineers permit, and pickleweed and cordgrass are becoming established in several areas (WRA 1998). Other sites of recent tidal marsh restoration, where sediment is accumulating quickly, include White Slough near the Napa River, Toy Marsh near Black Point, and outer Bair Island on the western side of South Bay. Some of these sites are discussed further in Chapter 6.

The sediment deposition rates in the above examples are high compared to rates for existing, older, higher marshes. For example, studies in South Bay indicate that the average annual deposition in three marshes over the past several decades ranged from about one-quarter inch to about two inches (Patrick and DeLaune 1990). Studies of sedimentation in remnants of historical tidal marshes in North Bay have revealed rates that match average sea level rise (Byrne 1997).

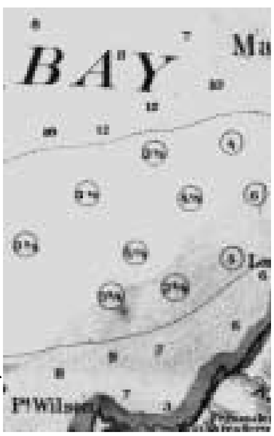
The Project's Hydrogeomorphic Advisory Team estimated that natural sedimentation in South Bay would take about 10 to 15 years to raise the bottom of a moderately subsided (minus 3 feet Mean Sea Level) salt pond to an elevation where native vegetation would become established. In the most severely subsided areas, as at New Chicago Marsh near Alviso, where the ground has subsided as much as 15 feet (Helley et al. 1979), natural restoration of tidal marsh would take longer. In North Bay, where diked lands have typically subsided less than in the South Bay, tidal marsh restoration using natural sedimentation could occur much faster.

Estimated rates of sedimentation are based on historical and existing sediment concentrations. While these concentrations are not expected to change quickly, it is important to recognize that the long-term sediment budget for the Estuary likely will differ from present conditions.

Environmental History of the Baylands

This section describes the past and present distributions of the baylands and adjacent habitats. Much of the information was derived from the views of the past and present baylands provided by the EcoAtlas (**Figures 2.6** and **2.7**). Appendix B presents past and present acreage of the key habitats in each of the Project's four subregions. These acreage values were also derived from the EcoAtlas, and the graphs presented in this chapter are based on them.

A View of the Past



Whitney 1873

This view of the past describes the bays, baylands, and adjacent habitats as they appeared about 200 years ago, when Europeans first arrived in the region. The descriptions start in the bays and move progressively through shallower tidal systems to the backshore, or ecotone, between the baylands and the adjacent watersheds.

The deep parts of the Estuary contained the submerged topography of ancient valleys, with old river courses draining the Santa Clara Valley and the Central Valley. Shallow water dominated the broad tidal basins of Suisun, North Bay, and South Bay. Central Bay was and is deeper and more subject to wave action from the outer coast. Together, the deep and shallow bays totaled about one-quarter of a million acres, roughly the same amount as the adjoining baylands.

Each major tributary had tidal flats and tidal marshes arrayed along a salinity gradient created by local runoff. Some gradients were steeper because they extended over short distances from fresh to saline conditions. Other gradients extended for longer distances from fresh to brackish conditions. For example, brackish marshes extended several miles along the larger creeks in North Bay, Central Bay, and South Bay. These subregional and local gradients of salinity created a complex system of tributary estuaries arrayed along the major salinity gradient between the Golden Gate and the Delta, which supported great physical and biological diversity (see **Figure 2.4**).

Each day, as the tide went out, almost 50,000 acres of tidal flats emerged along the margins of the bays and larger tidal channels. Under fresher conditions in Suisun and North Bay, where marsh plants colonized the lower intertidal zones, flats were scarce and relatively narrow. The steep topography and strong currents and waves limited their distribution in Central Bay. In South Bay, flats were ubiquitous and as wide as two miles.

Sandy beaches were common only in Central Bay and on the eastern shore of North Bay, where winds and waves could deposit coarser sediments, including sands, along the shoreline. There were about 23 miles of narrow beaches fringed with marshes and flats. Some of the beaches impounded runoff to form natural tidal lagoons, particularly along the steeper terrain of the San Francisco Peninsula and the Marin shoreline.

Landward of the flats and beaches around the Estuary were almost 200,000 acres of tidal marshes. Much of this habitat consisted of vast, contiguous tidal marshes that extended across 50,000 or more acres in Suisun, North Bay, and South Bay. In Central Bay, tidal marshes were much smaller, from tens of acres to several thousand acres, due to the steep topography.

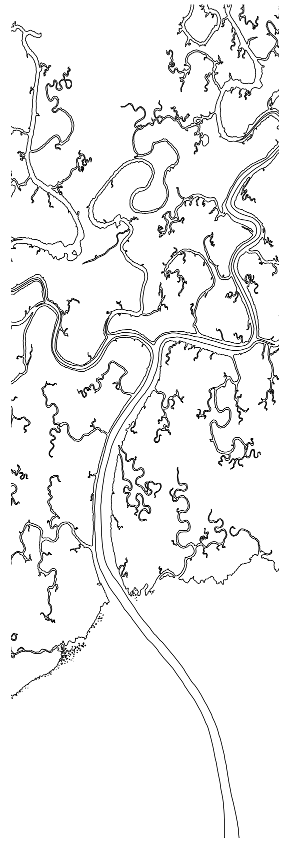
Large tidal channels connected the marshes to the bays and spread into dendritic networks of thousands of smaller channels distributed throughout the marshes. At their mouths, the major channels were several hundred feet across; the great volume of water that flowed in and out of the channel networks during each tidal cycle maintained deep and shallow channels through the marshes, tidal flats, and into the bays. In North Bay and South Bay, tidal flats extended along the banks of the larger tidal channels.

Looking at the marshlands from an adjacent hill, one would see hundreds, or thousands, of shallow pans scattered between the sinuous channels. These natural tidal marsh pans ranged in size from tens of feet in diameter to, in the case of the Sixth-Reach Pond in Suisun, two-thirds of a mile long. They were smallest and most numerous in the most saline marshes, and larger where conditions were more brackish.

Along the backshore of the saline marshes, where they met the adjacent uplands, the pans tended to be longer and narrower. In South Bay, these pans formed a nearly continuous string of shallow intertidal habitats. Native people used some pans for salt production and perhaps for waterfowl hunting. The best known of these pans, the Crystal Pond complex, in the Yrgin tribal region, covered more than 1,000 acres. It had physical and ecological similarities to some of the modern commercial salt ponds.

Adjacent to the baylands in the flatter portions of the region, especially at the entrances to broad valleys, the tidal marshes graded gently into low-lying moist grasslands. These grasslands evolved on patches of poorly drained soils of fine clay. Where the winds from across the bays were strongest, they extended the influence of salt inland (Helley et al. 1979), widening the transition zone between tidal marsh and adjacent upland. Near Fremont, Sonoma, and Potrero Hills, the transition zone involved grasslands with vernal pool complexes on ancient, impervious soils.

In this semi-arid region, where evapotranspiration can exceed precipitation by a factor of two or more (Rantz 1971), perennial ponds and lakes were uncommon. The greatest number of persistent, non-tidal, freshwater ponds and marshes occurred in the largest valleys with large catchment basins, such as the Santa Clara Valley, where the water table was close the ground surface. There were scattered springs and seeps along the backshore, where groundwater emerged at the edge of the tidal marsh, and along fault zones. Sag ponds existed along the San Andreas and Hayward faults in South Bay. In North Bay, Lake Tolay, an unusual feature in the hills between the Sonoma and Petaluma marshlands, covered several


Christina Wong

Intricate channels form in older tidal marshes.

The Yrgin worked the marsh for salt.

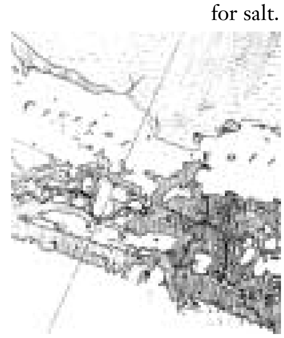
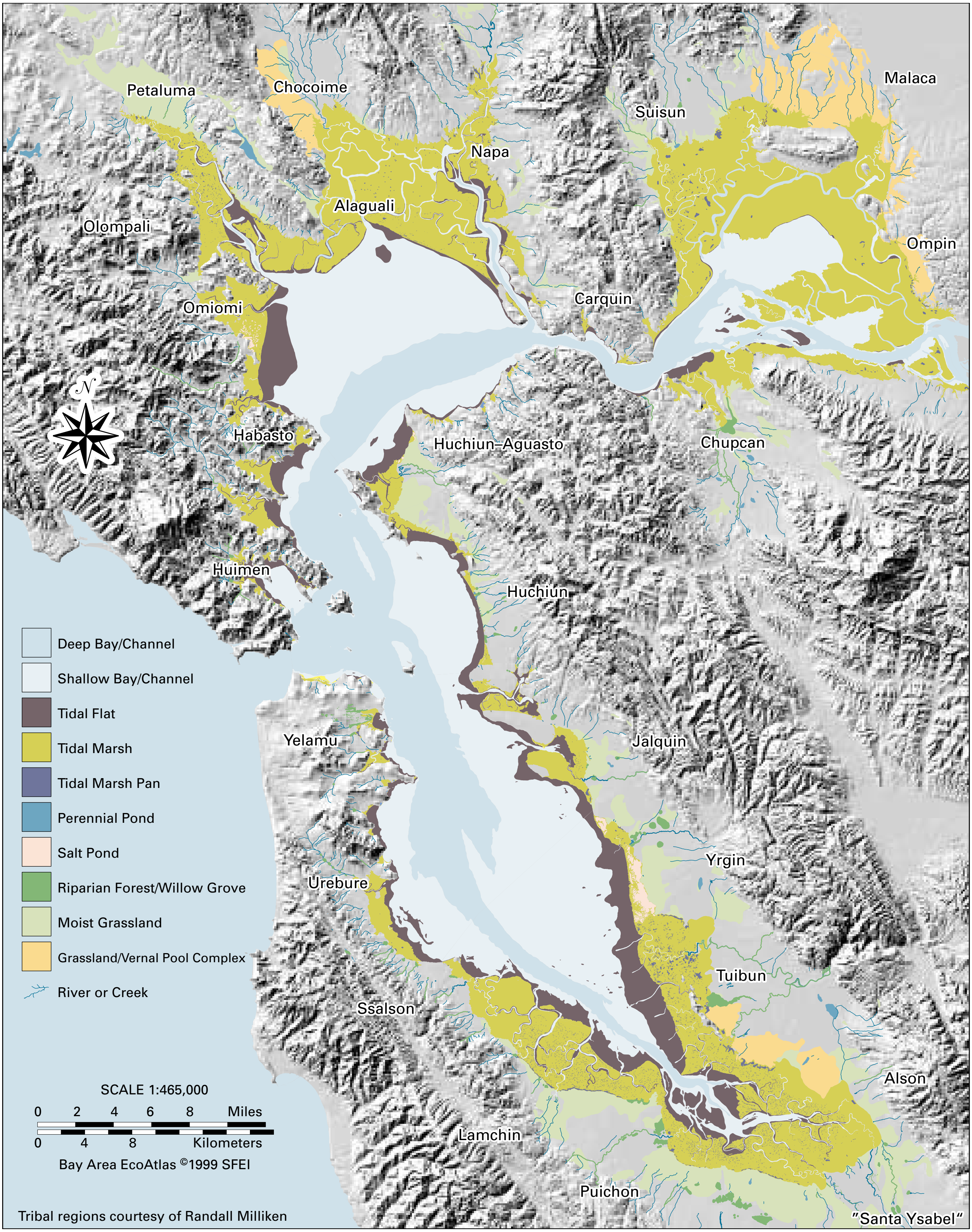
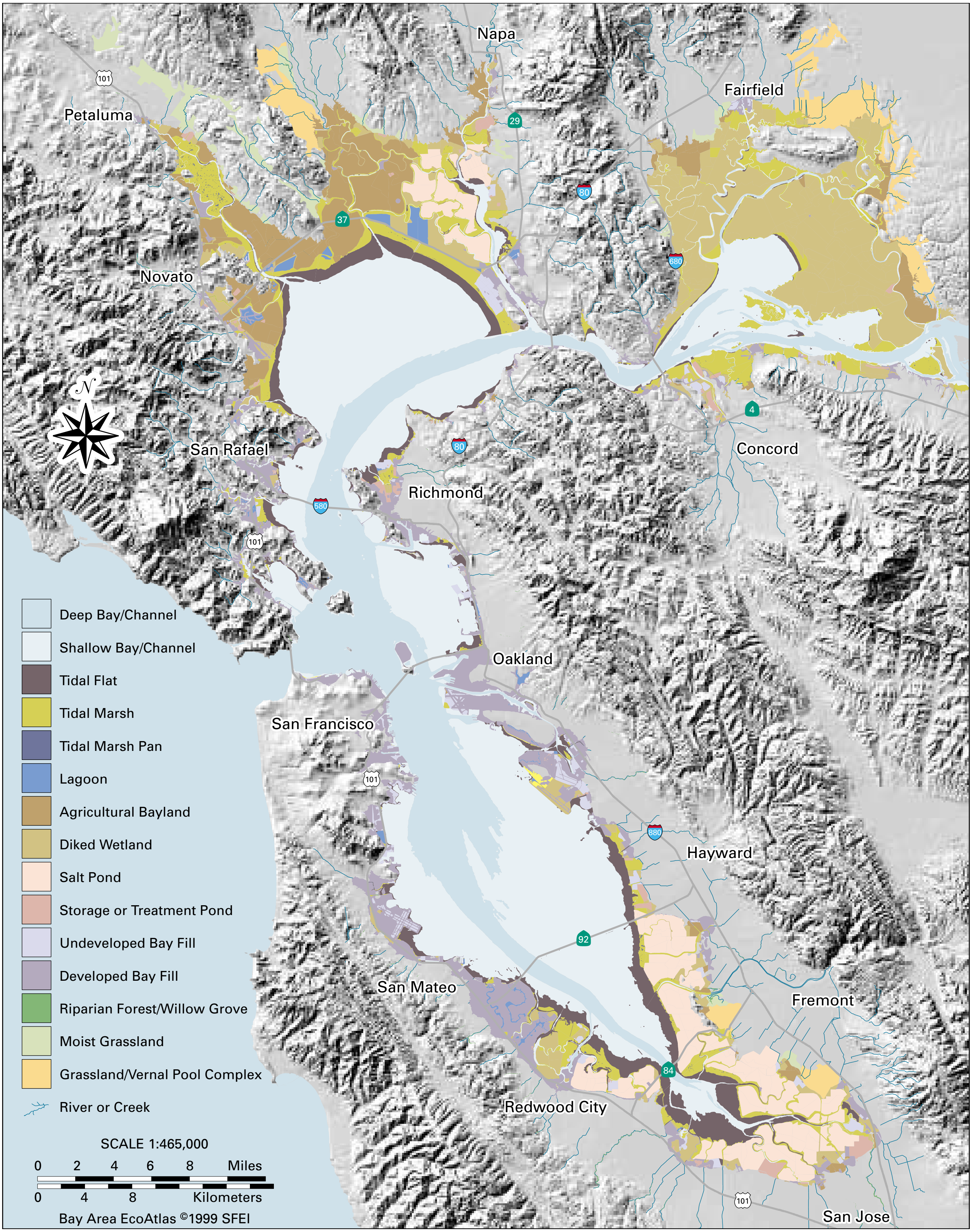

USCS 1857

FIGURE 2.6 **Past Distribution of Baylands and Adjacent Habitats (ca. 1800)**



The EcoAtlas Historical View shows past habitats based on various data. Only well-documented habitats are shown here.

FIGURE 2.7 **Present Distribution of Baylands and Adjacent Habitats (ca. 1998)**



The EcoAtlas Modern View is based on aerial photography (NASA 1995/96). Shaded relief is by Graham and Pike (1997).

Habitat Management Past and Present

Near present-day Hayward in South Bay, there used to be marsh pans twice as large as any others in the region. The Yrgin Ohlone apparently managed these pans to make salt (Brown 1960). The salt crystals were collected from willow sticks placed in the briny waters. The earliest Spanish missionaries adapted the native salt harvest practice and used the Ohlone to harvest the salt. Did the Ohlone modify the pans for salt production? Were there weirs or gates to control the tides?

In North Bay, near present-day Novato, the Omiomi Coastal Miwok lived beside some unusually large marsh pans. There is evidence to suggest that the Coastal Miwok may have used these pans for waterfowl hunting (Hagen, pers. comm.). Less than a century later, European immigrants began to hunt waterfowl on tidal marsh pans, a practice that later gave rise to private hunting clubs (Arnold 1996). To what extent does modern-day club management reflect the practices of the coastal Miwok?

About 200 feet upslope of the tidal marshes of Petaluma, there were three large shallow lakes, historically called lagunas. They are unlikely to have been natural features because they occupied sloping valleys with small catchment basins in a region with more potential evaporation than rainfall, and they emptied through narrow drainages into steep streams. It is more likely that the lagunas existed because of low dams that crossed the narrow drainages. Thousands of native people lived more or less directly downstream of these features for almost 50 centuries, under similar climatic conditions as today. Were these features perhaps created for hunting and fishing, or to deal with drought and deluge?

hundred acres, many times more than the cumulative total of all other North Bay perennial, non-tidal lakes and ponds.

Narrow riparian forests followed the larger creeks to the tides; on other creeks riparian trees were scarce. Many of the creeks did not reach the Bay, but fanned out onto the lower alluvial plains, sometimes into willow groves. The Spaniards called large stands of willows that were more or less isolated from other forest trees "sausals." These were common at low elevations near the backshore of tidal marshes in Central Bay and South Bay. In South Bay, some of the willow groves extended over more than 200 acres.

The tidal marshes, willow groves, riparian forests, and moist grasslands comprised complex mosaics or patterns of habitats throughout the region. There were at least two common mosaics, and topography controlled the patch size of habitats within these local mosaics. One mosaic was confined to the small coves and bays of the steep terrain along what is now Lake Merritt, the San Francisco Peninsula, the Marin shoreline, and the eastern shore of North Bay. It consisted of small patches of mudflat, tidal marsh, riparian forest, and sometimes beaches and willows groves. The other common mosaic consisted of much larger patches of tidal marsh and adjacent habitats. It was associated with the rivers and larger creeks flowing into South Bay, the eastern shore of Central Bay, and the northern shores of North Bay and Suisun.

These patterns of habitat distribution can serve as templates for baylands restoration. They suggest the mix of habitat type and patch size that would be sustained by the local topography, climate, and other natural habitat controls.

Overview of Land Use in the Baylands

Humans exert a major influence on the form and function of the baylands. How we use the baylands and the surrounding watersheds has a far-reaching effect on the baylands ecosystem. People began to alter the Bay Area landscape in major ways beginning about two hundred years ago. Understanding the extent of this alteration helps one to appreciate the many ways in which the baylands have changed.

Native Americans have lived near the Estuary for thousands of years. According to early reports described by Milliken (1995), villages were spaced three to five miles apart, and their populations generally ranged from about 60 to 90 people. The largest known village was near Carquinez Strait, with a population of about 400. Anthropologists have estimated that there were perhaps 20,000 to 25,000 Native Americans living in the Bay Area before Europeans arrived, but precise figures are not available. As indicated by **Figure 2.6**, Bay Area historical native populations lived in some two dozen main tribal groups.

These early inhabitants of the Bay Area harvested the bountiful resources of native fish and wildlife, including mussels, clams, oysters, fish, water birds, and mammals. They also utilized oak acorns and harvested salt from natural salt ponds. To maximize game and food plant production, native inhabitants used fire to control the structure of grasslands and oak woodlands, cultivated willows and other plants for building materials, and probably altered the hydrology of some tidal marsh pans. But these were few people compared to today, and it is unlikely that they significantly altered the baylands ecosystem.

Europeans first sighted San Francisco Bay in 1769; within a decade, the Spanish established a mission and a garrison at the site of San Francisco. Until 1821, when the Mexican revolution signaled the decline of the Spanish missions in California, the missionaries used the lands around the Estuary for grazing cattle and sheep. Associated with this land use were the first large-scale changes in the region's natural habitats: the clearing of oak woodlands, the conversion of large areas of native perennial grasslands to pastures of non-native invasive annual grasses, and the advent of excessive erosion from local hillsides and creek banks.

Beginning in the mid-1800s, following the Gold Rush in the Sierra Nevada, large areas of the Estuary's tidal marshes and mudflats were filled, diked, or drained. Extensive portions of the baylands were filled to provide land for ports, rail lines, and roads, as the Bay Area became a major transportation center. Early industrial developers in San Francisco, Oakland, and other shoreline cities built many facilities on Bay fill or on land immediately adjacent to the Bay (Perkins et al. 1991).

Farmers began diking and draining the tidal marshes in the 1850s. Much of the initial impetus for this activity stemmed from the federal Arkansas Act of 1850, which gave to the states all of the unsold federal land within their borders that was "swamp and overflowed". Subsequent State legislation, particularly the Green Act of 1868, also spurred the conversion of wetlands into agricultural uses (Kelley 1989). Initially, levees were small, as was the scope of reclamation. Chinese laborers conducted much of the work. By the 1870s, commercial dipper dredges and then larger clamshell dredges enabled the construction of taller and wider levees.

The diking of Suisun Marsh began in 1865, initially to enable livestock grazing. Most of the early diking was in the Marsh's eastern portion. Levee construction began on what is now Ryer Island and was well underway on other islands by the 1870s (Arnold 1996). In 1871, one landowner leveed 12,000 acres on Grizzly Island; by 1876, a low levee system surrounded the entire 22,000-acre area (Thompson and Dutra 1983). Other nearby islands that were reclaimed relatively early included Chipps, Hammond, Simmons, Wheeler, and Van Sickle.

"Every acre of reclaimed tide marsh implies a fractional reduction of the tidal current in the Golden Gate. For any individual acre the fraction is minute, but the acres of tide marsh are many, and if all shall be reclaimed the effect at the Golden Gate will not be minute."
— Grove Karl Gilbert 1917

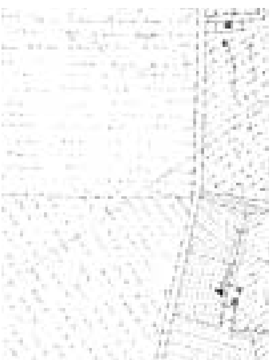
Early farmers diked and drained tidal marshes.

SFEI Archives

In the western portion of Suisun Marsh were hundreds of natural marsh ponds, large and small, that provided excellent habitat for shorebirds and waterfowl. It was at or near these natural ponds between Cordelia and Suisun sloughs that hunters, in the 1870s and 1880s, established the first duck clubs with the colorful names of Cordelia, Ibis, Teal, and Tule Belle (Arnold 1996). Above the backshore of the tidal marshes were vast expanses of grasslands, about half of which were seasonally moist. Extensive grasslands with vernal pools also occurred north of Potrero Hills and along the eastern boundary of the tidal marshes at the base of Montezuma Hills.

By the early 1900s, grazing in Suisun had given way to more lucrative land uses, and farmers were producing a variety of crops including sugar beets, asparagus, lima beans, oats, and barley, along with livestock and dairy products. Beginning in the 1920s, however, following several dry years and because of increased upstream water storage and diversion, saline water intruded past the Carquinez Strait more frequently (Means 1928). Eventually, as increasing salinity and, to a lesser extent, land subsidence made it difficult to regulate groundwater levels and soil salinity, agriculture began to fail and duck clubs displaced farming in the eastern portion of Suisun. Today, the only farming remaining in the Suisun baylands is the production of oat hay on some 1,500 acres. Many of the levees originally constructed to enable farming in Suisun are an integral part of the infrastructure for managing water levels in the duck clubs.

In North Bay, initial diking of tidal marsh was undertaken to develop grazing lands for livestock. Some of the early reclamation efforts converted large tracts of tidal marsh to diked baylands. For example, during the summer of 1870, 12,000 acres were being leveed to the west of the Napa River (Thompson and Dutra 1983). By the 1930s, diking for farming purposes was essentially complete. Livestock grazing was the sole agricultural practice in North Bay diked baylands for many decades, as the high water table and soil salinities discouraged the production of truck crops. Some owners let their lands "pond up" in the fall to provide opportunities for hunting waterfowl. However, in the past couple of decades, the remaining farmed areas have been managed for the production of dairy cattle silage, although oat hay farming continues, primarily for horses (Sheffer, pers. comm.). Several farmers recently established vineyards on the baylands. In total, there are about 28,000 acres of diked baylands in North Bay that are now, or recently were, in some form of agriculture.



USCS 1860

Farms beside the baylands...

In South Bay, the baylands were never extensively diked for agriculture. Instead, large areas were reclaimed for salt production. This diking for commercial salt production began around 1860 (Ver Planck 1958). By the 1930s, almost half of South Bay's historical tidal marshes had been converted into salt ponds. In 1952, the Leslie Salt Company (later purchased by the Cargill Salt Division) expanded salt production into North Bay with the purchase and conversion of nearly 11,000 acres of diked agricultural baylands to salt ponds (Josselyn 1983). By the middle of this century, salt ponds had replaced nearly one-fifth of the historical tidal marsh area in North Bay. At their peak, salt ponds covered about 36,000 acres in and adjacent to the baylands.

...still exist.

NASA 1995/96

Farmers began to produce crops in the moist grasslands adjacent to South Bay in the 1850s. To enable the shipment of these crops to San Francisco, entrepreneurs developed small ports along the bayshore or in major sloughs (e.g., Robert's Landing, Eden Landing, Alviso). As the human population of the

What's Special About Suisun?

Suisun Marsh is the Estuary's largest contiguous protected area. This protection covers a primary management area (89,000 acres of wetlands, channels, and bays) and a secondary management area (22,500 acres of adjacent uplands). It is the result of private and public efforts that were led by the Suisun Soil Conservation District [now the Suisun Resource Conservation District, (SRCD)].

The SRCD was formed in the early 1960s, and it began encouraging landowners to manage their lands more effectively. The California Department of Fish and Game and the Soil Conservation Service (now the Natural Resources Conservation Service) entered into agreements with the SRCD to support and assist in its conservation efforts. In the early 1970s, the State Legislature directed the San Francisco Bay Conservation and Development Commission (BCDC) to develop a *Suisun Marsh Protection Plan* (Protection Plan). In 1977, the Legislature passed the Suisun Marsh Preservation Act, which enacted the Protection Plan. Many state and federal agencies and private groups, particularly local duck club owners, supported this action. The Protection Plan directed state and local agencies to work together toward preserving wildlife values in the Marsh. The subsequent adoption of the Protection Plan by BCDC, Solano County, and the cities of Fairfield and Suisun City established strong protections for Suisun Marsh.

The Protection Plan contains specific policy language to guide marsh restoration: "Where feasible, historic marshes should be returned to wetlands status, either as tidal or managed wetlands. If, in the future, some of the managed wetlands are no longer needed for waterfowl hunting, they should be restored as tidal marshes."

The Protection Plan and subsequent documents, such as the Department of Water Resources' *Plan of Protection for the Suisun Marsh*, recognize the wildlife values of managed and tidal marshes. They also recognize the important contributions of private landowners and managed wetlands in maintaining the Marsh's wildlife. The Marsh landowners have made a commitment to enhance wildlife values, to foster wetland stewardship, and to maintain the hunting heritage.

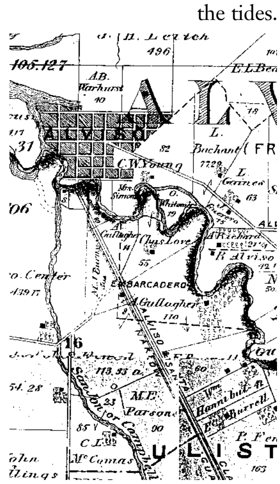
A common misconception is that Suisun Marsh is only for ducks and duck hunting. It is true that much of the Marsh is managed for wintering waterfowl and to provide hunting opportunities. But those who spend time in the Marsh understand that the managed areas also provide habitat for a wide variety of other birds, including shorebirds, and mammals, such as the salt marsh harvest mouse, muskrat, beaver, river otter, and tule elk.

Many people who have spent decades in and around Suisun Marsh are concerned with the Goals Project's recommendations to increase the amount of tidal marsh there. They believe these recommendations are inconsistent with past and present efforts to protect the Marsh and to maintain and enhance its waterfowl habitat. This highlights one of the dilemmas of future bayland management: how to protect existing habitat functions and wildlife uses while restoring other habitat functions that have been degraded or lost.

subregion increased, particularly in the past several decades, most of the agricultural areas adjacent to the baylands were developed for residential and industrial uses.

By the 1950s, there were only about 50,000 acres of tidal marshes in the Estuary, about one quarter of the historical amount (Van Royen and Siegel 1959 in Dedrick 1989). Since then, the loss of tidal marshes has continued, but at a much slower rate than in the past.

Towns grew where creeks met the tides.

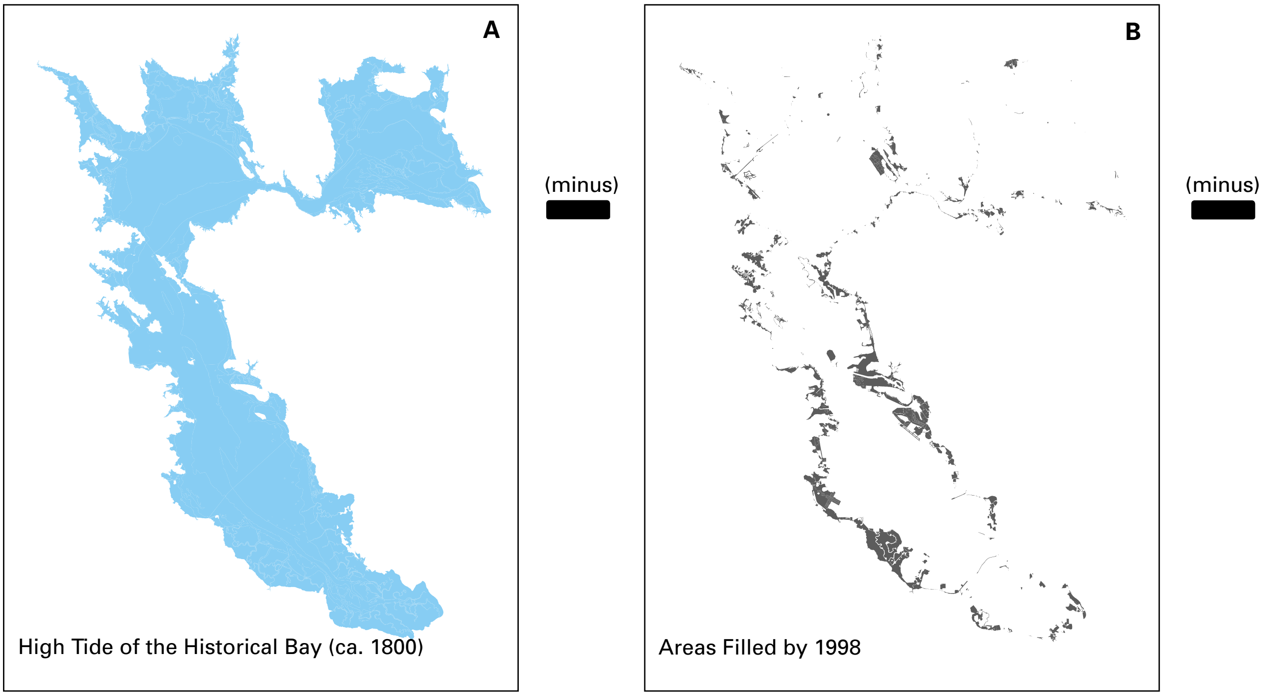


SFEI Archives

The Physical Effects of Development

Human activities have altered the baylands ecosystem in many ways. Some of these activities have been local, taking place within or immediately adjacent to the baylands, while others have occurred many miles upstream. This section describes some of the physical changes that have occurred in the baylands primarily as a result of human action.

FIGURE 2.8 **Changing the Size of the Estuary**



Overall, there has been a significant decrease in the size of the Estuary (**Figure 2.8**). This has been caused mainly by diking and filling.

In many parts of the Bay, there have been shifts in the locations of the baylands and adjacent habitats. These shifts have resulted from a combination of urbanization of moist grasslands and vernal pool complexes, reclamation of tidal habitats, and sediment deposition in subtidal habitats. Reclamation has converted some tidal habitats into seasonal wetlands, while urbanization destroyed similar habitats in the adjacent uplands. Sedimentation has converted some subtidal areas to more shallow, tidal habitats. The combined effect of these changes has been to shift seasonal wetlands and the baylands bayward.

As a result of this bayward shift, the area of the baylands has changed. In Suisun, North Bay, and Central Bay, the area has increased; in South Bay, it has decreased. Overall, the area of the baylands has increased from about 242,000 acres (circa 1800) to about 262,000 acres today (Appendix B). This does not contradict the fact that San Francisco Estuary downstream of the Delta (i.e., the combined area of all tidal and subtidal habitats) has been reduced in size by about one-third since the Gold Rush (**Figure 2.8**).

Based on the data in Appendix B, some important details about changes in habitat acreage can be quantified, as described below and as indicated by **Figure 2.9**.

- Deep and shallow bay habitats have decreased from about 270,000 acres to about 250,000 acres. This is a result of sediment deposition from Gold Rush hydraulic mining and of bayshore fill.

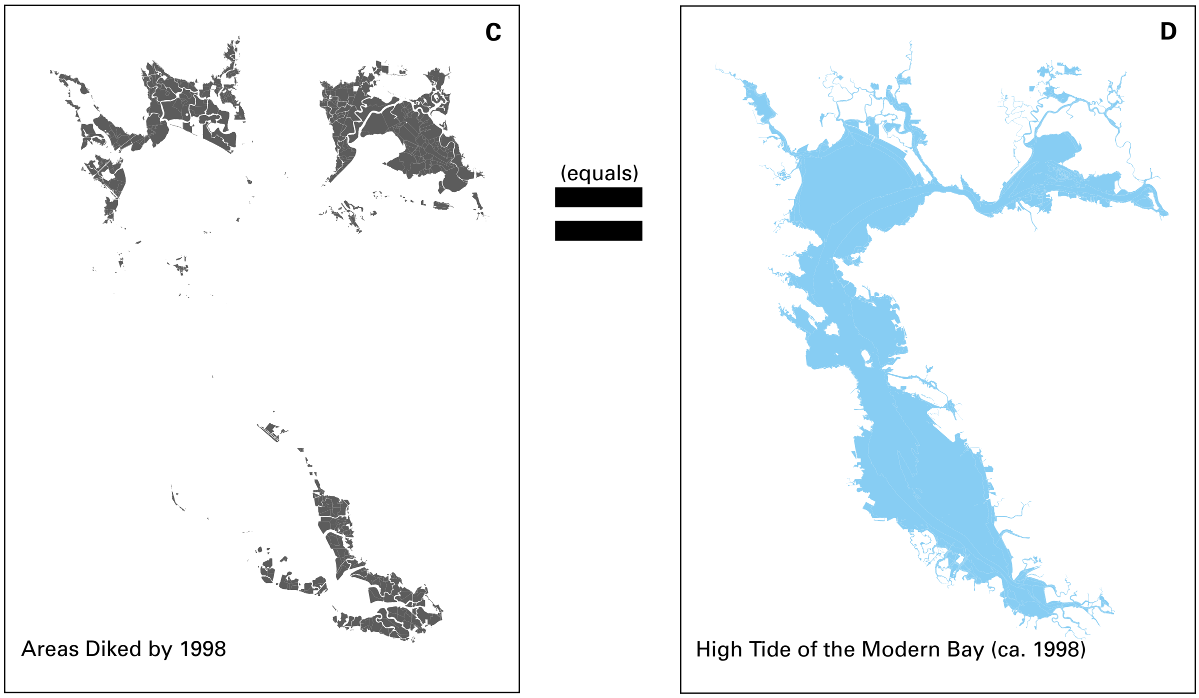
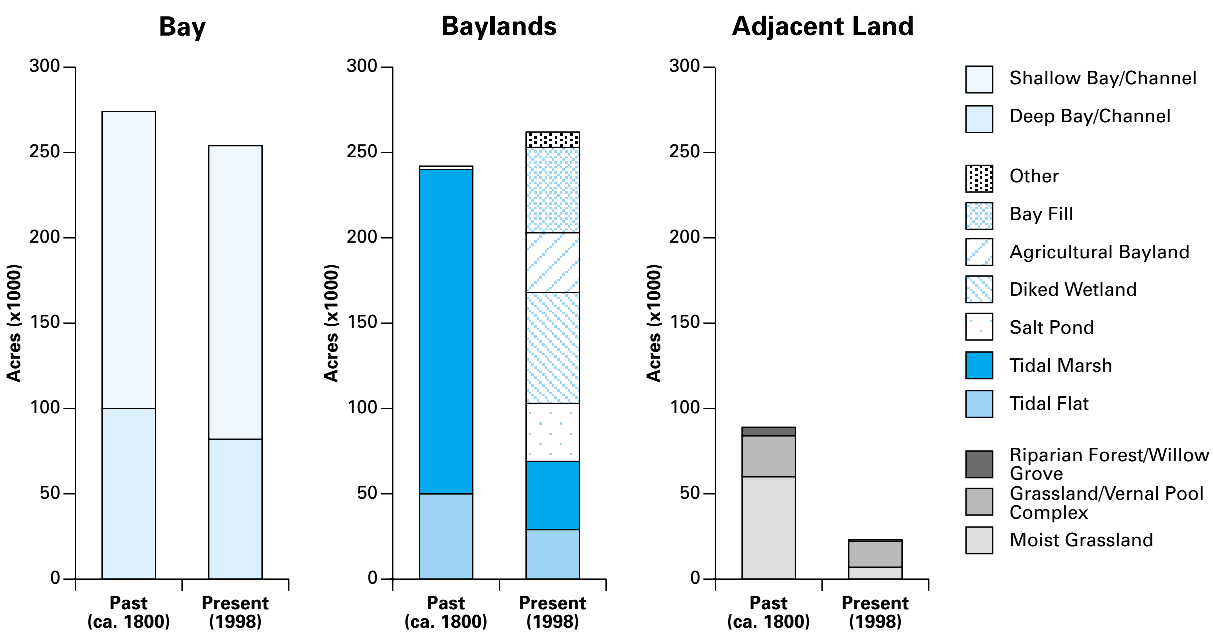


FIGURE 2.9 **Past and Present Habitat Acreage — Project Area (see Appendix B for numerical values)**



The Changing Baylands

Beginning in the mid-1800s, tens of thousands of acres of tidal baylands were diked, or reclaimed, for agriculture and other purposes. This resulted in shoaling of the tidal channels (Mitchell 1869) that had connected the marshes to the major rivers and open bays, and the channels filled or became fringed with new mudflats and tidal marsh. Later, the increased supply of sediment from hydraulic gold mining in the Sierra Nevada mountains helped fill the remnant tidal channels that remained between the diked baylands, and caused shallow bays to aggrade into mudflats, while deep bays became more shallow. Some of the mudflats built by hydraulic mining debris evolved into tidal marsh, and some of this new marshland was again reclaimed for agriculture and urban development by a second generation of levees.

- Tidal flat habitat has decreased from about 50,000 acres to about 30,000 acres. This is primarily a result of reclamation, bayfill, natural conversion of tidal flat to low tidal marsh, and erosion.
- Tidal marsh habitat has declined from about 190,000 acres to about 40,000 acres. This is a result of bayfill and diking to create managed marsh, agricultural baylands, and salt ponds.
- Moist grasslands have declined from about 60,000 acres to about 7,000 acres. This is a result of farming and urban uses.
- Moist grassland/vernal pool habitat has declined from about 24,000 acres to about 15,000 acres. This is a result of farming and urban uses.
- Riparian forest and willow grove habitats have declined from about 5,000 acres to about 700 acres. This is a result of farming, urban uses, and channel modifications for flood control.

Figures 2.10 – 2.13 illustrate the habitat acreage changes in each of the Project subregions.

The diking and filling of tidal baylands have had significant effects on the physical functions of the baylands. For example, they have greatly curtailed the influence of tidal marshes on the transport of sediment from local watersheds to the bays. Tidal marsh stores sediment that is transported by runoff from the watersheds. A portion of the suspended sediment that reaches the marsh in this way may wash back and forth between the marsh and the bays, and may be stored temporarily on tidal flats. However, most of the sediment that enters a marsh is retained in the channels or on the marsh plain. Without expanses of tidal flats and tidal marshes, the sediments generated in local watersheds tend to accumulate at the mouths of streams.

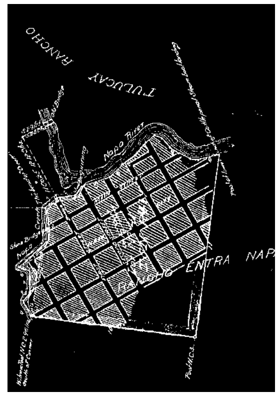
Diking and filling have eliminated large amounts of the historical local flood plains, and the concomitant loss of tidal prism has caused the tidal channels, including the tidal reaches of local rivers and streams, to become much more narrow and shallow (Dedrick and Chu 1993). Their capacities have been significantly decreased, and in some cases the local hazards of flooding have therefore been increased (Collins, L. 1998). Ironically, the loss of tidal prism due to reclamation has increased the need for dredging to maintain commercial and recreational navigation.

Diking is also expected to have had a substantial effect on the quality of the Bay's water. Many of the physical and biological processes of wetlands are known to improve water quality (Hammer 1989). Although a direct correlation has not been accurately documented, it is likely that the large loss of tidal marsh within the Estuary has contributed to decreased water quality and increased turbidity of the open bays.

Diking for agriculture resulted in a variety of major landscape changes. Initially, the most obvious change was the reduction or elimination of tidal marsh vegetation as the land was farmed. After diking, aerobic decomposition and de-watering of the peaty marsh soils caused the land surface to settle or subside. Subsidence was greatest in areas that correspond to the middle areas of the historical marsh plains, where the peat soils are deepest. In some cases, as in Suisun Marsh, the historical topography eventually became inverted — areas that once were high marsh drainage divides with pans became low, isolated depressions, lower than the relict channels and natural levees. Tidal channel topography typically persisted as sinuous swales.

Water storage and diversions in the Central Valley have affected the volume and timing of the major freshwater flows to the Estuary (Arthur et al. 1985). In some years, they reduce the volume of fresh water reaching the Bay by one-half. At the present level of development, they reduce flow into the Bay in all seasons except late summer and early fall. The effects of diversions are greatest in spring (SFEP 1992).

Reducing the volume of freshwater flows from the Delta has altered the salinity of the tides in Suisun and North Bay, and to a lesser extent in Central Bay and South Bay (Cloern and Nichols 1985). Beginning in the 1920s, upstream storage and diversions allowed saline conditions to intrude upstream in Suisun and the Delta. Parts of North Bay, such as the lower Napa River, also became



Bancroft Library

Creeks and roads shared the traffic.

The Economic Values of Wetlands

Ecologists consider wetlands to be among the most biologically productive kinds of habitat, providing many economic benefits. According to Mitsch and Gosselink (1993), a recent comprehensive review of wetlands economic benefits indicated that these habitats make possible commercial harvests of fish, shellfish, fur animals, waterfowl, and timber, and they also provide millions of days of recreational fishing and hunting each year. Wetlands can moderate the effects of floods, improve water quality, help maintain shipping channels, and they have aesthetic and heritage value. They also contribute to the stability of global levels of available nitrogen, atmospheric sulfur, carbon dioxide, and methane. In the crowded Bay Area, wetlands provide open space, a benefit appreciated by residents and visitors alike. During the past few decades, several researchers have quantified the economic benefits of wetlands (Gosselink et al. 1974, Anderson and Rockel 1991, Mitsch and Gosselink 1993). Although Meiorin et al. (1991) and SFEP (1993) described the functions and values of Bay Area wetlands, neither attempted to attribute an economic value to these resources. However, based on a recent analysis of California wetlands economic benefits, which indicates that the annual economic value of wetlands Statewide is somewhere between $6.3 billion and $22.9 billion (Allen et al. 1992), the economic value of Bay Area wetlands is indeed considerable.

FIGURE 2.10 Past and Present Habitat Acreage — Suisun Subregion

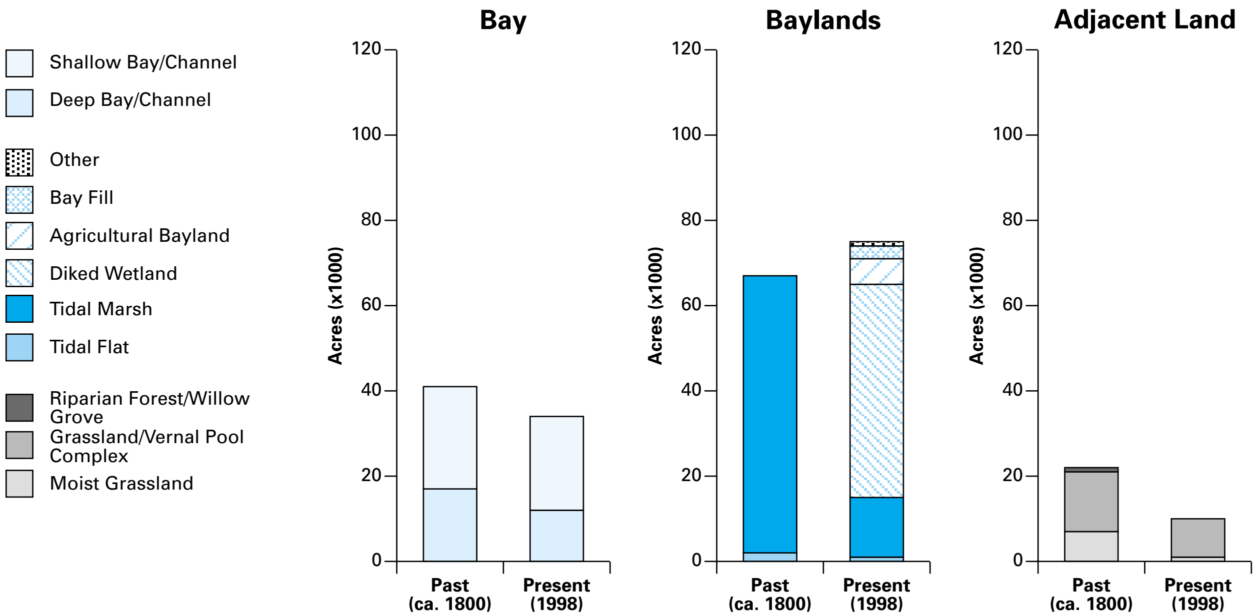


FIGURE 2.11 Past and Present Habitat Acreage — North Bay Subregion

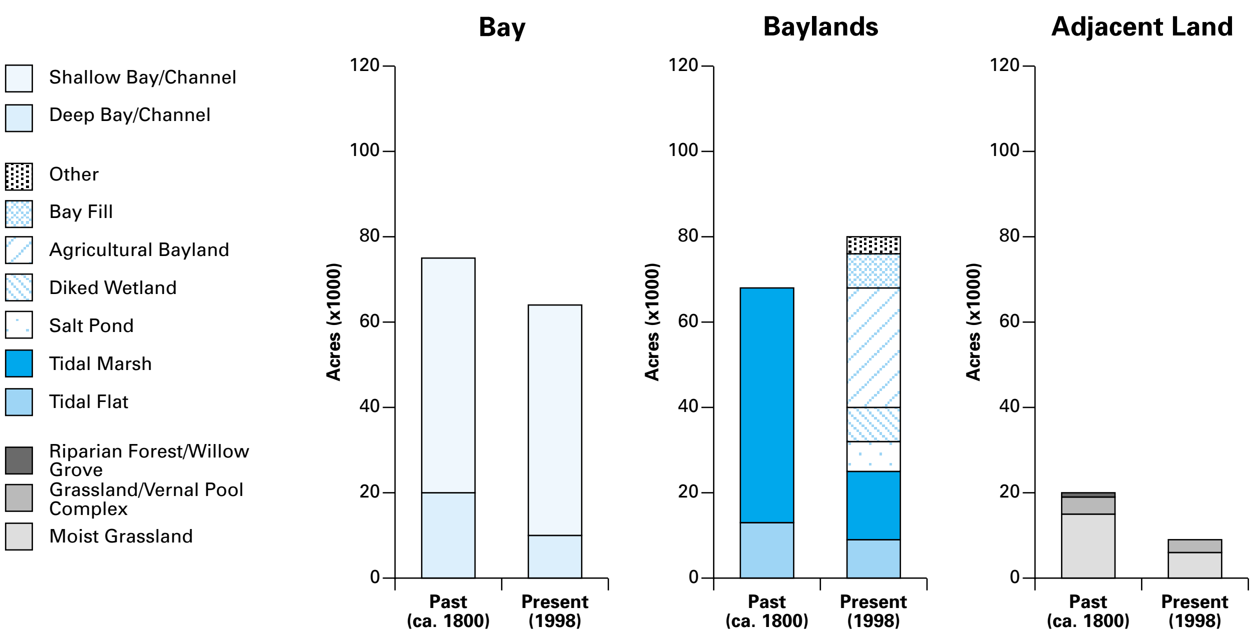


FIGURE 2.12 Past and Present Habitat Acreage — Central Bay Subregion

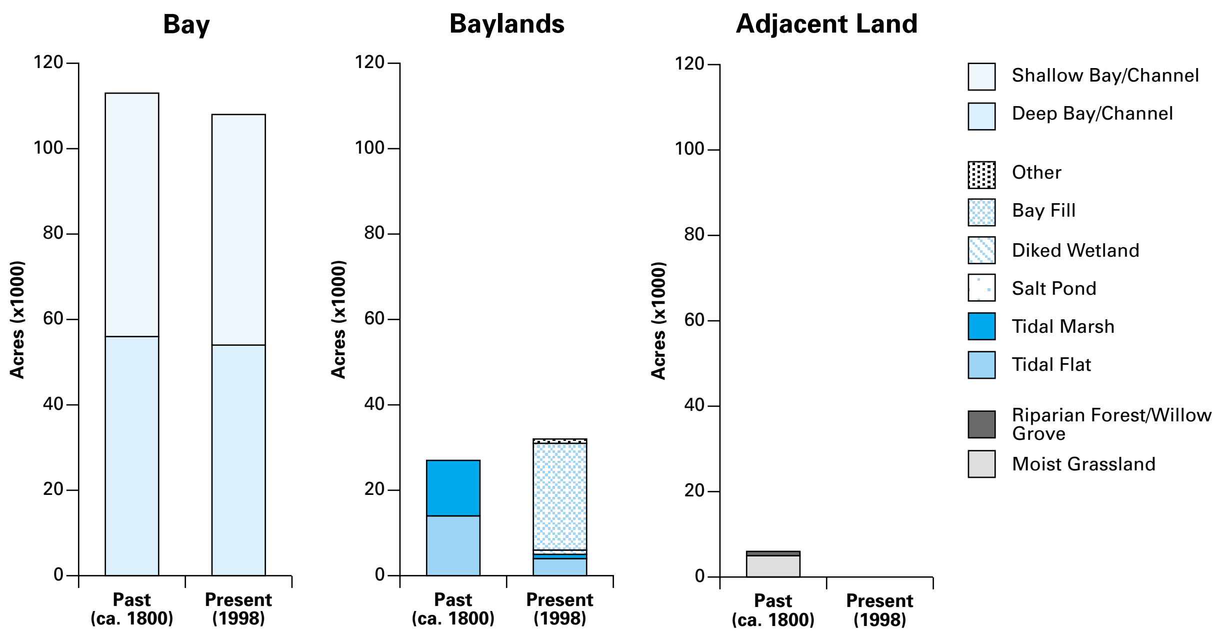
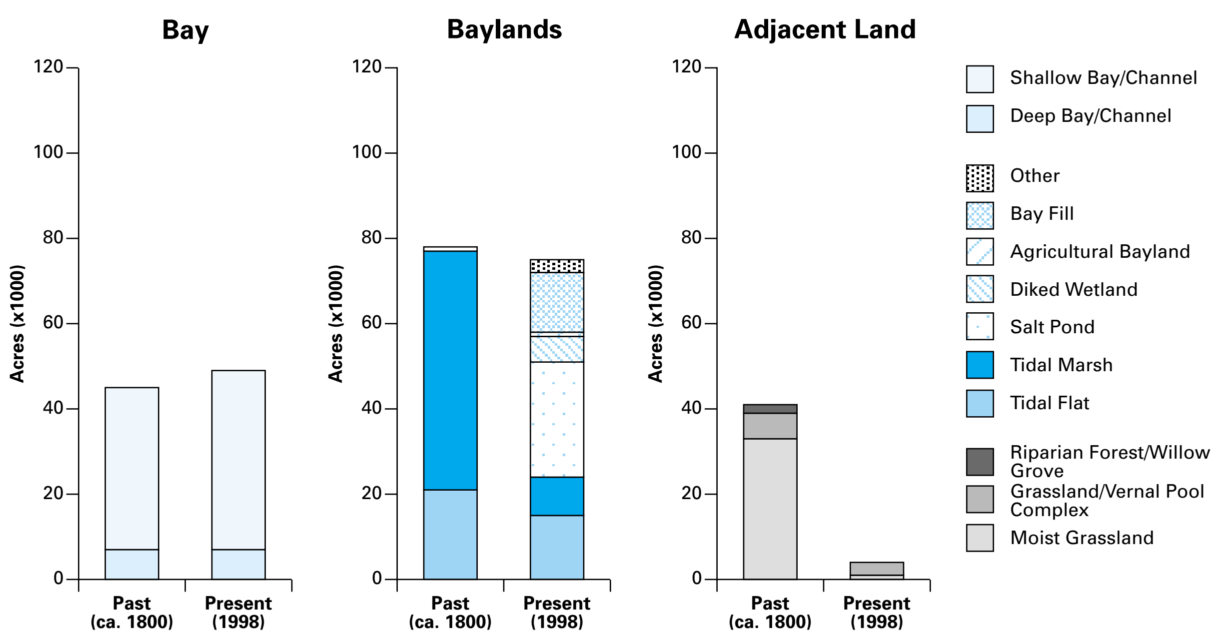


FIGURE 2.13 Past and Present Habitat Acreage — South Bay Subregion



more saline. Central Bay and South Bay were less affected because they were naturally saline.

Development in the Bay Area has changed the flow regimes of local streams and rivers that enter the baylands. One of the more obvious effects of this change is an increase in peak flow volumes, as large areas of developed, impervious surfaces cause more rainfall to reach streams more quickly. This has caused streams to erode, which in turn has increased the sediment supply to the tidal channels and marshes downstream.

Urban and suburban development adjacent to the baylands has had an especially severe impact on many of the ecosystem's plant communities. About 30 percent of the upland area in the nine Bay Area counties is now urban or suburban. This has resulted in the loss of most of the historical moist grasslands, natural seasonal and perennial wetlands, willow groves, and riparian forests.

Development also places homes, businesses, and roads too close to streams and often leads to landowner demands for flood control measures. These measures commonly include removing riparian vegetation and lining the stream bank with rock or concrete. Land development that incorporates inadequate setback requirements threatens the little remaining riparian forest habitat. Continued development will adversely affect wetlands and stream corridors in virtually every watershed around the Estuary (Blanchfield et al. 1991).

As a result of the extensive changes caused by development, the baylands today include a greater diversity of habitats than in the past. Where previously the baylands consisted almost entirely of tidal marsh and tidal flat, today they also include seasonal wetlands, grasslands, agricultural lands, salt ponds, and storage/treatment ponds.

Effects of Habitat Change on Fish and Wildlife

The Estuary's populations of fish and wildlife have changed markedly in the past century and a half. This is a result of a variety of natural and human-induced factors, including over-harvest, habitat loss and degradation, introduced species, pollutants, and modification of freshwater flows. Herbold et al. (1992) recently reviewed historical changes in the populations of many of the Estuary's aquatic resources, and Harvey et al. (1992) reviewed changes in wildlife populations. Although the relative effect of each factor varies according to species, overall, habitat loss and degradation have played key roles in many of the population declines.

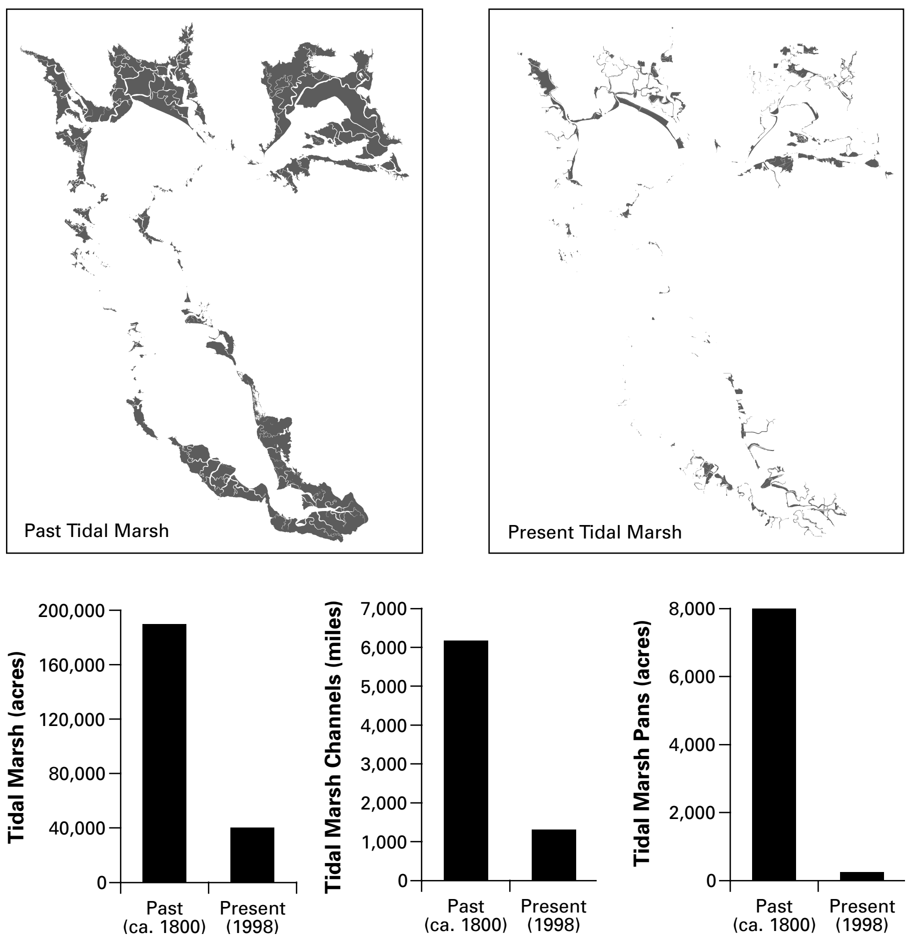
These declines in fish and wildlife populations have caused obvious economic losses through declines in sport and commercial hunting and fishing. The losses of bayland habitats have caused declines in aesthetics, pollution control, flood control, erosion control, and navigation, all of which have a price tag. These economic losses are just beginning to be considered as part of the rationale for baylands restoration.

The large number of bayland plants and animals that are under special protection currently reflects the effects of habitat loss or degradation. Today, there are 51 species of plants and animals that occur in or near the baylands that are listed as threatened or endangered under the state and federal endangered species acts. These include ten invertebrates, six fishes, one amphibian, two reptiles, nine birds, two mammals, and twenty-one plants (CDFG 1998).

There are few records of the exact historical distribution or abundance of the Estuary's fish and wildlife. There is no way of knowing for sure how many ducks there used to be, or whether the rare plants were always so. The best information of this kind must be inferred from the knowledge of the habitat requirements of the species, and from the maps of the historical distribution of their habitats.

The maps of historical and modern habitats (**Figures 2.6** and **2.7**) clearly indicate that, for many native species of fish and wildlife which inhabit the baylands, there have been large habitat losses. For species, such as the California clapper rail, that live only in the tidal baylands, and for other species such as Chinook salmon and California least tern that spend part of their lives outside of the Estuary but rely on the tidal baylands for feeding or breeding, these habitat losses (**Figure 2.14**) have undoubtedly contributed to population declines.

FIGURE 2.14 Loss of Tidal Marsh Habitats

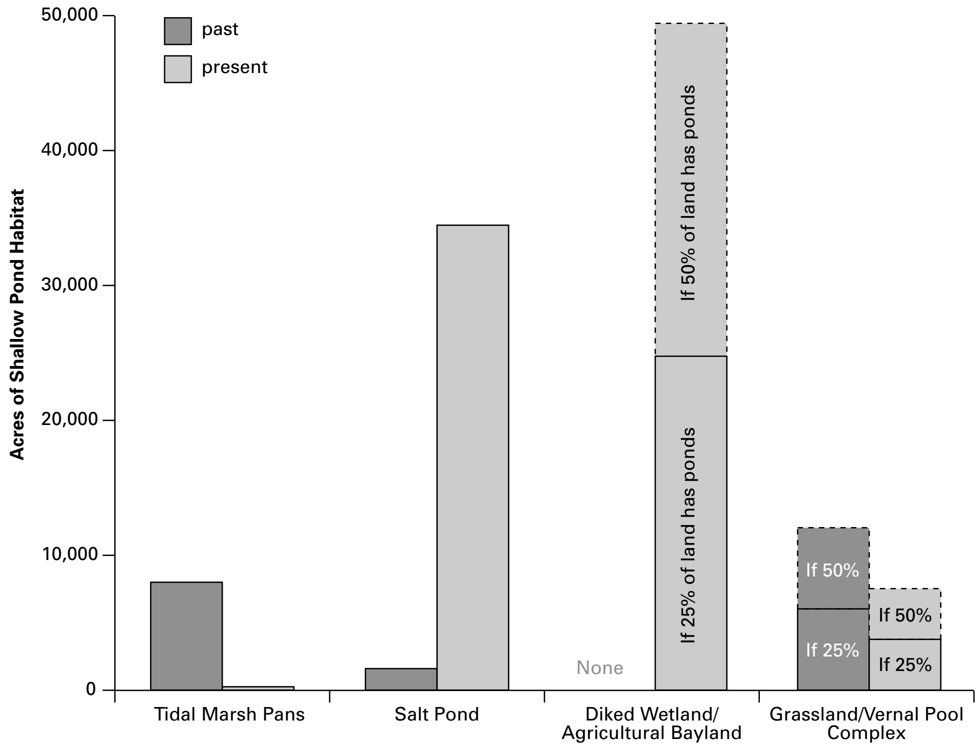


People have caused a 79% loss in tidal marsh during the last 200 years. Only about 8% of the historical marsh remains. The rest of the present marsh has naturally evolved from tidal flat, has been restored from diked baylands, or is muted by water control structures. Most tidal marsh fish and wildlife are associated with channels and pans. The loss of these habitats accounts for most of the decline in ecological function of tidal marsh.

The maps also indicate habitat increases for some native species of bayland fish and wildlife. For example, there has been an increase in the amount of habitat for some species of migratory waterfowl and shorebirds that use the salt ponds and diked marshes (**Figure 2.15**). The snowy plover is an example of a species that is native to California but that may not have inhabited the Estuary prior to the construction of levees around commercial salt ponds.

It is important to recognize that populations of fish and wildlife do not always increase just because they are provided more habitat. The quality of the habitat may be more important than its quantity. Also, populations of migratory species may decline for reasons unrelated to conditions in the Estuary. This does not, however, diminish our obligation to provide high quality habitat for all the native species that inhabit the baylands.

FIGURE 2.15 **Estimated Shallow Ponding**

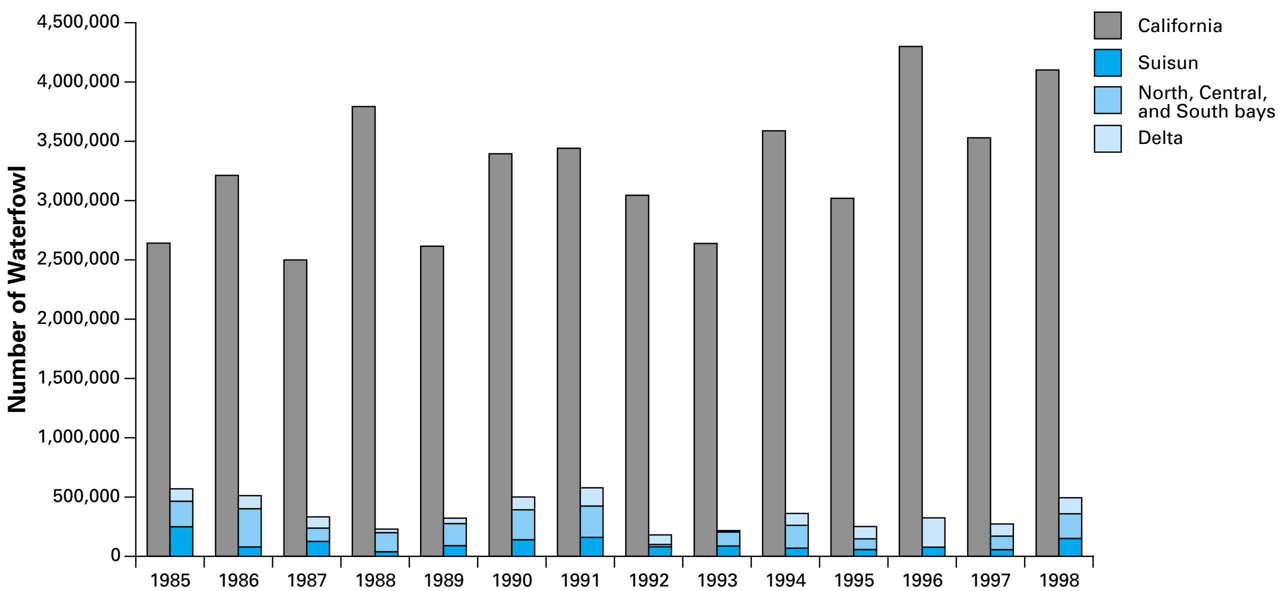


The shallow pond habitats of the baylands ecosystem are salt ponds, tidal marsh pans, seasonal ponds in diked baylands, and vernal pools in adjacent grasslands. The area of grasslands and diked wetlands/agricultural baylands that is covered by shallow ponds varies depending upon rainfall and local water management practices. Whether it is assumed that shallow water covers a large amount of these baylands (e.g., 50%) or a small amount (e.g., 25%), the total amount of shallow ponds is greater now than before, due mainly to the creation of diked habitats. For dabbling waterfowl that use diked wetlands, there has been an increase in habitat. For California tiger salamanders that prefer vernal pools or seasonal ponds in moist grasslands, there is less habitat. There has been a large loss of habitat for the California hornsnail that mainly inhabits tidal marsh pans.

The value of the baylands as habitat varies among migratory species of fish and wildlife. Nearly all of the shorebirds that migrate along the Pacific Flyway spend some time in the baylands (Harvey et al. 1992). The proportion of migratory waterfowl that use the baylands seems more variable, but never exceeds about one quarter of the total (**Figure 2.16**). The restoration of tidal marsh is a major aspect of plans to recover winter-run Chinook salmon and other anadromous fishes (CALFED 1998a).

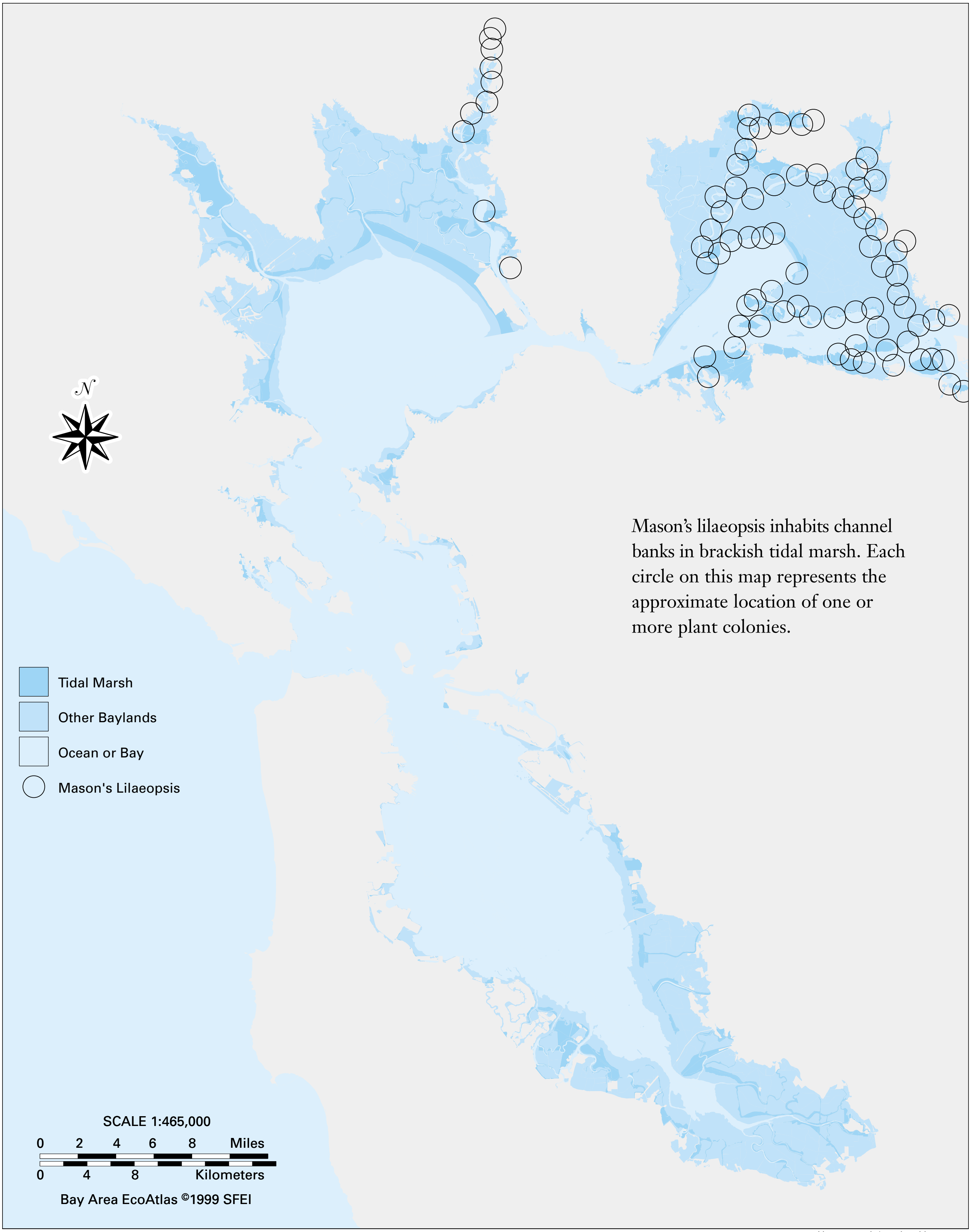
Maps of the modern distribution and abundance of baylands fish and wildlife help to identify their habitat needs. Synoptic, or region-wide, surveys are especially valuable because they reveal the relative importance of the different subregions, habitat types, and local habitat mosaics. Examples of regional surveys of selected species are shown as **Figures 2.17 – 2.22**. The distribution of these species in the intertidal zone is shown in **Figure 2.23**. These illustrate the need to consider all the baylands and adjacent habitats as part of the baylands ecosystem.

FIGURE 2.16 **Waterfowl Counts 1985 – 1998 for California, the Delta, and the Baylands**



These counts of waterfowl are from the mid-winter surveys conducted by the U.S. Fish and Wildlife Service. The data show that the total number of over-wintering waterfowl varies yearly, that almost 25% of these waterfowl occur in the Estuary during some years (e.g., 1985), and that between about 2% and 12% of the total occur in either the Delta, Suisun, or the baylands further downstream. Waterfowl habitat in the baylands depends on the tides, whereas inland habitat depends on rain and runoff. The use of baylands by waterfowl can therefore increase during droughts, when inland habitat is less available.

FIGURE 2.17 **Known Locations of Mason's Lilaeopsis**

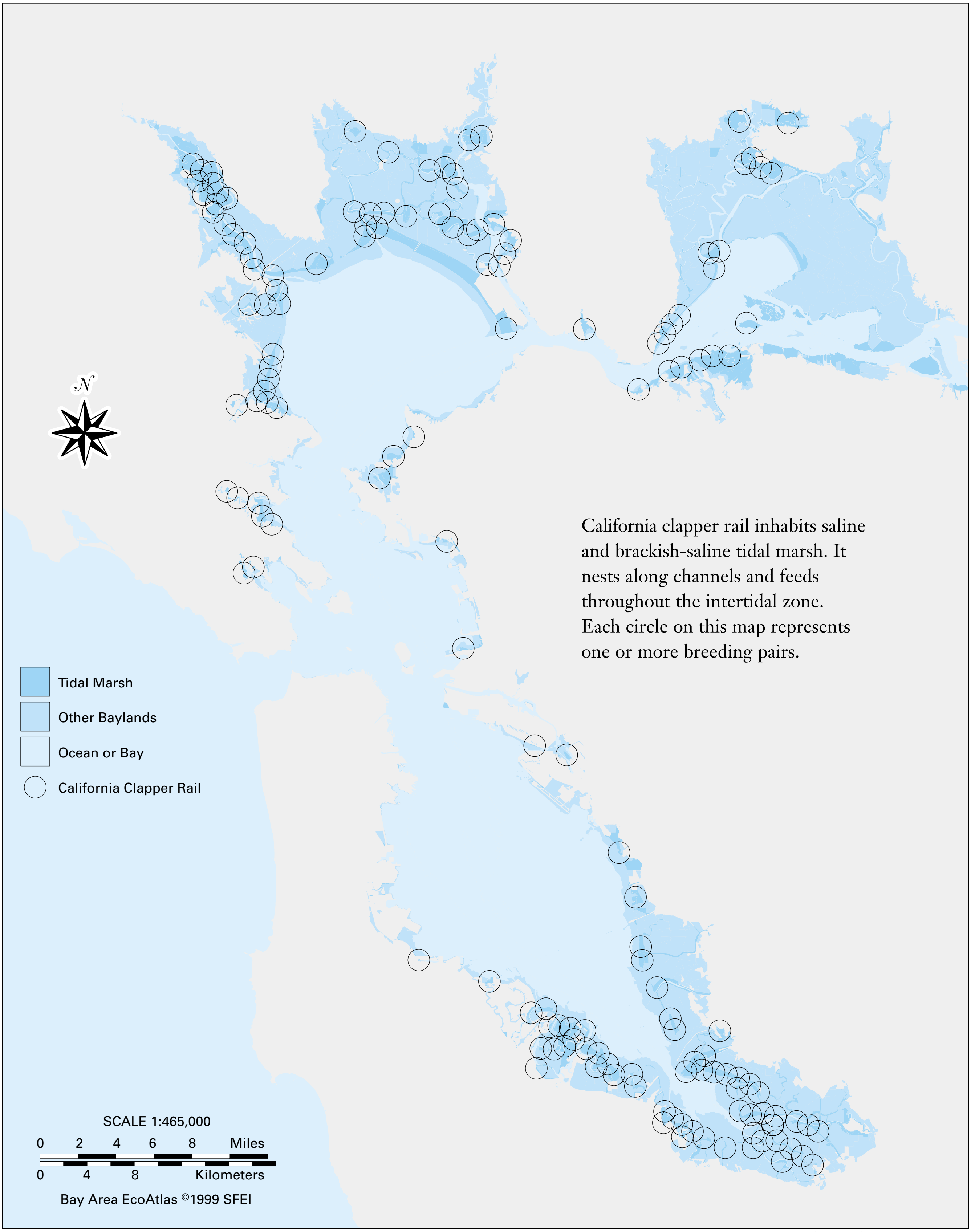


Source: Fiedler and Zebell 1993

FIGURE 2.18 **Known Locations of Soft Bird's-Beak**

Source: CDFG 1998

FIGURE 2.19 **Known Distribution of the California Clapper Rail**

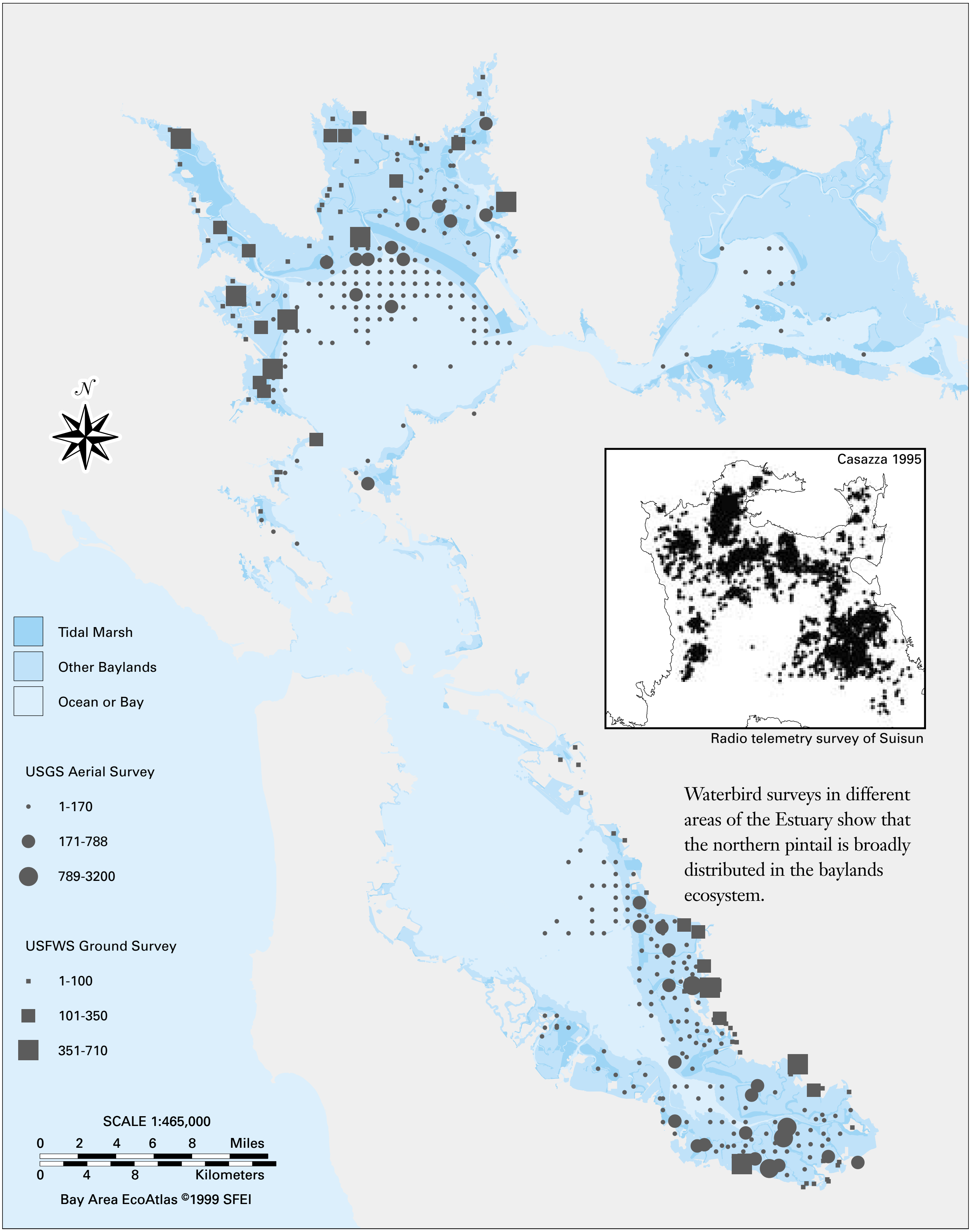


Source: Other Baylands Birds Focus Team

FIGURE 2.20 **Distribution of Tidal Flat Specialists**

Source: Shorebirds and Waterfowl Focus Team

FIGURE 2.21 **Distribution of Northern Pintail**

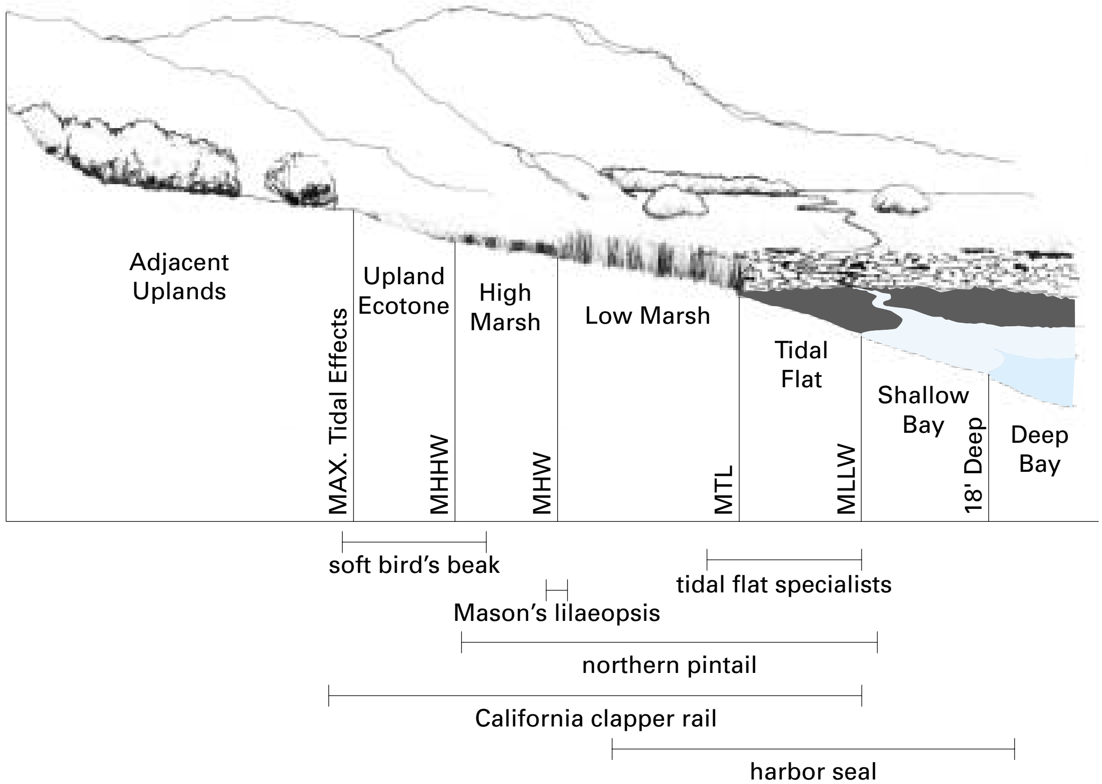


Waterbird surveys in different areas of the Estuary show that the northern pintail is broadly distributed in the baylands ecosystem.

FIGURE 2.22 **Known Distribution of Haul-Out Sites for Harbor Seals**

Source: MARI Focus Team, Harvey and Torok 1994, Kopec and Harvey 1995

FIGURE 2.23 **Intertidal Distribution of Selected Plants and Wildlife**



Mason's lilaeopsis, soft bird's-beak, California clapper rail, tidal flat specialists, northern pintail, and harbor seals are examples of plants and wildlife that inhabit different parts of the intertidal zone. Protection of these species requires consideration of the entire baylands ecosystem.