Baylands Ecosystem Habitat Goals

A Report of Habitat Recommendations Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project

Db	Deep Bay/Channel
Sb	Shallow Bay/Channel
Tf	Tidal Flat
Tm	Tidal Marsh
Tp	Tidal Marsh Pan
Lg	Lagoon
Bc	Beach/Dune
Ag	Agricultural Bayland
Dw	Diked Wetland
Sp	Salt Pond
St	Storage or Treatment Pond
Uf	Undeveloped Bay Fill
Df	Developed Bay Fill
Pr	Perennial Pond
Rw	Riparian Forest/Willow Grove
Mg	Moist Grassland
Gr	Grassland/Vernal Pool Complex

Legend for Baylands Segment Maps, Chapter Five

For descriptions of each habitat type, please see Chapter Four.

Basic Baylands Facts

The baylands exist around the Bay between the lines of high and low tide. They are the lands touched by the tides, plus the lands that the tides would touch in the absence of any levees or other unnatural structures.

There are 73,000 acres of tidal baylands and 139,000 acres of diked baylands.

There used to be 23 miles of sandy beaches. Now there are about seven miles of beaches. Most of the present beaches occur in different locations than the historical beaches.

There used to be 190,000 acres of tidal marsh with 6,000 miles of channels and 8,000 acres of shallow pans. Now there are 40,000 acres of tidal marsh with about 1,000 miles of channels and 250 acres of pans.

Only 16,000 acres of the historical tidal marsh remain. The rest of the present tidal marsh has naturally evolved from tidal flat, been restored from diked baylands, or muted by water control structures.

There used to be 50,000 acres of tidal flat. Now there are 29,000 acres of tidal flat. The reduction is due to bay fill, erosion, and tidal marsh evolution.

There used to be about 174,000 acres of shallow bay and 100,000 acres of deep bay. Now there are 172,000 acres of shallow bay and 82,000 acres of deep bay. About 16,000 acres of deep bay have become shallow and 18,000 acres of shallow bay have become tidal, diked, or filled baylands.

The total area of high tide downstream of the Delta used to be about 516,000 acres. Now it is about 327,000 acres.

The total amount of shallow ponds in the baylands and in the adjacent grasslands used to range from about 16,000 acres to 22,000 acres, depending on the amount of rainfall. Now there are between 63,000 and 92,000 acres, depending on rainfall and water management practices. The increase is due to ponding in diked baylands.

137,000 acres of baylands have been diked.

50,000 acres of baylands have been filled.

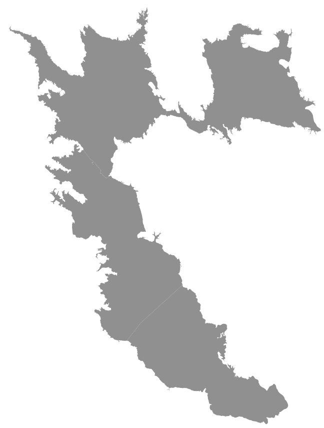
There are about 500 species of fish and wildlife associated with the baylands. Twenty of these species are threatened or endangered with extinction.

Seven million people live around the baylands.

Baylands Ecosystem

Habitat Goals

A Report of Habitat Recommendations



Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project

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March 1, 1999

Mike Monroe, Co-Chair
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San Francisco Bay Area Wetlands Ecosystem Goals Project

Dear Misters Monroe and Wilcox:

A Science Review Group was drawn to advise the Wetlands Ecosystem Goals Project on scientific questions of procedure and to look at the project reports. The advisors met as a group once over a two-day period, about midway through the project, and since then we have responded individually and collectively to your occasional requests for advice. This letter constitutes our final review of the goals project. An early draft of this letter was sent to the advisors, and the present text incorporates selected portions of their comments.

At its original meeting and through subsequent correspondence, the Science Review Group was asked to consider a variety of topics, such as project organization and supervision, in addition to science. We felt that, because many agencies were involved, the project's organization and supervision were outside the scope of our review. However, we made several suggestions to help improve the process. As advised, the project leaders developed a set of guiding principles, extended the project timeline to allow the technical teams more time to complete their work, and activated the team for hydrology and geomorphology.

There were two central scientific questions which we deliberated: whether selected species should be used to indicate habitat conservation goals, and whether the goals should be recorded on maps.

With regard to the question about species-based habitat goals, we did not reach complete agreement. One issue was whether species' present or past distributions could be used to prescribe future habitats as goals toward which change might be directed. Furthermore, since not all of the 500 or so candidate species, large or small, could be individually considered, there was concern that a selected list might not represent the whole system. Our scientific assessment of this species-based approach was influenced by the obvious fact that a great deal of knowledge of the various species was in the minds and the records of many local experts. This mass of knowledge could be organized by enlisting the help of the large population of experienced people. It was also recognized that the expert consideration of representative species would likely lead to a view of habitat and hence to the more important topic of habitat evolution and maintenance. This in fact is the procedure that evolved. With some misgivings, the Science Advisors endorsed the idea of using species as the most practical indicators.

With regard to the question about maps, we found more agreement. We found it logical to use maps to quantify and to illustrate the habitat goals. A matter of scientific concern was the appropriate detail and accuracy of the maps to be used, and how they would be combined. This was resolved by the participants in the project, who judged the maps produced for the project to be of sufficient quality to inform their scientific discourse and quantify their recommendations. At the end of this long process, all the technical teams worked together on the final maps of the habitat goals, which therefore satisfied the need for integration among the recommendations from all the teams.

Use of the final maps to illustrate and present the goals became subject to two related concerns: the specificity of the maps relative to the quality of the data, and how to show their specificity without raising public ire. As for the concern about data quality, the advisors concluded that the dozens of technical people compiling the data had in their collective experience the best source and that their information was the best available. As for the political concern, the advisors felt that the criterion should be the most logical and understandable method of presentation, not the matter of whether some landowners will object to having their property included in a map, or whether some agencies will be challenged by the scientific findings.

The Goals Project and the extensive work done was a meeting between environmental science and management. The report of this combined effort is not purely scientific. The next steps of implementation must involve monitoring as well as research. The collection of data in the monitoring process will also be a combination of management and science, for the avowed end is improvement of ecosystem health through management.

Based on our review of the draft and final reports, we believe that the Goals Project has established a reasonable, scientific basis for restoration of the baylands ecosystem. However, we caution against any large effort to achieve the goals that is not supported by a program of research and monitoring that can explain failure or success.

Luna B. Leopold

Luna B. Leopold
Chair, Science Review Group
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Technical Advice and Assistance

This report was made possible by the hard work of the nearly 100 Project participants listed on pages v – viii. Many of these individuals worked on the Project on their personal time. Members of the Resource Managers Group, and particularly the focus team leaders, collectively contributed thousands of hours of time.

Several Project participants were especially helpful in providing information and technical expertise for the production of this report. They include Peter Baye, Dennis Becker, Howard Cogswell, Glen Holstein, Paul Jones, Wes Maffei, Karl Malamud-Roam, Howard Shellhammer, and Jim Swanson. Several technicians assisted the focus teams for extended periods of time, including Janice Alexander, David Casady, Joan Goodmundson, Laura Hanson, Catherine Hickey, Thomas Ryan, and Feride Serifidden.

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Special thanks to Alexis Strauss, Acting Director, Water Division, U.S. Environmental Protection Agency, Region 9, and Loretta Barsamian, Executive Officer, San Francisco Bay Regional Water Quality Control Board, for their unfailing support of the Project.

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We appreciate the use of photographs provided by Herb Lingl/Aerial Archives (415-771-2555, herb@aerialarchives.com).

EcoAtlas

The EcoAtlas is a regional GIS (Geographic Information System) for Bay Area ecological resources which was used to support the development of the Goals. Numerous people contributed to the development of the EcoAtlas. Josh Collins and Robin Grossinger supervised the integration of scientific information. Zoltan Der directed GIS operations. Christina Wong did GIS and related technical work. Elise Brewster did historical research and cartography. Technical assistance was provided by Ted Daum, Todd Featherston, and Jung Yoon. Especially deserving of credit are the more than 200 local volunteers who contributed over 10,000 hours of volunteer time to the project. Without their talent and dedication, the detail and accuracy of the EcoAtlas would not be possible.

These interns and their area of focus were: Ann Baker, Alameda County; Katie Bickell, Spanish land grant cases and red-legged frog industry; Margot Cunningham, Contra Costa and Alameda counties and data management; Zoltan Der, San Mateo County and data management; Spence Everson, Santa Clara County; Arlie Haig, GIS development; Corrine Humphrey, data management; Maggie Hynes, Marin County; Ellie Insley, Sonoma County; Rebecca Johnson, Spanish land grant cases; Steve Jones, Contra Costa County; Alan Kaplan, Solano County; Isaac Shukima, Spanish documents; Katy Suttorp, native land-use and freshwater influences on tidal marsh; and Dennis Worrell, early soil surveys.

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Draft Report Comments

A draft of this report was distributed to 550 people, and it was made available on the Internet. In addition to comments from Project participants, comments from the following reviewers helped to clarify issues and to improve the final report: Rosemary Alex, Anthony Arnold, Linda Bagneschi, James Bancroft, Ron Barclow, Viola Barclow, Bill Bisso, Bill Bousman, John Bowers, Bill Britt, Wil Burns, John Callaway, Paul Campos, Mike Casazza, Dave Cavanaugh, Terrance Connolly, Bill Coon, Jerry Corda, Paul Crappuchettes, Carole D'Alessio, Norbert Dall, Ron Davis, Frank Delfino, Janice Delfino, Francesca Demgen, Don Dickenson, Suzanne Eastridge, Timothy Egan, Steve Engle, Arthur Feinstein, Harvey Goldberg, Julie Grantz, Sandra Guldman, Jim Haire, Catherine Hayes, Myrna Hayes, Stana Hearne, Totten Hefflefinger, Larry Johmann, Ellen Johnck, Frank Johnson, Mike Josselyn, Sheila Junge, Bruce Kern, Donald Kibby, Lee Lehman, Arnold Lenk, Clyde Low, Jean Matsuura, James McGrath, Gavin McHugh, Jim McKinney, Sunne McPeak, Janet Meth, Mike Miller, Evan Monroe, Frank Morris, Trish Mulvey, Ralph Nobles, Arvid Olson, Brad Olson, Kay Olson, Rick Parmer, Phil Peterson, Jim Reese, Richard Rodagondo, Brian Ross, Barbara Salzman, Jacqueline Schafer, Paul Shepherd, Jill Singleton, Jim Stark, Dwight Steele, Leonard Stefanelli, Ann Thomas, Will Travis, Mike Vassey, Bill Walter, Doug Wheeler, Wayne White, Kirk Willard, Roderick Wood, and William Wright.

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PREFACE

This report presents the findings of the San Francisco Bay Area Wetlands Ecosystem Goals Project. It is intended to be a guide for restoring and improving the baylands and adjacent habitats of the San Francisco Estuary.

Scientists and resource managers developed the Goals Project's recommendations, but this report has been written for the public rather than for a scientific or technical audience. This report is to be used in conjunction with another Goals Project document, entitled *Species and Community Profiles*, which provides background information on many of the animal species and plant communities of the Project area. The reader may request a copy of that document from the San Francisco Estuary Project.

During the development of the Goals, the Project's Resource Managers Group solicited public input on many occasions. In summer 1998, the public provided verbal and written comments on a draft Goals report. The Resource Managers Group reviewed all of these comments and made every effort to address them appropriately in this final report. The following items provide additional information on the main issues of concern.

- The maps in this report are meant to inform the reader about past and present habitat conditions in and adjacent to the baylands. The map in Appendix E shows one way, among many possibilities, that habitats might be arranged in order to implement the Project recommendations. These maps do not indicate the jurisdictional limits of wetlands, and they should not be used for regulatory purposes.
- Many local, state, and federal agencies were involved in the Goals Project. This does not imply that these agencies concur with each and every recommendation in this report or that they will take all of the actions necessary to implement the recommendations.
- The Project focused on the baylands, but there are many other areas in the region that are biologically important and which could benefit from some kind of an effort to develop habitat goals. The Project's emphasis on the baylands does not mean that these other areas are not in need of improvement and better protection.

- The habitat recommendations in this report are meant to be implemented voluntarily, incrementally, and cautiously in the coming decades. They encourage habitat improvement projects of many different sizes and with many different purposes.
- Project participants sought to develop habitat recommendations based primarily on ecology and physical science. In this way, they attempted to provide for the needs of fish and wildlife, even though certain considerations — economic constraints, landowner desires, zoning, and societal interests — might make it difficult or impossible to implement some recommendations. Restoration projects will need to analyze these considerations during initial planning phases.
- This report is not an environmental impact statement or an environmental impact report intended to meet requirements of the National Environmental Policy Act or the California Environmental Quality Act. Any project that proposes to implement the Project recommendations will need to undergo appropriate environmental impact analysis.

In spite of an extensive outreach effort, some members of the public, particularly rural landowners, indicated that they were unaware of the Goals Project until the release of the draft Goals report. Any efforts to revisit and update the Goals in the coming years should include better outreach to landowners.

Making the habitat changes envisioned in this report will require a better scientific understanding of bayland processes and of the effects of habitat conversion. It also will necessitate closer coordination among many public and private interests. These needs can best be met through the development of a regional wetlands plan. This Goals report and other appropriate documents should form the basis of such a plan.

The Resource Managers Group invites the citizens of the Bay Area to read this report and to develop an understanding of the habitat changes needed to ensure a healthy baylands ecosystem. Above all, we encourage everyone who will be involved in transforming the baylands to work together in a creative and cooperative fashion. The coming decades should be an exciting time in which the baylands are restored and enhanced in a way that benefits everyone in the region.

CONTENTS

FIGURES

TABLES

BOXES

This report presents recommendations for the kinds, amounts, and distribution of wetlands and related habitats that are needed to sustain diverse and healthy communities of fish and wildlife resources in the San Francisco Bay Area. It represents the culmination of more than three years of work by scientists, resource managers, and other participants of the San Francisco Bay Area Wetlands Ecosystem Goals Project (Goals Project).

The geographic scope of the Goals Project included portions of the San Francisco Estuary that are downstream of the Sacramento-San Joaquin Delta. These include Suisun Bay, San Pablo Bay, and San Francisco Bay. Within this area, Project participants focused their attention on the baylands — the lands within the historical and modern boundaries of the tides — and adjacent areas.

The San Francisco Estuary Project identified a need for habitat goals in 1993. Subsequent discussions among representatives of fish and wildlife agencies confirmed this need. The Goals Project began in 1995 and involved more than 100 participants representing local, state, and federal agencies, academia, and the private sector. Participants were organized in several groups, each of which had a unique role in developing the Goals. The Resource Managers Group, composed of representatives of state and federal resource agencies, oversaw the Project and was ultimately responsible for the content and format of the Goals.

Developing the Goals

The process for developing the Goals involved several steps. These included selecting key species and key habitats, assembling and evaluating information, preparing recommendations, and integrating recommendations into Goals. The Resource Managers Group decided to develop goals based on species needs because there was relatively abundant information available on bayland species and habitats. There was general agreement that goals developed to improve habitats for many kinds of plants and animals would concurrently provide other important wetlands services, such as nutrient cycling, flood control, and water quality improvement.

In selecting key species of the baylands ecosystem, technical focus teams screened nearly 400 species of fish and wildlife and evaluated plant communities from the Bay to the adjacent uplands. The focus teams ultimately selected 120 species of invertebrates, fish, amphibians, reptiles, mammals, and birds to represent the complexity of the baylands ecosystem.

In developing the list of key habitats, Project participants reviewed habitat lists created for previous wetland planning efforts. Ultimately, they designated some two dozen key habitats of the baylands ecosystem. Most of the habitat designations had been commonly used in the region for years; however, some were unique to the Project.

After selecting key species and habitats, Project participants assembled qualitative and quantitative data on them and prepared initial habitat recommendations. These recommendations were integrated into a draft report that was circulated for public comment. This final report is based on the draft report, on verbal and written public comments submitted on the draft report, and on new information.

Habitat Goals

The Goals are presented at three levels of specificity — by region, by subregion, and by segment. The regional and subregional recommendations are fairly general and are summarized below. The segment recommendations are more detailed and are provided in the main body of the report.

The Goals recommendations are founded on one important premise:

> There should be no additional loss of wetlands within the baylands ecosystem. Furthermore, as filled or developed areas within the baylands become available, their potential for restoration to fish and wildlife habitat should be fully considered.

Regional Recommendations

The Goals recommend major habitat changes region-wide. They call for:

- Many large patches of tidal marsh connected by corridors to enable the movement of small mammals and marsh-dependent birds.
- Several large complexes of salt ponds managed for shorebirds and waterfowl.
- Extensive areas of managed seasonal ponds.
- Large expanses of managed marsh.
- Continuous corridors of riparian vegetation along the Bay's tributary streams.
- Restored beaches, natural salt ponds, and other unique habitats.
- Intact patches of adjacent habitats, including grasslands, seasonal wetlands, and forests.

This regional perspective embodies several ecological design principles which state that bayland restoration plans should:

- Center tidal marsh restoration, where possible, around existing populations of threatened and endangered species.
- Include restoration of tidal marsh along the salinity gradients of the Estuary and its tributaries.

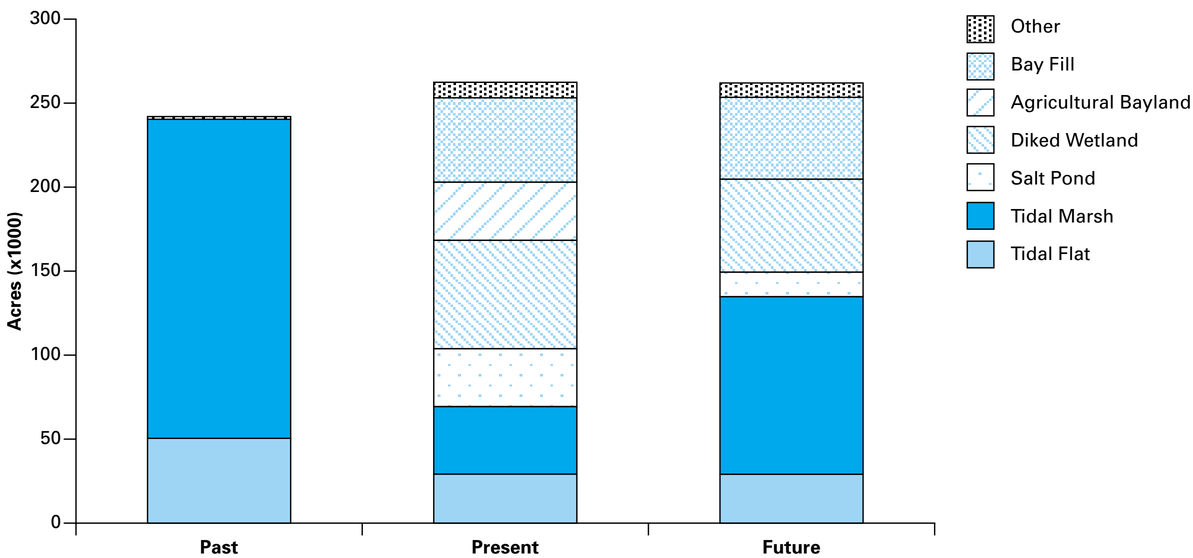
- Emphasize restoring tidal marsh along the Bay edge and where streams enter the baylands.
- Provide natural features, such as pans and large tidal channels, within tidal marshes.
- Reestablish natural transitions from tidal flat through tidal marsh to upland, and between diked wetlands and adjacent uplands.
- Provide buffers on undeveloped adjacent lands to protect habitats from disturbance.

The figure below shows the approximate regional acreage goals for the key bayland habitats. For perspective, it presents the Goals alongside graphs of past and present habitat acreage. Please keep in mind that these recommended changes should occur gradually over a period of several decades.

As the figure shows, restoring large areas of tidal marsh will reduce the acreage of some other habitats, especially salt pond, agricultural bayland, and managed marsh — each of which currently provide habitat for many species. These losses should be offset in the following ways:

- To offset the conversion of salt pond habitat, the remaining salt ponds should be managed to maximize wildlife habitat functions, particularly for shorebirds, waterfowl, and other water birds. There should be salt pond complexes in North Bay and in South Bay adjacent to important shorebird foraging areas. Each complex should be managed to maintain a range of salinities and water depths that favor the desired bird species.
- To offset the conversion of agricultural bayland habitat, the remaining agricultural areas should be managed as seasonal pond habitat to improve habitat functions for shorebirds, waterfowl, and other water birds.

Past, Present, and Recommended Future Bayland Habitat Acreage for the Region



- To offset the conversion of managed marsh habitat, the remaining managed marshes should be managed to increase their waterfowl habitat functions.

Although the Goals recommend reducing the acreage of some key habitat types in most of the subregions, they call for increasing the region's overall ability to support a full range of fish and wildlife. In essence, the Goals shift some of the functions of managed habitats from one subregion to another.

Subregional Recommendations

The subregional recommendations are more specific than the regional recommendations, but they are still fairly general. They are described here, and the subregional habitat acreage goals are presented in the main body of the report.

Suisun Subregion

The overall goal for the Suisun subregion is to restore tidal marsh on the northern and southern sides of Suisun Bay, Grizzly Bay, and Honker Bay, and to restore and enhance managed marsh, riparian forest, grassland, and other habitats.

In Suisun Marsh, tidal marsh should be restored in a continuous band from the confluence of Montezuma Slough and the Sacramento/San Joaquin rivers to the Marsh's western edge. This band of tidal marsh should extend in an arc around the northern edge of the Marsh and should blend naturally with the adjacent grasslands to provide maximum diversity of the upland ecotone, especially for plant communities. A broad band of tidal marsh also should be restored along the southern edge of Suisun Marsh and around Honker Bay, in large part to improve fish habitat.

On the majority of lands within Suisun Marsh, the long-standing practice of managing diked wetlands primarily for waterfowl should continue. These brackish marshes should be enhanced, through protective management practices, to increase their ability to support waterfowl. On the periphery of the Marsh, moist grasslands with vernal pools should be enhanced, as should riparian vegetation along the tributary streams.

On the Contra Costa shoreline, full tidal action should be restored to many of the marshes that currently are diked or that receive muted tidal flow. Restoration should incorporate broad transition zones to foster a higher diversity of plant communities and associated animals. It also should provide buffers to protect these populations from adjacent disturbance. Riparian vegetation should be restored along as many stream corridors as possible.

In the northern part of this subregion, achieving the Goals will depend largely on the willingness of private duck club owners to convert managed marsh to tidal marsh. On the Contra Costa shoreline, achieving them will depend on the willingness of public and private landowners to restore many marshes to full tidal action.

North Bay Subregion

The overall goal for the North Bay subregion is to restore large areas of tidal marsh and to enhance seasonal wetlands. Some of the inactive salt ponds should be managed to maximize their habitat functions for shorebirds and waterfowl, and others should be restored to tidal marsh. Tributary streams and riparian vegetation should be protected and enhanced, and shallow subtidal habitats (including eelgrass beds in the southern extent of this subregion) should be preserved or restored.

Tidal marsh restoration should occur in a band along the bayshore, extending well into the watersheds of the subregion's three major tributaries — Napa River, Sonoma Creek, and Petaluma River. Seasonal wetlands should be improved in the areas that currently are managed as agricultural baylands. All remaining seasonal wetlands in the uplands adjacent to the baylands should be protected and enhanced.

In much of this subregion, achieving the Goals will depend on the willingness of farmers to convert agricultural baylands to tidal marsh and to allow the remaining areas to be managed as seasonal pond habitat.

Central Bay Subregion

The overall goal for the Central Bay subregion is to protect and restore tidal marsh, seasonal wetlands, beach dunes, and islands. Natural salt ponds should be restored on the East Bay shoreline. Shallow subtidal habitats (including eelgrass beds) should be protected and enhanced. Tributary streams and riparian habitats should be protected and enhanced.

Tidal marshes should be restored wherever possible, particularly at locations that abut streams and at the upper reaches of dead-end sloughs. Tidal marsh restoration in urban areas is encouraged.

Although topography and urban and industrial development limit the potential for large-scale habitat restoration in this subregion, there are many opportunities to restore relatively small tidal marshes and other habitats, and these should be pursued. Even small, disconnected patches of tidal marsh would provide habitat islands for migrating native wildlife species and improve overall habitat conditions. Even the smallest restoration efforts should try to incorporate transitions from intertidal habitats to adjacent uplands, as well as upland buffers. Shorebird roosting sites should be protected and enhanced.

In this subregion, achieving the Goals will depend largely on the willingness of many private and public landowners to undertake habitat restoration and enhancement in the most urbanized portion of the baylands.

South Bay Subregion

The overall goal in the South Bay subregion is to restore large areas of tidal marsh connected by wide corridors of similar habitat along the perimeter of the Bay. Several large complexes of salt ponds, managed to optimize shorebird and waterfowl habitat functions, should be interspersed throughout the subregion, and naturalistic, unmanaged salt ponds should be restored on the East Bay shoreline. There should be natural transitions from mudflat through tidal marsh to adjacent uplands, wherever possible. Adjacent moist grasslands, particularly those with vernal pools, should be protected and improved for wildlife. Riparian vegetation and willow groves should be protected and restored wherever possible.

In this subregion, achieving the Goals will depend largely on the willingness of the Cargill Salt Division to undertake major changes in its operations. It also will depend on the efforts of many other private and public landowners.

Restoration Benefits

Achieving the Goals region-wide would have major environmental benefits. A primary anticipated benefit would be the recovery of the baylands' many threatened and endangered species. For example, restoring large areas of tidal marsh would enable populations of salt marsh harvest mouse and California clapper rail to rebound, eliminating the need for their current special protection. Likewise, restoring tidal marsh would improve habitat conditions for the endangered Chinook salmon and the threatened Delta smelt.

Restoring large amounts of tidal marsh would improve the Bay's natural filtering system and enhance water quality, increase primary productivity of the aquatic ecosystem, and reduce the need for flood control and channel dredging.

Enhancing diked wetlands would increase the regional and subregional support of migratory birds. Restoring vernal pools and other seasonal wetlands would reverse declines of unique plant and animal communities. Restoring riparian corridors would benefit many species of amphibians, mammals, and birds.

Implementing the Goals Recommendations

Several issues influence the implementation of the recommendations in this report. These include large-scale physical factors, such as sea level rise and sediment supply and deposition, as well as more site-specific design and management considerations.

Restoring the baylands also will require addressing a variety of complicated technical and policy issues, including:

- Phasing of projects so that the habitat functions of diked baylands — especially seasonal wetlands, salt ponds, and managed marsh — are provided when tidal marsh is restored.
- Determining how and when to use dredged material for tidal marsh restoration.
- Balancing the need for public access with the needs of bayland wildlife.
- Controlling non-native invasive plants and introduced animal species.
- Ensuring adequate funding to acquire, restore, and manage bayland habitats in the long term.

Science Needs

There has been considerable scientific information compiled about the Estuary and the baylands in the past decades. Increased information promotes a better understanding of this complex environment and will help improve habitat design and management. However, even with all of the information that is available, there is still a need for more.

The Resource Managers Group warned that there is a significant ecological risk in undertaking region-wide bayland restoration efforts without an adequate program of science support. Appropriate steps should be taken immediately to establish a regional science program to support the management of the baylands ecosystem. The initial emphasis should be placed on making existing and new information more available for those who can use it to improve restoration planning, design, and management decisions. Local scientists and other experts should develop the baylands science program. The Estuary Institute should coordinate the effort as part of the Regional Monitoring Strategy. Local, state, and federal agencies and others should participate in developing and implementing the program.

Next Steps

The Goals establish a flexible vision for restoring bayland habitats. Because they are not a blueprint of specific projects, implementing the Goals recommendations will require close coordination among landowners, agencies, and others. Accordingly, the RMG recommended that the agencies and the public work together to develop an appropriate process for implementing the Goals. This process should seek to ensure better coordination, identify appropriate research and monitoring, and improve agency policies and procedures.

The Estuary Project's *Comprehensive Conservation and Management Plan* designates the California Resources Agency as the lead agency for developing a regional wetlands plan. The Resources Agency agreed to work with the Bay Area Wetlands Planning Group in developing this plan. This past winter, group members drafted a general scope for this effort. The tasks in the draft scope include forming a stakeholder committee, holding technical workshops, preparing a draft plan, seeking public comments on the draft plan, and preparing a final plan. The stakeholder committee will include landowners, business interests, environmental groups, and local governments. Initial stakeholder meetings are scheduled to begin in mid-1999, and developing the wetland plan is expected to take six to twelve months.

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

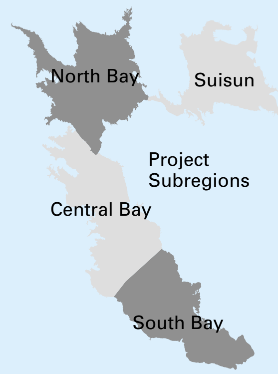
The need to establish a long-term vision for the Bay Area's wetlands arose initially during discussions among participants of the San Francisco Estuary Project

[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

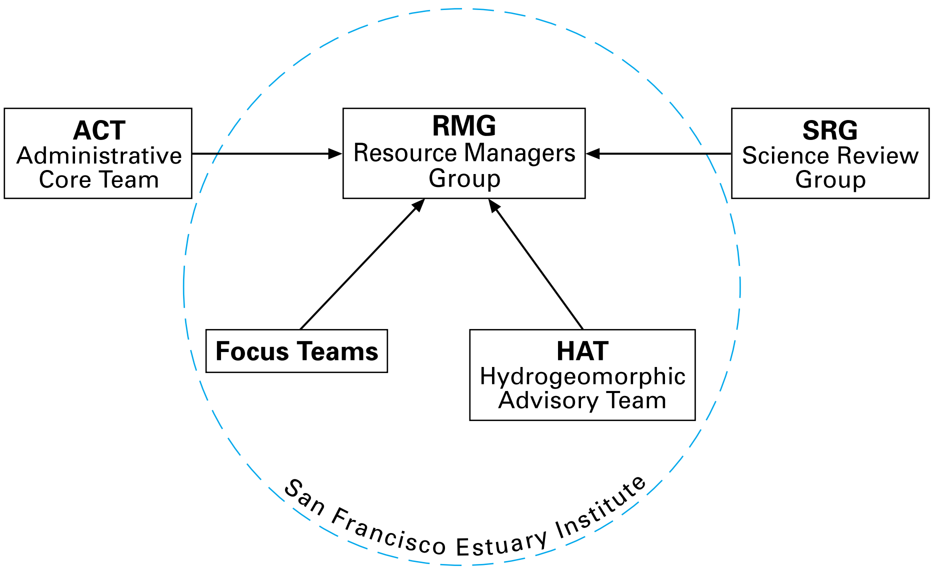
Participants and Project Organization

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.

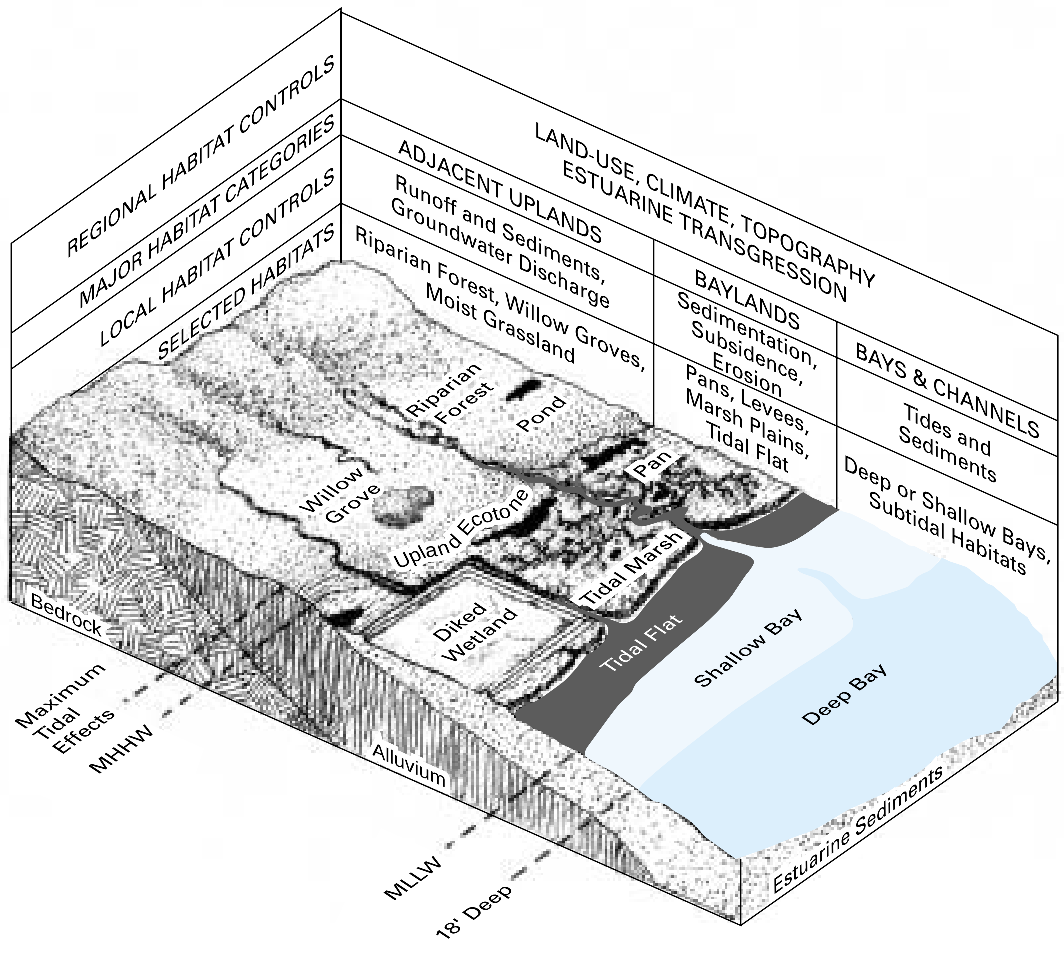
Many different models may be used to study the relationships of habitat controls and their effects on the baylands ecosystem. Several useful models are described in recent work done for the CALFED Bay-Delta Program's Comprehensive Monitoring and Research Program (CALFED 1998a). **Figure 2.1** illustrates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

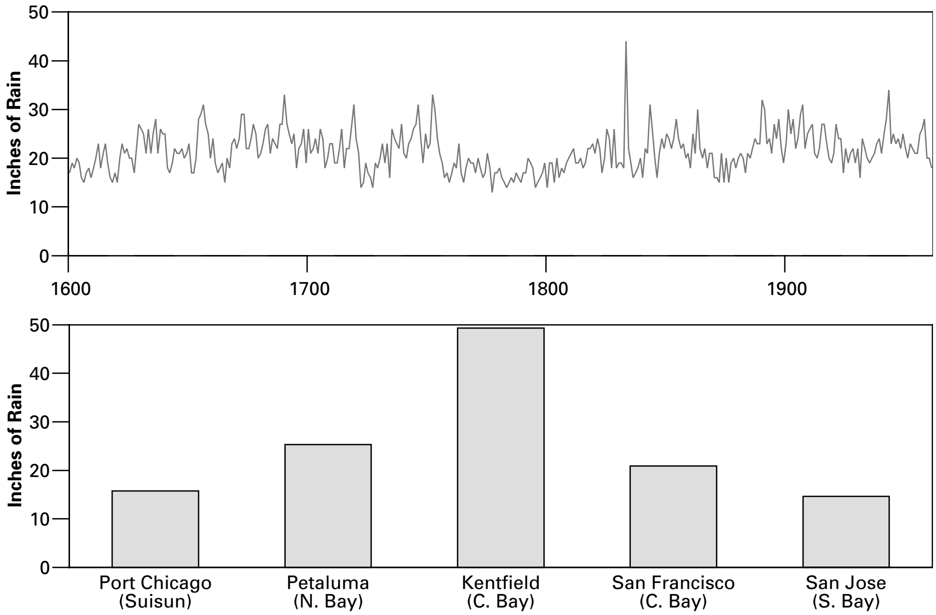
The climate of a region is defined by the seasonal and year-to-year patterns of air temperature and rainfall. Climate is forever operating on the baylands; it ultimately controls the *amount* of water and sediment that is available to create and maintain

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.

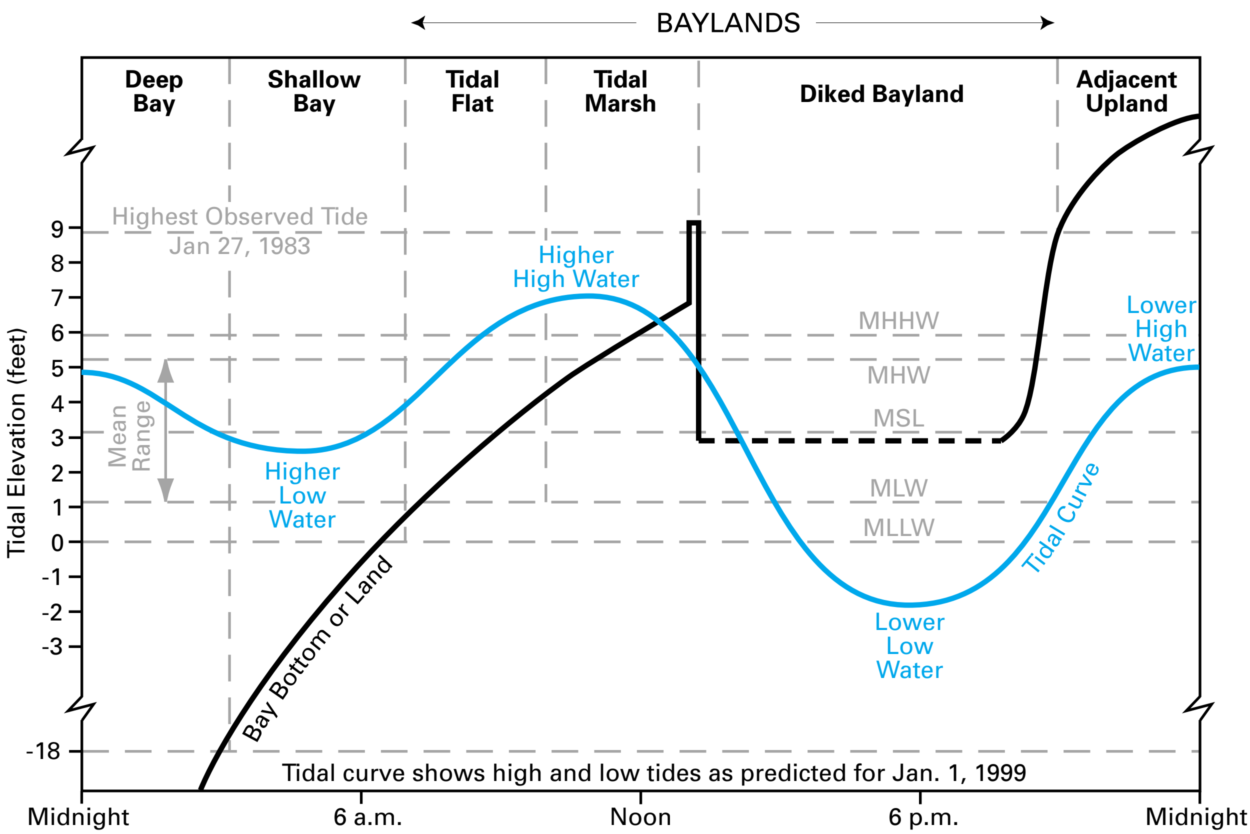
Water

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.

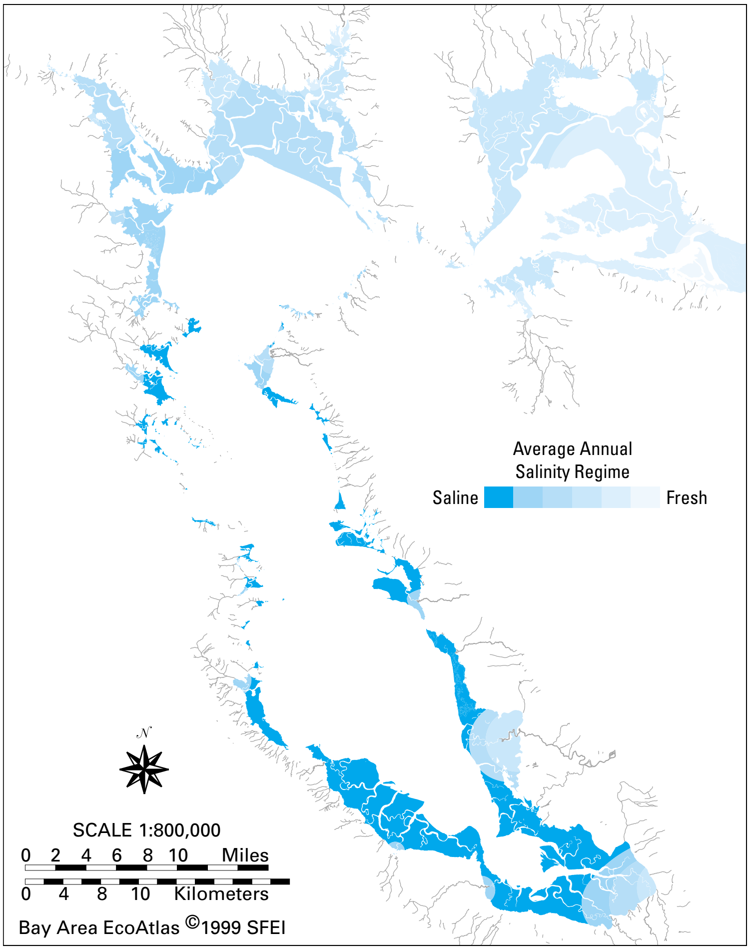
To preserve the natural diversity of the baylands, tidal marshes must be restored along the salinity gradients of the Estuary, such that fresh and brackish species of plants and animals have someplace to go as sea level rises and the Estuary moves inland.

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).

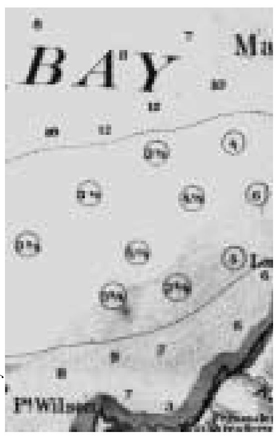
The Project's Hydrogeomorphic Advisory Team estimated that natural sedimentation in South Bay would take about 10 to 15 years to raise the bottom of a moderately subsided (minus 3 feet Mean Sea Level) salt pond to an elevation where native vegetation would become established. In the most severely subsided 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**).

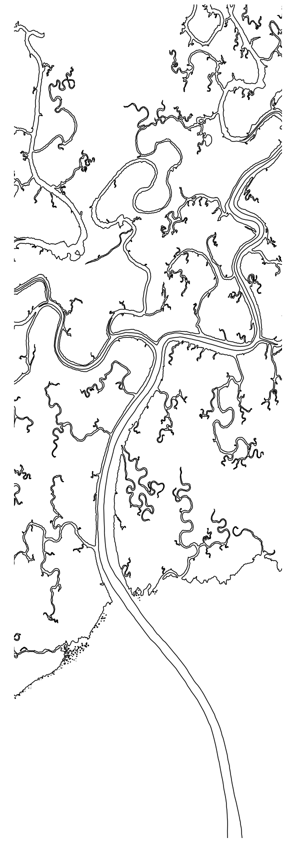
Each day, as the tide went out, almost 50,000 acres of tidal flats emerged along the margins of the bays and larger tidal channels. Under fresher conditions in Suisun and North Bay, where marsh plants colonized the lower intertidal zones, flats were scarce and relatively narrow. The steep topography 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.


Christina Wong

Intricate channels form in older tidal marshes.

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.

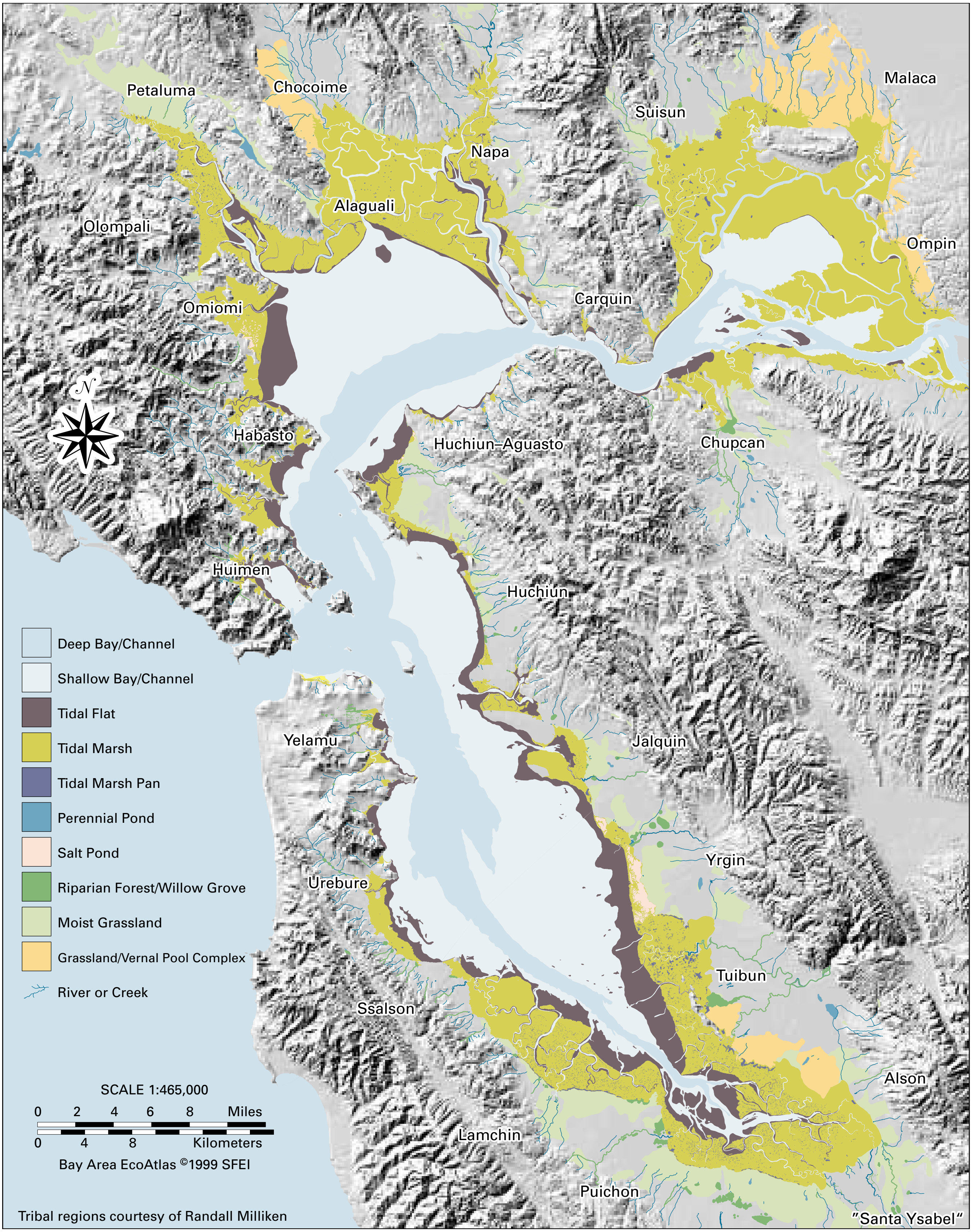
Adjacent to the baylands in the flatter portions of the region, especially at the entrances to broad valleys, the tidal marshes graded gently into low-lying moist grasslands. These grasslands evolved on patches of poorly drained soils of fine clay. Where the winds from across the bays were strongest, 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.

The Yrgin worked the marsh for salt.


USCS 1857

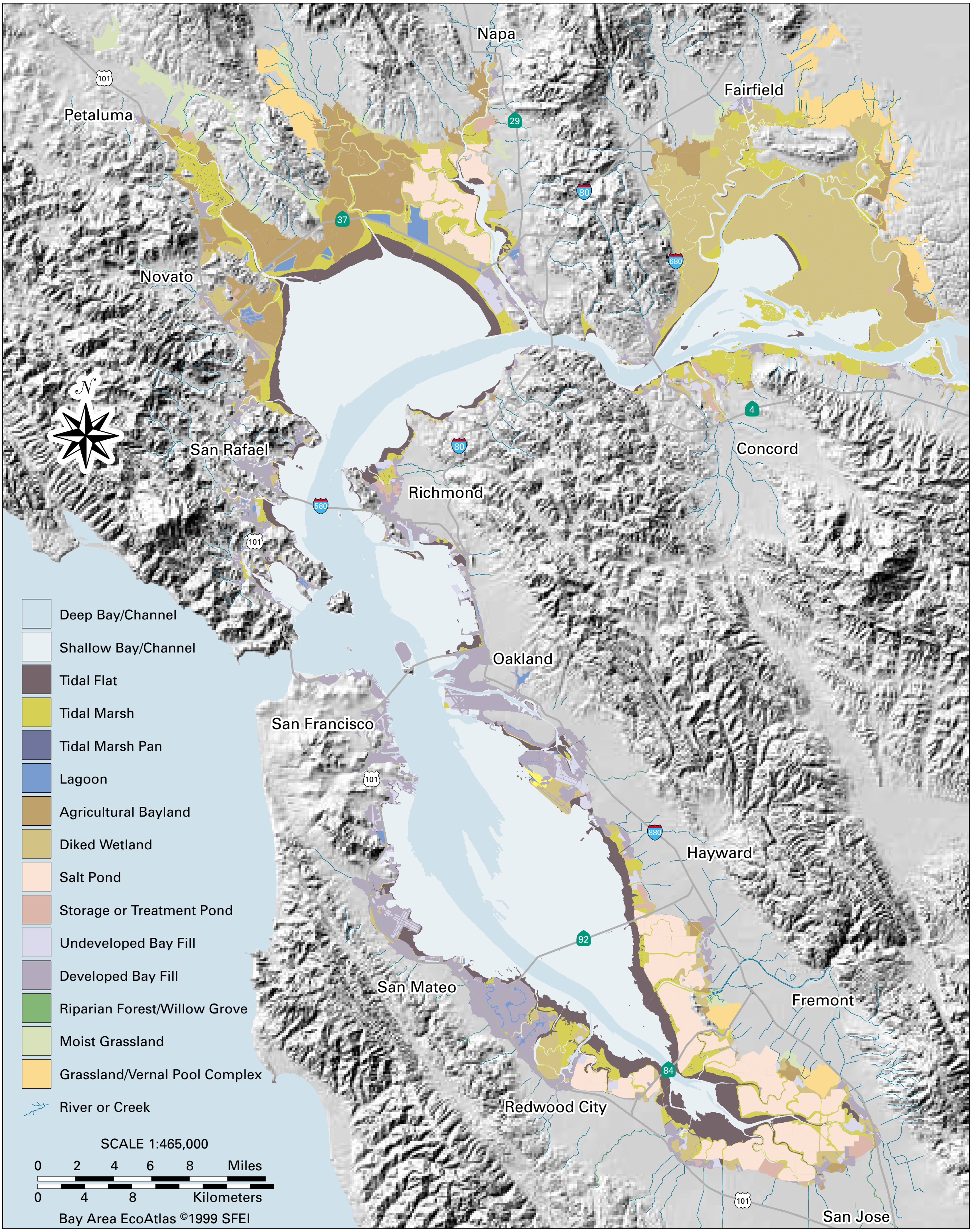
In this semi-arid region, where evapotranspiration can exceed precipitation by a factor of two or more (Rantz 1971), perennial ponds and lakes were uncommon. The greatest number of persistent, non-tidal, freshwater ponds and marshes occurred in the largest valleys with large catchment basins, such as 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

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

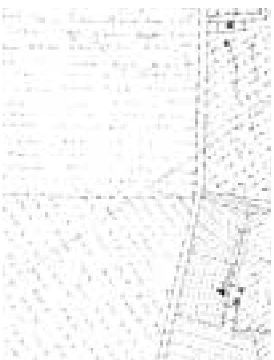
Early farmers diked and drained tidal marshes.

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...

...still exist.

NASA 1995/96

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.

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.

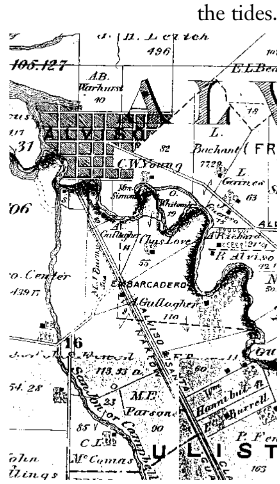
A common misconception is that Suisun Marsh is only for ducks and duck hunting. It is true that much of the Marsh is managed for wintering waterfowl and to provide hunting opportunities. But those who spend time in the Marsh understand that the managed areas also provide habitat for a wide variety of 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.

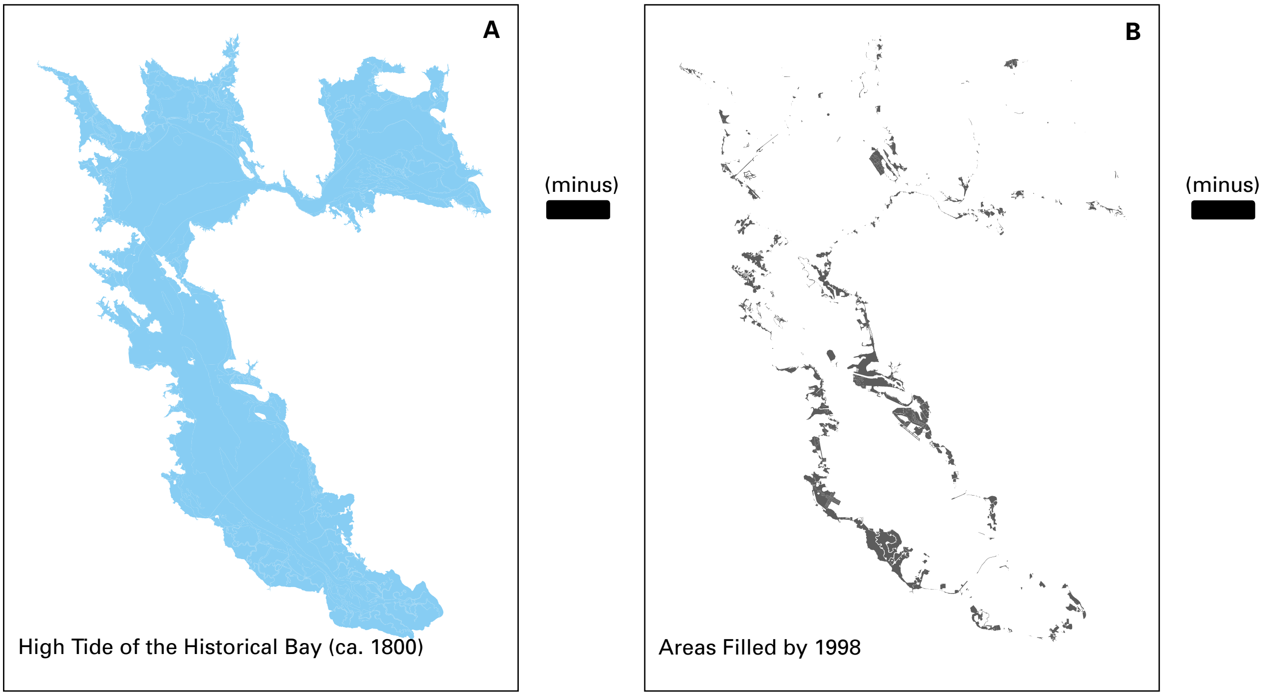


SFEI Archives

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.

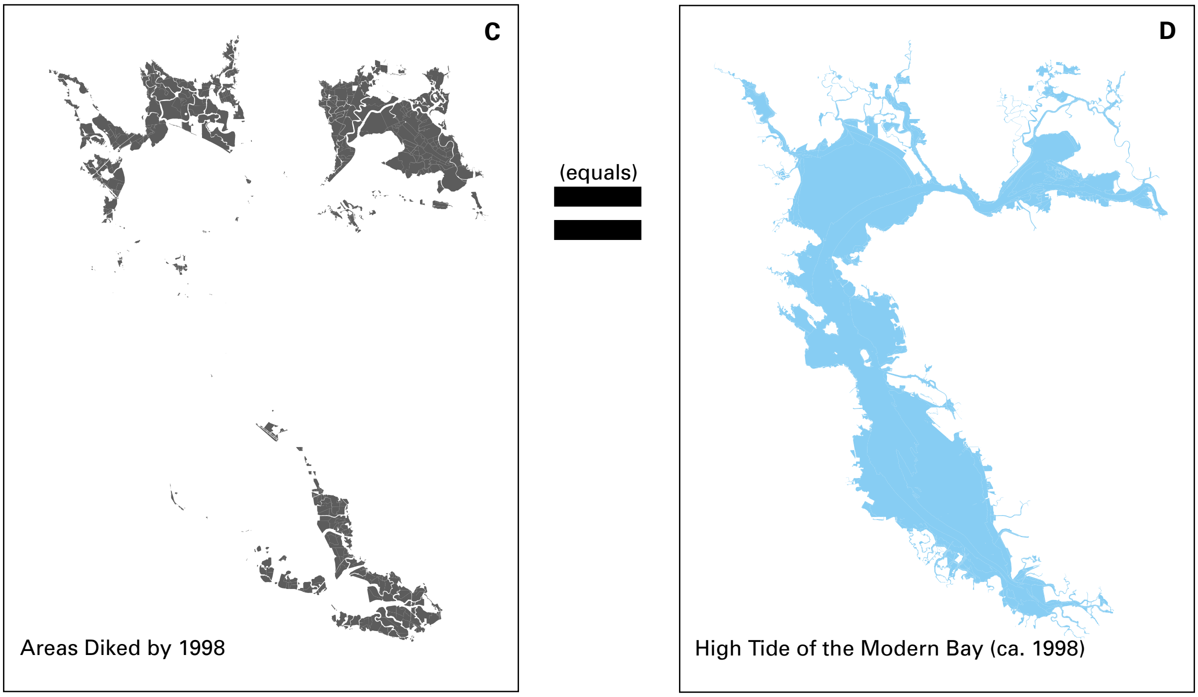
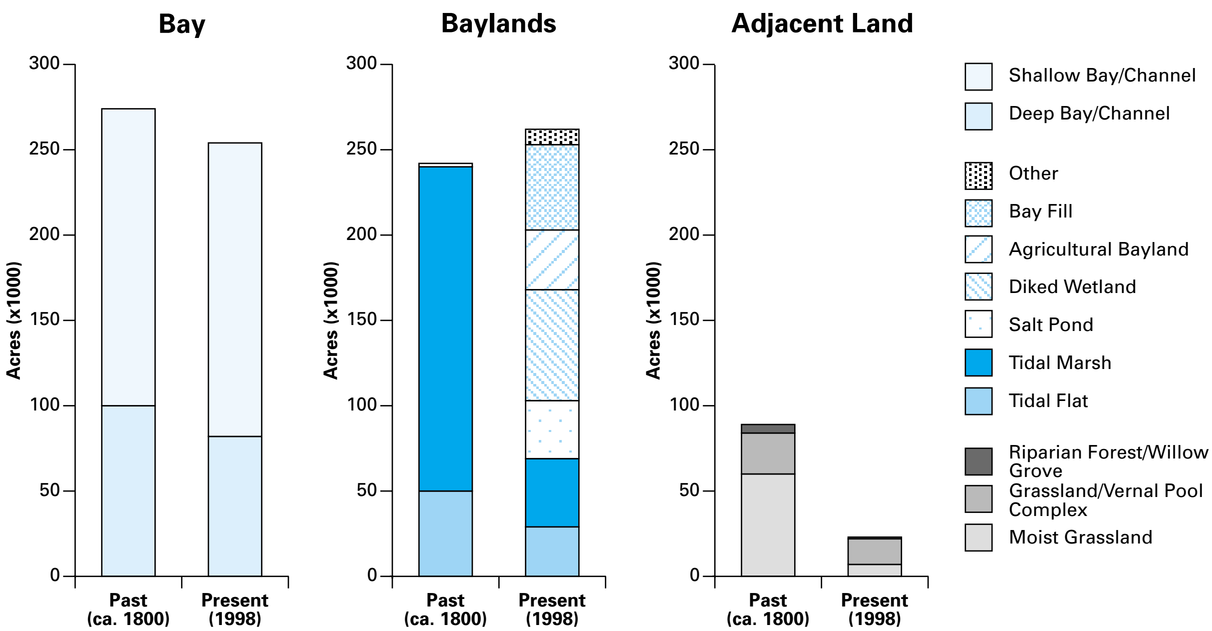


FIGURE 2.9 **Past and Present Habitat Acreage — Project Area (see Appendix B for numerical values)**



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.

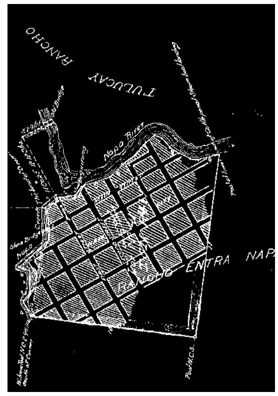
Figures 2.10 – 2.13 illustrate the habitat acreage changes in each of the Project subregions.

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 dewatering 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.



Bancroft Library

Creeks and roads shared the traffic.

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

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**

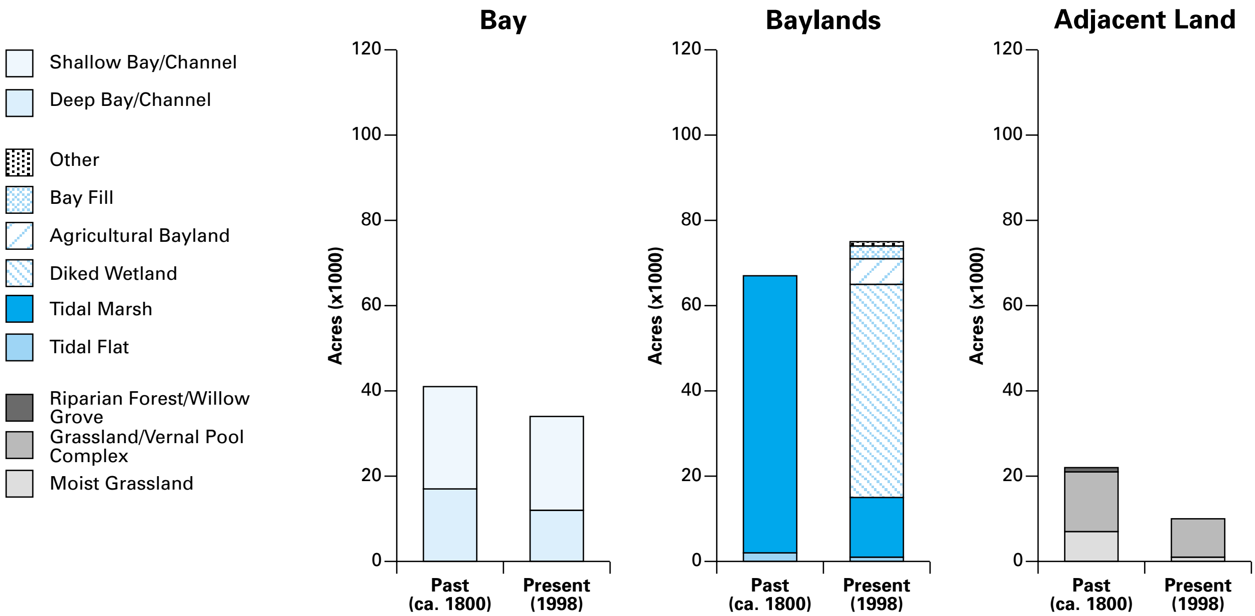


FIGURE 2.11 **Past and Present Habitat Acreage — North Bay Subregion**

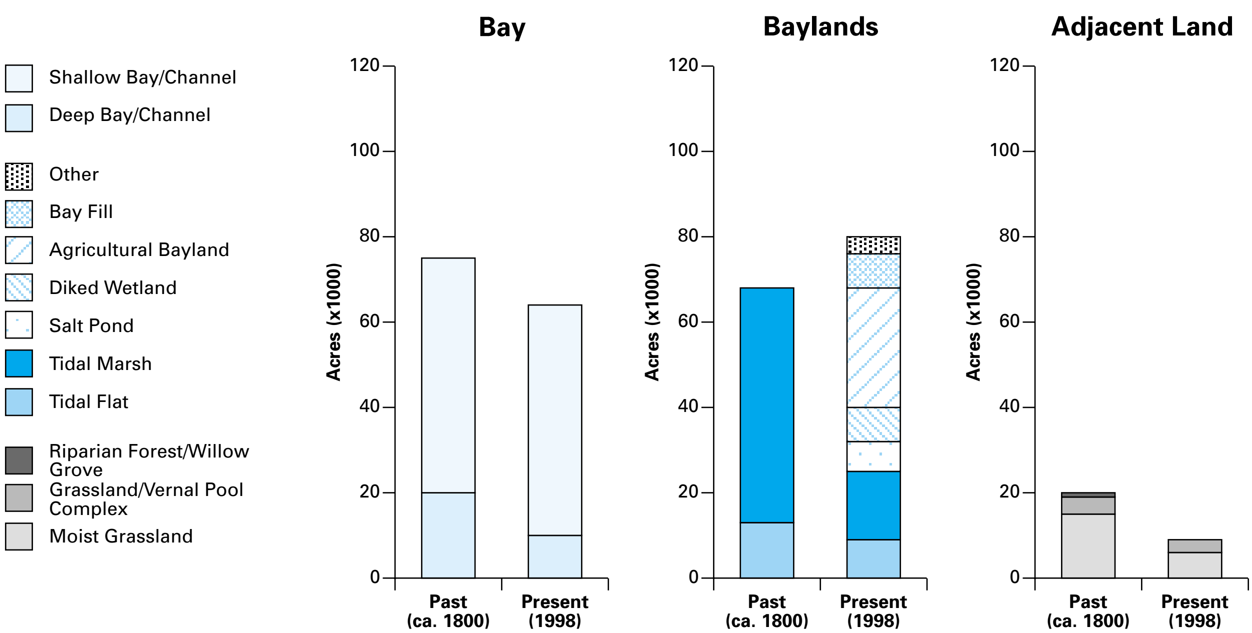


FIGURE 2.12 Past and Present Habitat Acreage — Central Bay Subregion

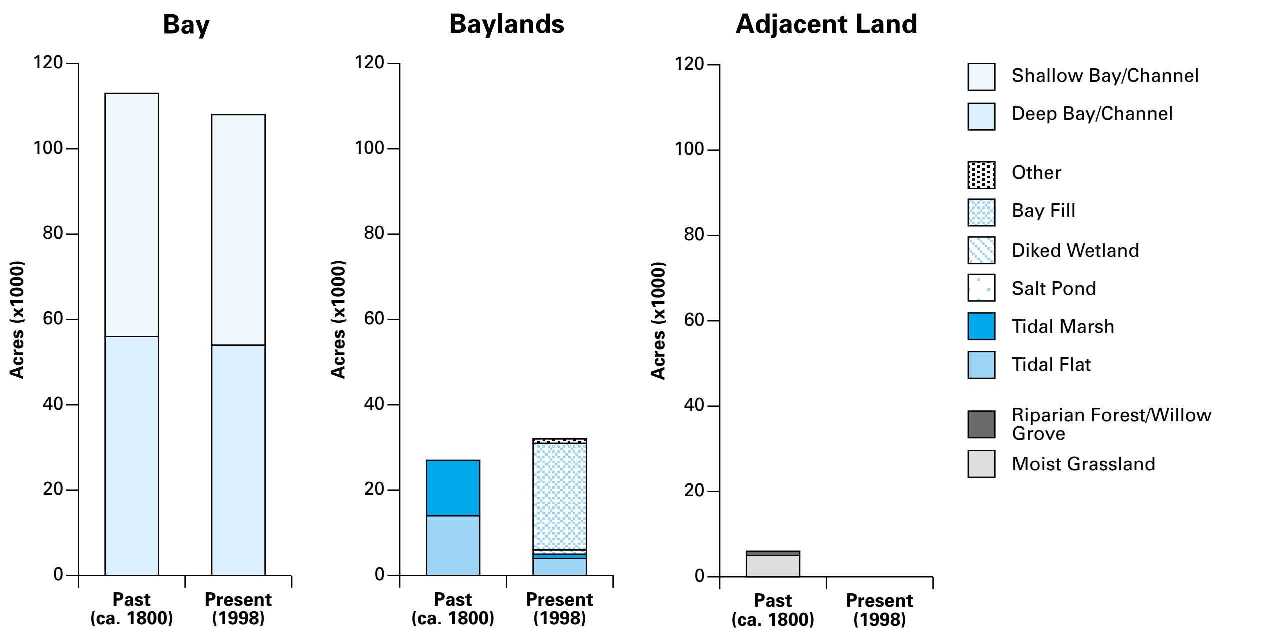
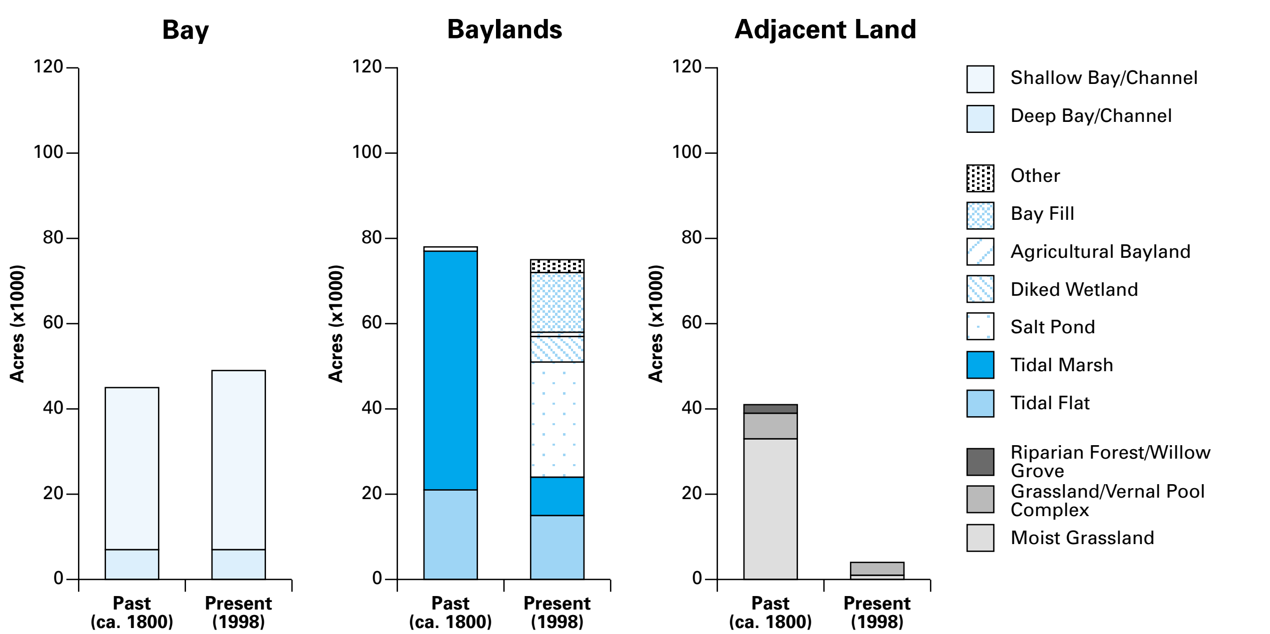


FIGURE 2.13 Past and Present Habitat Acreage — South Bay Subregion



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.

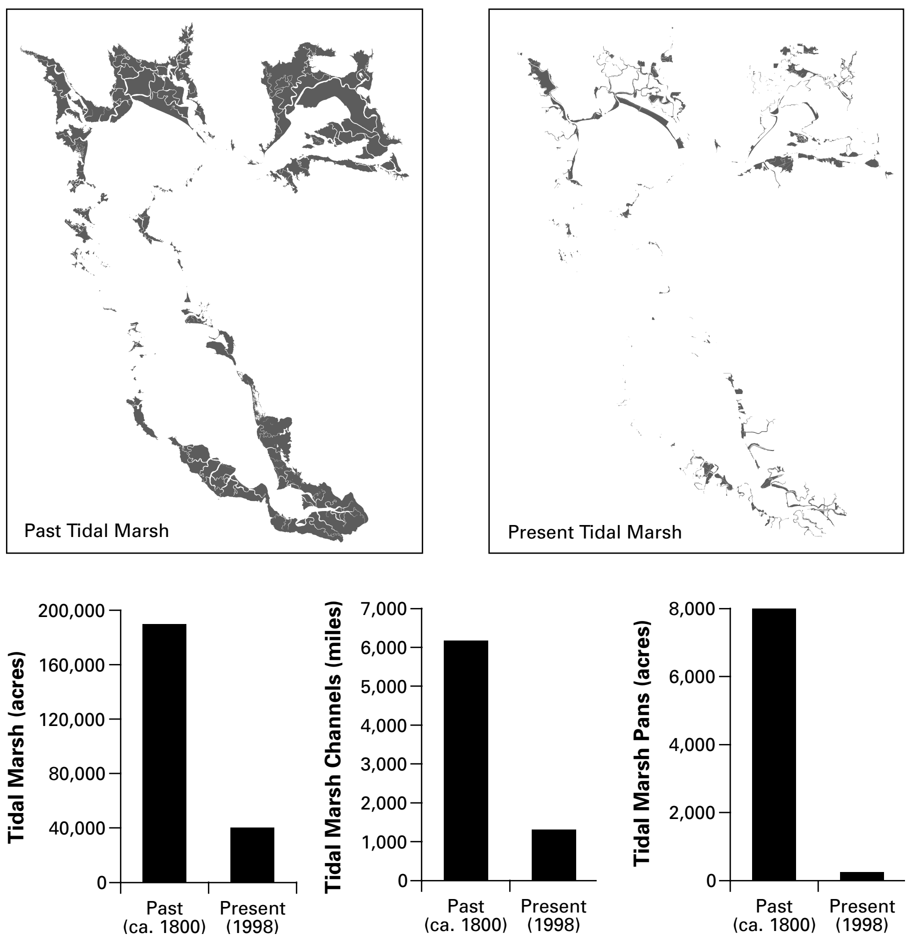
These declines in fish and wildlife populations have caused obvious economic losses through declines in sport and commercial hunting and fishing. The losses of bayland habitats have caused declines in aesthetics, pollution control, flood control, erosion control, and navigation, all of which have a price 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**

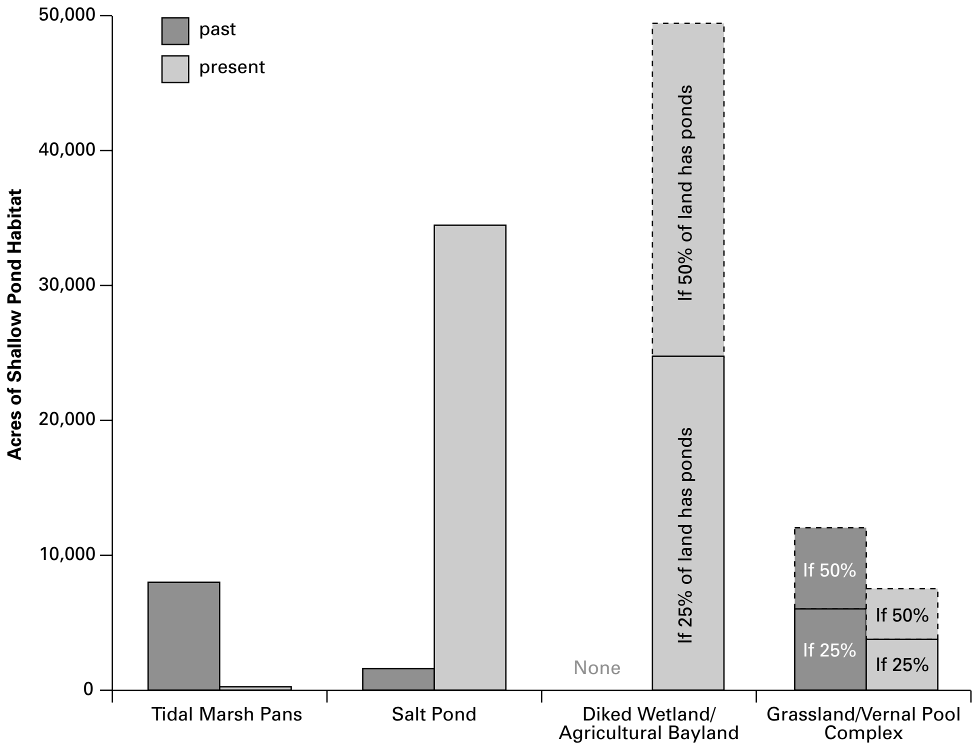


People have caused a 79% loss in tidal marsh during the last 200 years. Only about 8% of the historical marsh remains. The rest of the present marsh has naturally evolved from tidal flat, has been restored from diked baylands, or is muted by water control structures. Most tidal marsh fish and wildlife 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**

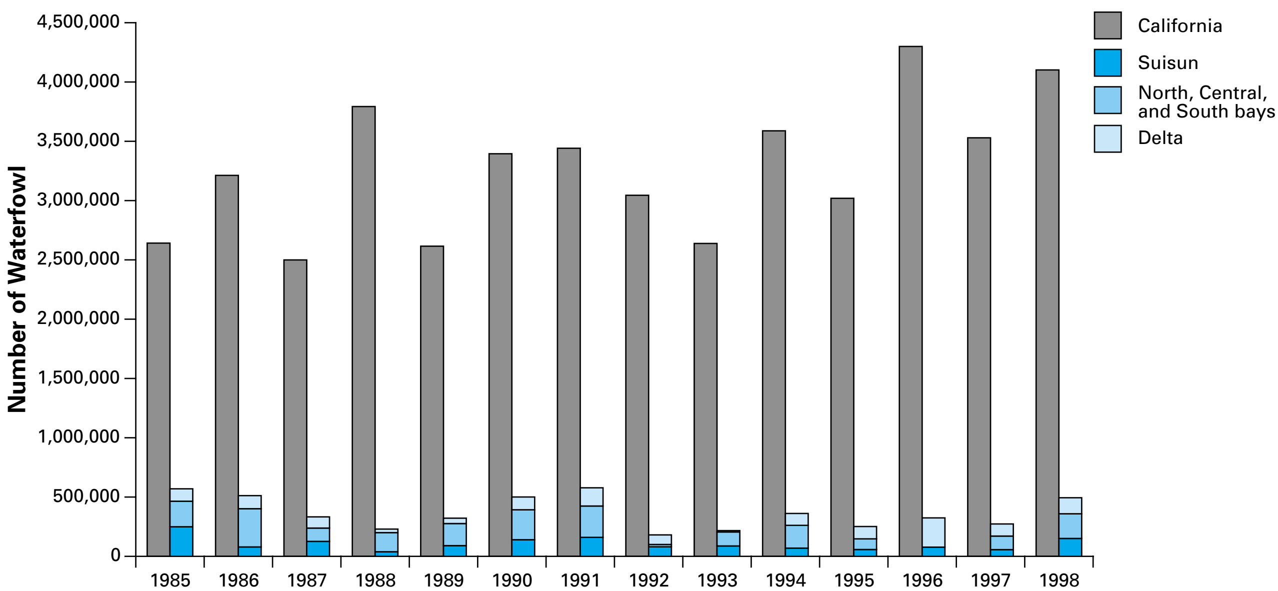


The shallow pond habitats of the baylands ecosystem are salt ponds, tidal marsh pans, seasonal ponds in diked baylands, and vernal pools in adjacent grasslands. The area of grasslands and diked wetlands/agricultural baylands that is covered by shallow ponds varies depending upon rainfall and local water 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).

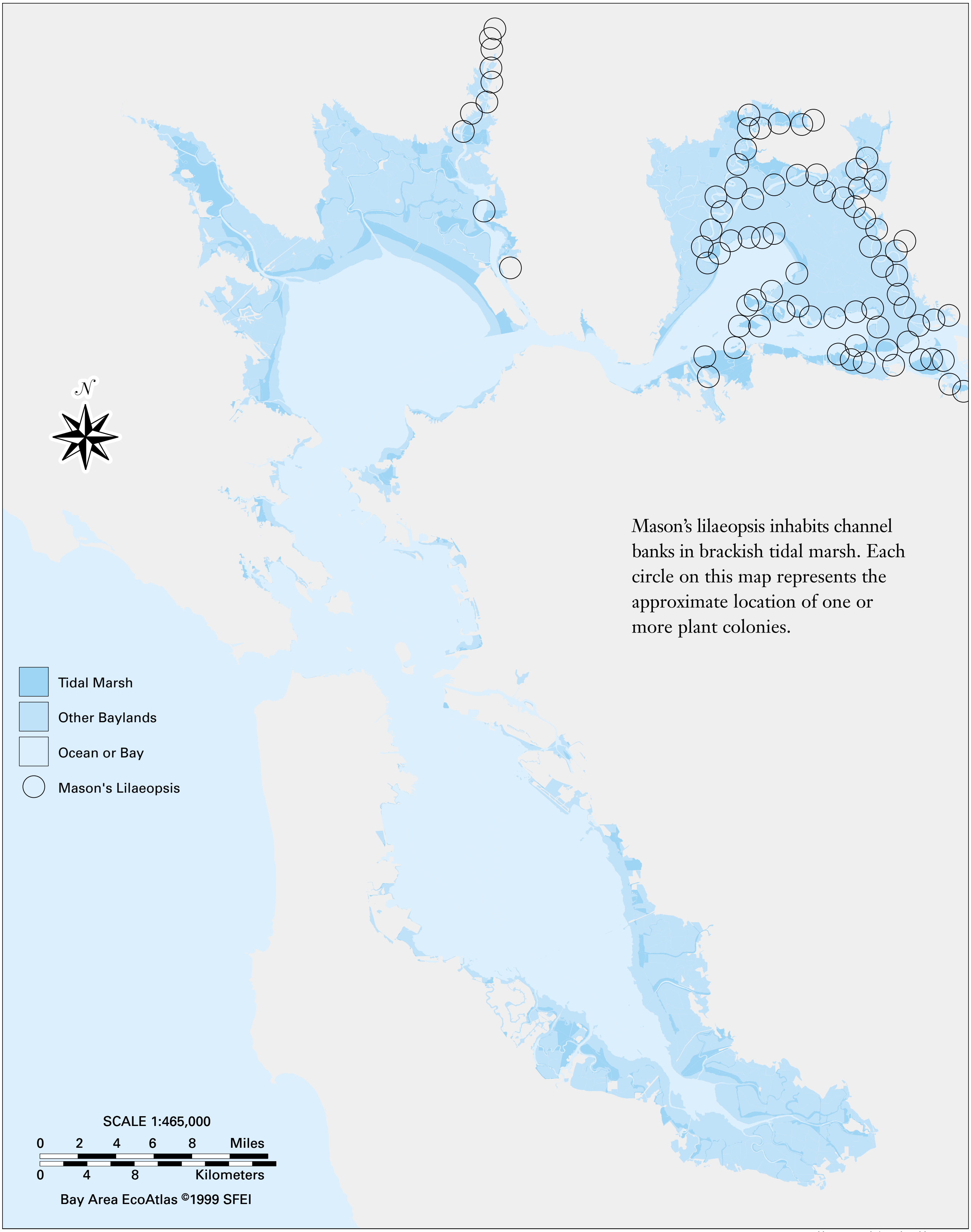
Maps of the modern distribution and abundance of baylands fish and wildlife help to identify their habitat needs. Synoptic, or region-wide, surveys are especially valuable because they reveal the relative importance of the different subregions, habitat types, and local habitat mosaics. Examples of regional 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**



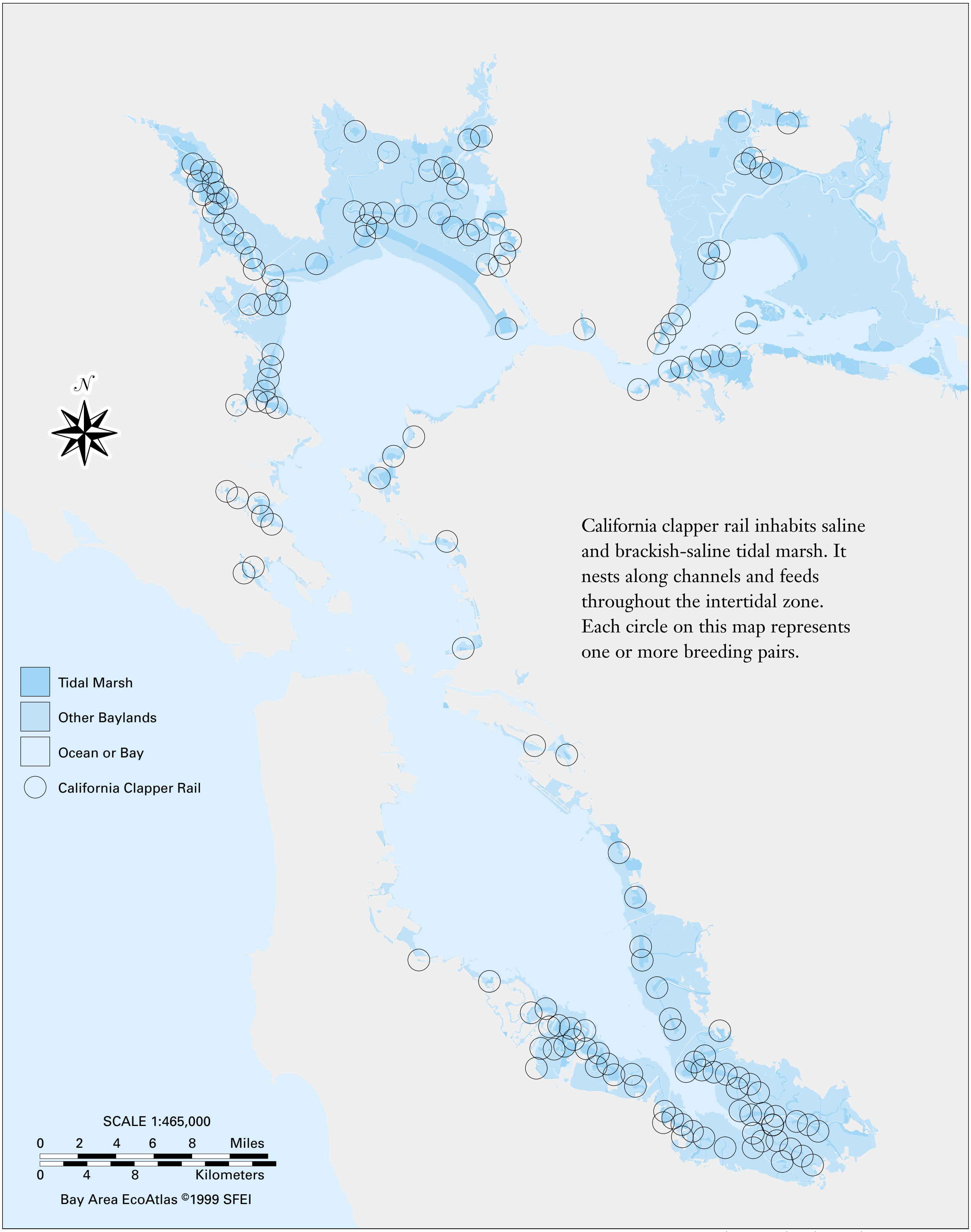
Source: Fiedler and Zebell 1993

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

Soft bird's-beak inhabits the ecotone between brackish tidal marsh and adjacent upland. Each circle on this map represents the approximate location of one or more plant colonies.

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**

Western sandpipers, marbled godwits, and long-billed dowitchers are migratory shorebirds that use the baylands for resting and feeding. The largest number of individuals of these species have been found in the far North Bay, far South Bay, and along the east side of South Bay.

Source: Shorebirds and Waterfowl Focus Team

FIGURE 2.21 **Distribution of Northern Pintail**

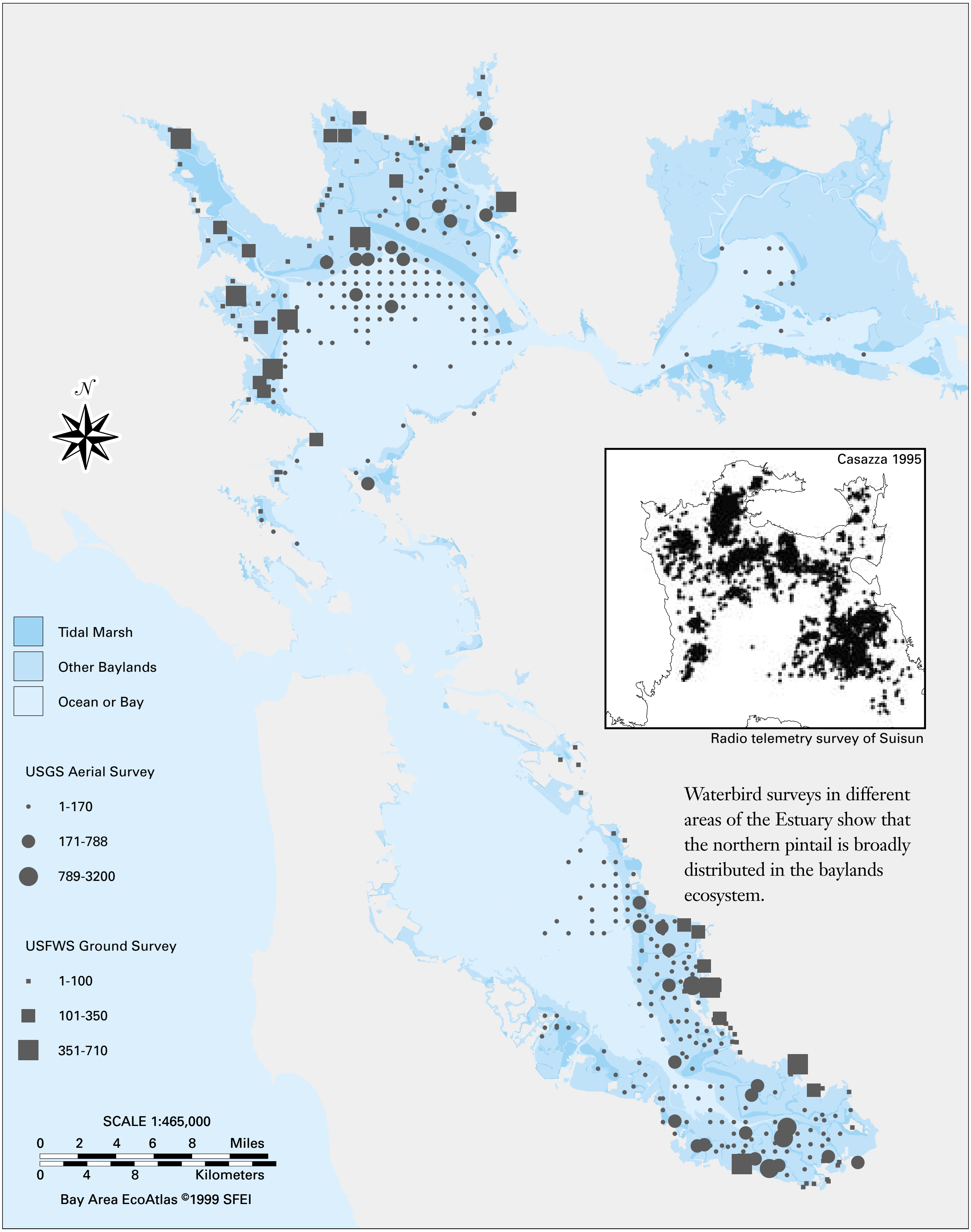
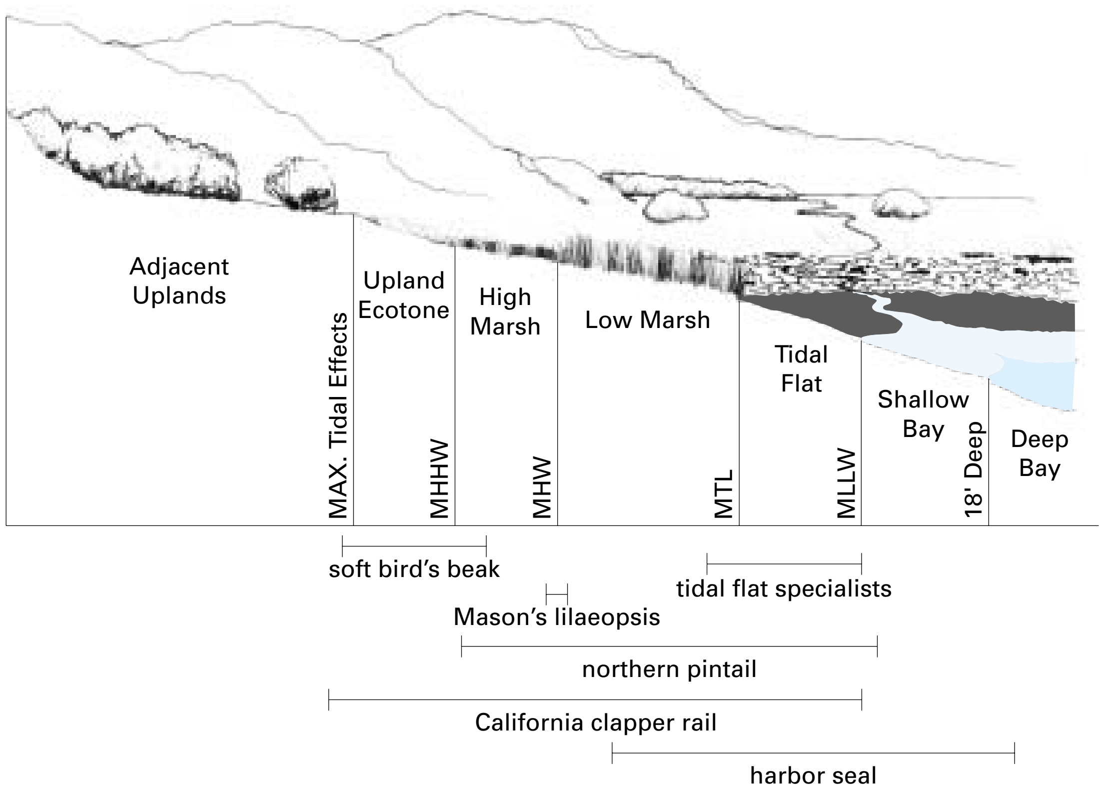


FIGURE 2.22 Known Distribution of Haul-Out Sites for Harbor Seals

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.

CHAPTER 3

Developing the Goals

Years ago, shortly after the Goals Project began, the RMG adopted a general approach for establishing habitat goals. This chapter describes this approach and explains how the Goals were developed.

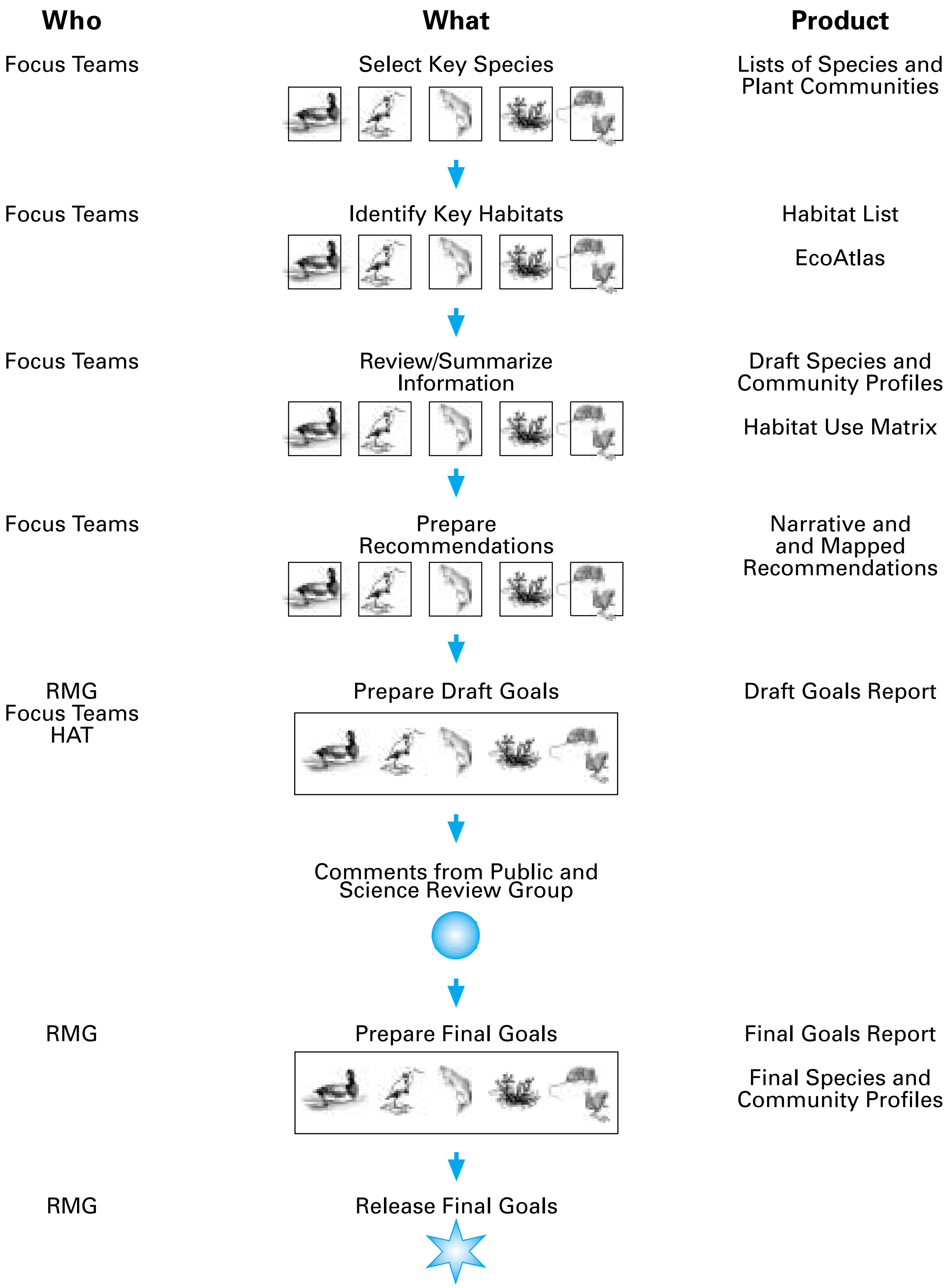
The approach for developing habitat goals involved several steps, including selecting key species and habitats, assembling and evaluating information on the species and habitats, preparing recommendations, and integrating recommendations into goals (**Figure 3.1**). The RMG oversaw the process and was ultimately responsible for the contents of the final Goals. Under the general guidance of the RMG, and with support from the Estuary Institute, five focus teams did the bulk of the scientific work. RMG members led the focus teams and were responsible for relaying information between the groups.

Recognizing that the Project's success depended on the participation of qualified experts, the RMG used considerable care in forming the focus teams. From an initial list of more than 100 candidates, it enlisted 65 team members. After considering several possible ways to structure the teams, the RMG formed five teams to focus on plants and animals and one to advise on hydrology and geology. The teams included:

- Plants Focus Team
- Fish Focus Team
- Mammals, Amphibians, Reptiles, and Invertebrates (MARI) Focus Team
- Shorebirds and Waterfowl Focus Team
- Other Baylands Birds Focus Team
- Hydrogeomorphic Advisory Team (HAT)

The RMG encouraged the focus teams to modify the approach as needed and made every effort to respond to their suggestions. Although this lengthened the time necessary to develop the Goals, it ultimately produced more meaningful results.

FIGURE 3.1 **Process for Establishing Goals**



The Focus on Species

During the Project's early stages, Project participants discussed the proposed emphasis on habitats as support for plant, fish, and wildlife species. Some believed that the Project should also consider other important wetland functions such as primary production, nutrient cycling, flood control, shoreline protection, tidal prism conservation, and water filtration. The RMG considered many options and decided that the Project should emphasize restoring and protecting habitats for living resources.

This decision was justified because concern about species and human health drives most federal and state environmental laws and policies. Also, most of the available scientific information on the baylands is about wildlife and their habitats. The RMG believed that protecting key species by improving their habitats would concurrently improve other important wetland functions.

Guiding Principles

At the recommendation of the Science Review Group, the RMG prepared a set of principles to guide the development of the habitat goals. In essence, the principles comprise the RMG's assumptions of what the Goals should be. The RMG solicited comments from the public, the focus teams, the HAT, and the Science Review Group before preparing the final list of guiding principles. According to these principles, the Goals should:

- Present a vision of habitat changes needed to improve the Bay's ecological functions and biodiversity.
- Increase the quantity and quality of wetlands without trying to "reach" the past.
- Be based on evaluations of the habitat needs of representative species.
- Give priority to the habitat needs of native species.
- Emphasize protecting and restoring wetlands that support threatened, endangered, and other special-status species while ensuring adequate habitat for other species.
- Enhance the Bay's ability to support resident and migratory species.
- Recognize that it will be impossible to maximize habitat for all species.
- Recognize the habitat values provided by some existing land uses such as farming and salt production.
- Include recommendations for habitats adjacent to the baylands.
- Be based on existing biological information, knowledge of historical conditions, and sound professional judgment.
- Be modified in the future to reflect improved scientific understanding and practical experience in wetland restoration.

The focus teams also developed principles, or tenets, to help guide their work (**Table 3.1**). The RMG encouraged each team to do this by looking exclusively at the habitat needs of its key species, and this explains the narrow perspective of some of these tenets.

TABLE 3.1 Focus Team Tenets

Plants Team

- Consider the needs of plant species from a community perspective.
- Develop recommendations for communities rather than for species.
- Consider plant communities within and near the Project boundary.
- Develop recommendations that reflect plant communities which are present today, as well as those which were present before European settlement.
- Evaluate the plant species of a given community in the context of the following criteria:
  -Dominant species -Rare species -Populations in decline -Locally extinct species

Fish Team

- Consider the needs of fishes and aquatic invertebrates first.
- Assign highest priority to native and special-status species.
- Preserve and restore habitats that improve species diversity.
- Restoration activities should not go against natural trends.
- Natural, self-sustaining habitats are better for fishes and aquatic invertebrates than are managed habitats.
- A few large, contiguous patches of habitat are preferable to many small, separate patches.

Mammals, Amphibians, Reptiles, and Invertebrates Team

- Increase the amount of available wetlands and associated uplands.
- Preserve native species.
- Include buffers wherever possible as refugia from flooding, as transitional areas or ecotones between wetlands and uplands, and as safe havens from humans and non-native or feral animals.
- Preserve and enlarge wetland habitats with existing source populations.
- Preserve and enlarge wetland habitats with endangered or sensitive species.
- Systems should be self-maintaining. Energy should originate primarily from the sun, or from tides or other hydrologic sources, and not from artificially maintained and costly equipment.
- Control non-native species (e.g., red fox, Norway rat, and feral cats and dogs) that negatively affect native species.

Shorebirds and Waterfowl Team

- Protect, preserve, and enhance waterfowl and shorebird habitats.
- Protect specific local areas that are critical to key species.
- Convert specific local habitats important to key shorebird and waterfowl species only if the habitat values are replaced elsewhere.

Other Baylands Birds Team

- Use umbrella or keystone species to represent habitat types and larger assemblages of species.
- Protect and enhance habitat for native species.
- Emphasize sensitive species endemic to the estuary over species that have become more abundant or have colonized the Bay as a result of habitat alterations.
- Minimize habitat fragmentation.
- Maintain or restore historical habitat gradients to express a full range of biodiversity within the estuary.
- Emphasize restoration of self-maintaining systems.
- Restore large patches of habitat to provide a diversity of habitat functions and to support larger bird populations. Small habitat patches can provide important connections between larger patches.

Selecting Key Species and Habitats

Once the focus teams were established, the RMG asked them to select key species of plants, fish, and wildlife and to identify the habitats that support them. The RMG defined key species as those species that collectively represent the overall complexity of the baylands ecosystem[1]. Protecting and supporting these species was the objective of the focus team recommendations and the final habitat goals. There was substantial iteration between selecting key species and identifying the support habitats, and these first two steps of the process took many months. The following sections summarize this work, starting with the selection of plants by the Plants Focus Team.

Key Plants

The Plants Focus Team considered the ecological needs of plants from a community perspective, and so it selected key plant communities rather than key species. This focus on communities is partly due to the Projects emphasis on major habitats that are shared by many plant species.

The Plants Focus Team selected four key bayland communities: shallow bay and intertidal bayland, tidal marsh, diked bayland, and salt pond (**Table 3.2**). In addition, it also identified several plant communities of the bayland/upland ecotone, including riparian forest, willow grove, grassland, oak woodland, and evergreen forest. As the following section on key habitats explains, these ecotone communities are integral parts of the baylands ecosystem.

Several unique plant species evolved along the edge of the baylands.

USCS 1857

[1] In other Project documents, key species are sometimes called indicators, evaluation species, or target species.

TABLE 3.2 Key Plant Communities and Representative Plant Species

Species	*Botanical Name*	Ecological Significance*
Intertidal and Subtidal Baylands		
Eelgrass	*Zostera marina*	D, KS, PE
Tidal Marsh		
Sea-pink	*Armeria maritima* ssp. *californica*	SM: UE, X
California saltbush	*Atriplex californica*	SM: UE, X
Fat-hen, spear scale	*Atriplex triangularis*	C, UE
Johny-nip, salt marsh owl's clover	*Castilleja ambigua* ssp. *ambigua*	SM: PE, RR, UE
Suisun thistle	*Cirsium hydrophilum* var. *hydrophilum*	BM: FTE, R, STE, UE
Point Reyes bird's-beak	*Cordylanthus maritimus* ssp. *palustris*	SM: RR, UE
Soft bird's-beak	*Cordylanthus mollis* ssp. *mollis*	BM: FTE, PE, R, UE
Dodder	*Cuscuta salina*	SM: C-D
Saltgrass	*Distichlis spicata*	D, UE
Alkali-heath	*Frankenia salina*	SM: C
Gumplant	*Grindelia stricta* var. *angustifolia*	C, UE
Jaumea	*Jaumea carnosa*	SM: C
Baltic and salt rush	*Juncus balticus* and *J. lesueurii*	BM: C
Smooth goldfields	*Lasthenia glabrata*	PE, RR, UE
Delta tule pea	*Lathyrus jepsonii* var. *jepsonii*	BM: R, RR, UE
Pepper grass	*Lepidium latifolium*	D, IA
Mason's lilaeopsis	*Lilaeopsis masonii*	BM: R, STE
Sea lavender, marsh rosemary	*Limonium californicum*	SM: UE
Silverweed	*Potentilla anserina* ssp. *pacifica*	BM: C, UE
Pickleweed	*Salicornia virginica*	SM: D, KS
Hardstem bulrush (tule)	*Scirpus acutus*	BM
California bulrush (tule)	*Scirpus californicus*	BM: C
Alkali bulrush	*Scirpus maritimus*	BM: D, KS
Olney's bulrush	*Scirpus pungens*	BM: C
Smooth cordgrass	*Spartina alterniflora*	D, IA
Dense-flowered cordgrass	*Spartina densiflora*	IA
Pacific cordgrass	*Spartina foliosa*	D, KS
Saltmeadow cordgrass	*Spartina patens*	IA
California sea-blite	*Suaeda californica*	SM: FTE, UE, X
Cattails	*Typha* spp.	BM: C

* Key:

BM	Brackish marsh	SM	Salt marsh
C	Common	D	Dominant
FTE	Federally listed as threatened or endangered	IA	Invasive alien (exotic)
KS	Keystone species (habitat structure or trophic)	L	Found locally or very locally within this community
NA	Naturalized alien (exotic)	PE	Partly extirpated within San Francisco Bay estuary
R	Rare	RR	Regionally rare in San Francisco Bay estuary
STE	State-listed as threatened or endangered	U/D	Uncommon or declining
UE	Upland ecotone, high marsh, upper marsh edge	X	Extirpated

TABLE 3.2 *(continued)*

Species	*Botanical Name*	Ecological Significance*
Lagoon		
Wigeon grass	*Ruppia maritima*	C, KS
Diked Baylands (includes diked wetlands and diked agricultural lands)		
Oat bent-grass	*Agrostis avenacea*	C, NA
Wild mustards	*Brassica* spp. and *Hirschfeldia incana*	D, NA
Goosefoot	*Chenopodium berlandieri*	NA, C
Poison hemlock	*Conium maculatum*	NA, C
Brass-buttons	*Cotula coronopifolia*	D, NA
Saltgrass	*Distichlis spicata*	D
Dittrichia	*Dittrichia graveolens*	C, IA
Watergrass	*Echinochloa crus-galii*	C, NA
Fennel	*Foeniculum vulgare*	NA, C
Barley	*Hordeum marinum* var. *gussoneanum*	D, NA
Baltic and salt rush	*Juncus balticus* and *J. lesueurii*	C
Pepper grass	*Lepidium latifolium*	D, IA
Bird's foot trefoil	*Lotus corniculatus*	C, NA
Loosestrife	*Lythrum hyssopifolia*	D, NA
Sago pondweed	*Potamogeton pectinatus*	C
Dock	*Rumex crispus*	C, NA
Pickleweed	*Salicornia virginica*	D, KS
Alkali bulrush	*Scirpus maritimus*	C, KS
Cattails	*Typha* spp.	C
Salt Pond		
Dunaliella	*Dunaliella salina*	D, KS
Ecotonal Communities (communities related to the edges of key plant communities)		
• **Riparian Forest**		
Box elder	*Acer negundo californicum*	C
Giant reed	*Arundo donax*	C, IA
Santa Barbara sedge	*Carex barbarae*	D
Creeping wildrye	*Leymus triticoides*	D
Western sycamore	*Platanus racemosa*	L
Cottonwood	*Populus fremontii*	D

* Key:

BM	Brackish marsh	SM	Salt marsh
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FTE	Federally listed as threatened or endangered	IA	Invasive alien (exotic)
KS	Keystone species (habitat structure or trophic)	L	Found locally or very locally within this community
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UE	Upland ecotone, high marsh, upper marsh edge	X	Extirpated

TABLE 3.2 *(continued)*

Species	*Botanical Name*	Ecological Significance*
Ecotonal Communities (communities related to the edges of key plant communities; *continued*)		
• **Riparian Forest** *(continued)*		
Valley oak	*Quercus lobata*	L
California wild rose	*Rosa californica*	C
California blackberry	*Rubus vitifolius*	C
Red willow	*Salix laevigata*	D
Arroyo willow	*Salix lasiolepis*	D, KS
Elderberry	*Sambucus caerulea*	C
California bay laurel	*Umbellularia californica*	L
• **Willow Grove**		
California blackberry	*Rubus vitifolius*	D
Red willow	*Salix laevigata*	D
Arroyo willow	*Salix lasiolepis*	D, KS
• **Grassland**		
Wild oat	*Avena fatua* and *A. barbata*	D, NA
Ripgut brome	*Bromus diandrus*	D, NA
Soft chess	*Bromus hordeaceus*	D, NA
Santa Barbara sedge	*Carex barbarae*	U/D
Creeping wildrye	*Leymus triticoides*	U/D
Italian ryegrass	*Lolium multiflorum*	D, NA
Purple needlegrass	*Nassella pulchra*	U/D
• **Moist Grassland**		
Santa Barbara sedge	*Carex barbarae*	C
Baltic rush	*Juncus balticus*	C
Iris-leaved rush	*Juncus xiphioides*	C
Creeping wildrye	*Leymus triticoides*	C
Italian ryegrass	*Lolium multiflorum*	D, NA
• **Grassland/Vernal Pool Complex**		
Downingia	*Downingia pulchella*	D
Coyote-thistle	*Eryngium aristulatum*	D
Goldfields	*Lasthenia* spp.	C
Loosestrife	*Lythrum hyssopifolium*	C, NA
Popcorn flower	*Plagiobothrys bracteatus*	D

* Key:

BM	Brackish marsh	SM	Salt marsh
C	Common	D	Dominant
FTE	Federally listed as threatened or endangered	IA	Invasive alien (exotic)
KS	Keystone species (habitat structure or trophic)	L	Found locally or very locally within this community
NA	Naturalized alien (exotic)	PE	Partly extirpated within San Francisco Bay estuary
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UE	Upland ecotone, high marsh, upper marsh edge	X	Extirpated

TABLE 3.2 *(continued)*

Species	*Botanical Name*	Ecological Significance*
Ecotonal Communities (communities related to the edges of key plant communities; *continued*)		
• **Coastal Prairie**		
Sweet vernal grass	*Anthoxanthum odoratum*	D, NA
Pacific reedgrass	*Calamagrostis*	C
California oatgrass	*Danthonia californica* var. *californica*	U/D
Pacific hairgrass	*Deschampsia cespitosa* ssp. *holciformis*	U/D
Velvet grass	*Holcus lanatus*	D, NA
Douglas iris	*Iris douglasiana*	C
• **Coastal Sage**		
California sagebrush	*Artemisia californica*	D (southern)
Coyote brush	*Baccharis pilularis*	D (northern)
• **Coast Live Oak Woodland**		
Pacific madrone	*Arbutus menziesii*	C
Toyon	*Heteromeles arbutifolia*	C
Cream bush	*Holodiscus discolor*	C
Coast live oak	*Quercus agrifolia*	D, KS
California blackberry	*Rubus vitifolius*	D
Creeping snowberry	*Symphoricarpos albus* var. *laevigatus*	C
Poison oak	*Toxicodendron diversilobum*	D
• **Foothill and Valley Oak Woodland**		
Common manzanita	*Arctostaphylos manzanita*	C
Santa Barbara sedge	*Carex barbarae*	C
Buckbrush	*Ceanothus cuneatus*	C
Creeping wildrye	*Leymus triticoides*	D
Digger pine	*Pinus sabiniana*	C
Blue oak	*Quercus douglasii*	LD, KS
Valley oak	*Quercus lobata*	LD, KS
California coffeeberry	*Rhamnus californica*	C
Pink-flowering currant	*Ribes anguineum*	C
• **Mixed Evergreen Forest**		
Bigleaf maple	*Acer macrophylum*	C
Madrone	*Arbitus menzeisii*	C
Coyote brush	*Baccharis pilularis*	D
Poison oak	*Toxicodendron diversilobum*	D
California bay laurel	*Umbellularia californica*	D, KS
California huckleberry	*Vaccinium ovatum*	C

* Key:

BM	Brackish marsh	SM	Salt marsh
C	Common	D	Dominant
FTE	Federally listed as threatnened or endangered	IA	Invasive alien (exotic)
KS	Keystone species (habitat structure or trophic)	L	Found locally or very locally within this community
NA	Naturalized alien (exotic)	PE	Partly extirpated within San Francisco Bay estuary
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Key Fish and Wildlife

Each of the four animal focus teams developed criteria for selecting key species (**Table 3.3**). Although the selection criteria varied among the teams, there were many similarities. These similarities led to the development of a set of standardized selection criteria (**Table 3.4**) which the RMG later used to help evaluate the adequacy of the lists of key species.

Using their selection criteria, the focus teams screened several hundred species and ultimately selected 131 key species (**Table 3.5**). As the table shows, the teams selected most of the key species because they were dominant species, or habitat or community indicators. Each team included sensitive species and some teams included important commercial or recreational species.

Key Habitats

Once the focus teams had initial lists of species, they had to identify, name, and describe their habitats. The RMG considered using the list of habitat types described in the San Francisco Estuary Project's *Status and Trends Report on Wetlands and Related Habitats*[2], but realized the need for more detail. The RMG also wanted to be able to show habitat distributions, and so desired to use habitat types that could be readily mapped.

After several refinements by Project participants, the RMG finalized the list of key habitats. Within the baylands, the key habitats include tidal flat, tidal marsh, lagoon, diked wetland, agricultural bayland, salt pond, and treatment/storage pond. Key habitats outside of the baylands but within the baylands ecosystem include deep bay/channel, shallow bay/channel, willow grove, riparian forest, grassland, oak woodland, and mixed evergreen forest.

The Estuary Institute mapped the location of the key habitats on the EcoAtlas and developed estimates of their past and present acreage. It also helped organize the list of habitats and develop a classification system or "typology" for the Project. Chapter 4 presents the habitat typology and describes the key habitats.

Plants blur the boundaries between baylands and uplands.

Elise Brewster

[2] Habitats described in the Estuary Project's *Status and Trends Report on Wetlands and Related Habitats* include: subtidal and tidal waters, intertidal mudflat, tidal salt marsh, tidal brackish marsh, diked seasonal and perennial wetlands, salt ponds, lakes and ponds, adjacent riparian woodland, and adjacent upland.

TABLE 3.3 Criteria Developed by Focus Teams for Selecting Key Species

Estuarine Fish and Associated Invertebrates

Species selected because it:

- Is protected due to concern over low population numbers, loss or degradation of habitat, etc. (e.g., federal or state-listed threatened or endangered species).
- Is a principal element (e.g., prey item) in the food web or webs of the estuarine ecosystem.
- Inhabits ecotones or moves across habitat-type edges in such a way as to establish an ecological link between them.
- Has recognized commercial or recreational values.
- Is considered an indicator species for a particular habitat type.
- Is native to the San Francisco Bay estuary.
- Is, or has been, relatively abundant in one or more of the subregions of the estuary and baylands (e.g., Suisun Bay).
- Has available sufficient information about it to enable establishing regional habitat .
- Represents or is an indicator species for a particular taxon, guild, life history characteristic, or some other feature of the ecosystem deemed to have significant value.

Mammals, Amphibians, Reptiles, and Invertebrates

Species selected because it is:

- Threatened or endangered.
- Essential to threatened or endangered species.
- Keystone for larger communities.
- Keystone in food webs.
- Important for productivity, diversity, or other ecological standard.
- Dependent on wetland habitat.
- An indicator of wetland health.
- A major or dominant prey item for a key species selected by other focus teams.
- Unique to the Project area.
- A significant non-native pest (to be controlled or removed).
- A native pest of historical and current significance.

Shorebirds and Waterfowl

Species selected because it:

- Is currently, or was historically, very abundant in the Bay.
- Is strongly associated with marine or estuarine habitats.
- Relies on the Bay as a critical area within the Pacific Flyway.
- Relies on the Bay as a major wintering area.
- Nests in the Bay region.
- Is dependent on specific habitat (e.g., fresh or brackish wetland, salt pond, rocky intertidal).
- Is federally listed as threatened or endangered, or is a candidate for such listing.
- Is of economic or recreational importance or is harvested for food.
- Has symbolic value within our society.

TABLE 3.3 *(continued)*

Other Baylands Birds

Species selected because it:

- Requires large, well-developed tidal marsh habitat.
- Uses salt pond or shallow saline pond habitat.
- Uses high tidal marsh and upland transition area.
- Is representative of a particular habitat type, such as riparian, seasonal ponds, freshwater marshes, adjacent uplands, open bay, and rocky shores or islands.
- Depends on baylands habitats for critical support function, i.e., breeding, foraging, or migration.
- Is representative of a broader group or guild of species that use the baylands.
- Is endemic to, or breeds only in, the baylands.
- Is locally or regionally limited in number and distribution.

TABLE 3.4 Standardized Selection Criteria

1. Community Indicator: Species is indicative of a community, guild, or assemblage of species. A community indicator can represent other species because of similar habitat requirements.
2. Habitat Indicator: Species is indicative of a key habitat. The presence of the species helps define the habitat.
3. Sensitive Species: Slight changes in habitat conditions might cause large changes in population status, or the species has been recommended for legal protection (differentiated from "candidate" status below).
4. Protected Species: Species is listed, or is a candidate to be listed, for protection under state and/or federal law because it is rare, threatened, or endangered.
5. Economic Indicator: Species is an important commercial or recreational species.
6. Dominant Species: Species strongly influences community structure as a major prey item, keystone species, pollinator, or ecological engineer. In the strictest sense, a keystone species is a predator that exerts a strong measurable influence on the relative abundance of other species in the community. In the Project, the term applies to any species, predator or not, that exerts such influence. An ecological engineer is a plant or animal that changes the physical environment in a way that strongly affects other species.
7. Pest Species: Species is an invasive species or a pest to people.
8. Practical Species: Species is a convenient indicator of a community, guild, assemblage or habitat because it is well studied or easily studied. This criterion helps to select among the many possible community or habitat indicator species.

TABLE 3.5 Key Fish and Wildlife Species and Standardized Selection Criteria

Common Name	Scientific Name	Standardized Selection Criteria
Estuarine Fish and Associated Invertebrates		
Chinook salmon	*Oncorhynchus tshawytscha*	2,4,5,6,8
Steelhead	*Oncorhynchus mykiss*	2,5,6,8
White sturgeon*	*Acipenser transmontanus*	1,2,4,6,8
Striped bass	*Morone saxatilis*	2,5,6,8
Sacramento splittail	*Pogonichthys macrolepidotus*	2,4,5,6,8
Pacific herring	*Clupea pallasi*	2,4,6,8
Northern anchovy	*Engraulis mordax*	2,4,6,8
Arrow goby	*Clevelandia ios*	1,2,6,8
Bay goby	*Lepidogobius lepidus*	2,4,6,8
Delta smelt	*Hypomesus transpacificus*	2,4,6,8
Jacksmelt	*Atherinopsis californiensis*	5,6,8
Topsmelt	*Atherinops affinis*	2,5,6,8
Longfin smelt	*Spirinchus thaleichthys*	6,8
Pacific staghorn sculpin	*Leptocottus armatus armatus*	5,6,8
Prickly sculpin	*Cottus asper*	6,8
Rainwater killifish*	*Lucania parva*	2,8
Plainfin midshipman*	*Porichthus notatus*	2,5,6,8
Shiner perch	*Cymatogaster aggregata*	2,5,6,8
Tule perch	*Hysterocarpus traski*	2,6,8
Three-spined stickleback	*Gasterosteus aculeatus*	6,8
White croaker	*Genyonemus lineatus*	2,5,6,8
Leopard shark	*Triakis semifasciata*	1,4,6,8
Bat ray	*Myliobatus californica*	2,6,8
Brown rockfish	*Sebastes auriculatus*	2,5,6,8
California halibut	*Paralichthys californicus*	2,5,6,8
Starry flounder	*Platichthys stellatus*	2,5,6,8
Longjaw mudsucker	*Gillichthys mirabilis*	2,5,6,8
Dungeness crab	*Cancer magister*	2,4,6,8
Rock crab	*Cancer antennarius*	2,4,6,8
Rock crab	*Cancer productus*	2,4,6,8
Mud crab*	*Hemegrapsus oregonensis*	1,4,6,8
California bay shrimp*	*Crangon franciscorum*	2,4,6,8
Blacktail shrimp*	*Crangon nigricauda*	6,8
Opossum shrimp	*Neomysis mercedis (relicta)*	2,6

* Species profile not prepared.
1. Community Indicator
2. Habitat Indicator
3. Sensitive Species
4. Protected Species
5. Economic Indicator
6. Dominant Species
7. Pest Species
8. Practical Species

TABLE 3.5 *(continued)*

Common Name	Scientific Name	Standardized Selection Criteria
Estuarine Fish and Associated Invertebrates (continued)		
Softshell clam*	*Mya arenaria*	2,6,8
Japanese littleneck clam*	*Tapes japonica*	2,4,6,8
Ribbed horsemussel*	*Arcuatula demmisum*	2,4,6,8
California horn snail*	*Cerithidea californica*	2,6,8
Amphipods*	Amphipoda spp.	1,2,6,8
Other Invertebrates		
Franciscan brine shrimp	*Artemia franciscana (salina)*	2,5,6,8
Conservancy fairy shrimp*	*Branchinecta conservatio*	4,2,3
Fairy shrimp*	*Branchinecta lynchi*	2,3
Fairy shrimp*	*Linderiella occidentalis*	4,2,3
California vernal pool tadpole shrimp	*Lepidurus packardi*	2,3,4,6
Reticulate water boatman	*Trichocorixa reticulata*	2,3,6,8
Delphacid planthopper*	*Prokelisia marginata*	1,2,6,8
Cixiid planthopper	*Cixius praecox*	1,2,6
Tiger beetle	*Cicindela haemorrhagica*	2,3
Tiger beetle	*Cicindela oregona*	2,3
Tiger beetle	*Cicindela senilis senilis*	2
Diffuse water scavenger beetle*	*Enochrus diffusus*	2,6
Minute moss beetle*	*Ochthebius rectus*	2
Western tanarthrus beetle	*Tanarthrus occidentalis*	2,3,6
Leaf beetle*	*Erynephala morosa*	2,6
Inchworm moth	*Perizoma custodiata*	2,6,8
Pygmy blue butterfly	*Brephidium exilis*	2,6,8
Summer salt marsh mosquito	*Aedes dorsalis*	2,7,8
Winter salt marsh mosquito	*Aedes squamiger*	2,7,8
Washino's mosquito	*Aedes washinoi*	2,7,8
Western encephalitis mosquito	*Culex tarsalis*	2,7,8
Winter marsh mosquito	*Culiseta inornata*	2,7,8
Grodhaus's midge*	*Tanypus grodhausi*	2,6
Flower fly*	*Eristalinus aeneus*	6
Cinereus brine fly	*Ephydra cinerea*	1,2,6,8
Millbrae brine fly	*Ephydra millbrae*	1,2,6,8
Riparian shore fly (brine fly)*	*Ephydra riparia*	2
Brine fly	*Lipochaeta slossonae*	2,6,8
Jamieson's compsocryptus wasp	*Compsocryptus jamiesoni*	2,3

* Species profile not prepared.
1. Community Indicator
2. Habitat Indicator
3. Sensitive Species
4. Protected Species
5. Economic Indicator
6. Dominant Species
7. Pest Species
8. Practical Species

TABLE 3.5 *(continued)*

Common Name	Scientific Name	Standardized Selection Criteria
Amphibians		
California tiger salamander	*Ambystoma californiense*	1,3,4
California toad	*Bufo boreas halophilus*	2,6
Pacific treefrog	*Hyla regilla*	2,6
California red-legged frog	*Rana aurora draytonii*	1,2,3,4
Reptiles		
Western pond turtle	*Clemmys marmorata*	1,2,3,4
California alligator lizard	*Elgaria multicarinata multicarinata*	6
Central coast garter snake	*Thamnophis atratus atratus*	2,6
Coast garter snake	*Thamnophis elegans terrestris*	2,6
San Francisco garter snake	*Thamnophis sirtalis tetrataenia*	3,4
Mammals		
Salt marsh harvest mouse	*Reithrodontomys raviventris*	1,2,3,4,6
California vole	*Microtus californicus*	6,8
Salt marsh wandering shrew	*Sorex vagrans haliocoetes*	1,2,3,4,6
Suisun shrew	*Sorex ornatus sinuosis*	1,2,3,4,6
Ornate shrew	*Sorex ornatus californicus*	2,6
North american river otter	*Lutra canadensis*	2,3
Southern sea otter	*Enhydra lutris nereis*	2,3,4
Harbor seal	*Phoca vitulina richardi*	2,3
California sea lion	*Zalophus californianus*	2,3
Norway rat	*Rattus norvegicus*	7
Roof rat	*Rattus rattus*	7
Red fox	*Vulpes vulpes regalis*	7
Waterfowl		
Tule greater white-fronted goose	*Anser albifrons gambelli*	1,2,3,4
Mallard	*Anas platrhynchos*	1,2,5
Northern pintail	*Anas acuta*	1,2,5
Canvasback	*Aythya valisineria*	1,2,5
Surf scoter	*Melanitta perspicilata*	1,2
Ruddy duck	*Oxyura jamaicensis*	1,2
Shorebirds		
Western snowy plover	*Charadrius alexandrinus nivosus*	2,3,4
Marbled godwit	*Limosa fedoa*	1,2
Black turnstone	*Arenaria melanocephala*	1,2
Red knot	*Calidris canutus*	1,2,3
Western sandpiper	*Calidris mauri*	2
Long-billed dowitcher	*Limnodromus scolopaceus*	1,2
Wilson's phalarope	*Phalaropus tricolor*	1,2,3

* Species profile not prepared.
1. Community Indicator
2. Habitat Indicator
3. Sensitive Species
4. Protected Species
5. Economic Indicator
6. Dominant Species
7. Pest Species
8. Practical Species

TABLE 3.5 *(continued)*

Common Name	Scientific Name	Standardized Selection Criteria
Other Baylands Birds		
Eared grebe	*Podeceps nigricollis*	2
Western/Clark's grebe	*Aechmophorus occidentalis*	2
American white pelican	*Pelecanus erythrorhynchus*	2,3
Brown pelican	*Pelecanus occidentalis*	2,3
Double-crested cormorant	*Phalacrocorax auritus*	1
Snowy egret	*Egretta thula*	2
Black-crowned night heron	*Nycticorax nycticorax*	2
Northern harrier*	*Circus cyaneus*	2,3
Peregrine falcon*	*Falco peregrinus*	1,2,3,4
California clapper rail	*Rallus longirostris obsoletus*	2,3,4
California black rail	*Laterallus jamaicensis corturniculus*	2,3,4
Common moorhen	*Gallinula chloropus*	2
California gull	*Larus californicus*	6
Western gull*	*Larus occidentalis*	6
California least tern*	*Sterna antillarum browni*	1,2,4
Forster's tern	*Sterna forsteri*	1,2
Caspian tern	*Sterna caspia*	1,2
Burrowing owl	*Speotyto cunicularia hypugaea*	2,3
Belted kingfisher*	*Ceryle alcyon*	2
Horned lark*	*Eremophila alpestris*	2
Yellow warbler*	*Dendroica petechia*	2
Salt marsh common yellowthroat	*Geothlypis Trichas sinuosa*	2,3
Savannah sparrow	*Passerculus sandwichensis*	2
Song sparrow (3 subspecies)	*Melospiza melodia samuelis*	2,3
	Melospiza melodia pusillula	2,3
	Melospiza melodia maxillaris	2,3

* Species profile not prepared.
1. Community Indicator
2. Habitat Indicator
3. Sensitive Species
4. Protected Species
5. Economic Indicator
6. Dominant Species
7. Pest Species
8. Practical Species

Checking Species and Habitat Lists

After preliminary lists of key species, communities, and habitats were prepared, the RMG asked the focus teams to undertake several exercises to ensure that the lists were appropriate and adequate, and to help initiate the transfer of relevant information between focus teams. The teams were asked to document, to the extent practicable, complex biological relationships such as trophic structure, species interrelationships, and overall representation of community complexity along gradients of tidal elevation and degree of tidal influence and salinity.

As part of this work, several teams developed functional matrices or tables to show which habitats support which species, and in what ways. The Estuary Institute compiled the focus team matrices into a single large matrix. This matrix was extremely detailed, and showed which habitats and habitat components provide support for each species. For example, within shallow channel habitat, the matrix showed the support functions provided by channel bottom, channel bank, and open water; and within mid-tidal marsh habitat, it showed support functions provided by vegetated plain, salt pan, channel, and so on.

The matrix, while initially developed to help evaluate the sufficiency of the lists of key species and habitats, also served other purposes — it identified species that share key habitats or components of habitats, and it helped to identify species that would be most affected by changes in habitat quality, distribution, and abundance.

Figure 3.2 presents an abbreviated form of the matrix. The matrix indicates the resting, foraging, and breeding support functions provided by each of the key habitats for each of the key species. Please keep in mind that Figure 3.2 provides general information regarding habitat function and is not a site-specific guide.

Assembling and Evaluating Information

The next step in the process required the focus teams to assemble available data on their key species, communities, and habitats. The Plants Focus Team compiled information regarding plant community composition, distribution, and habitat controls. The animal focus teams compiled data on life history, use of habitats, and historical and current distribution. The teams summarized this information in brief papers referred to as "profiles."

The purpose of the profiles was to provide Project participants with information needed to develop goals. However, some participants suggested that the materials might be more generally useful. Accordingly, the Project published them as a companion document entitled *Species and Community Profiles* (Goals Project 2000). The profiles provide additional background information for the Goals, and some identify additional research needs that are not discussed in this report. Also, many of the profiles list species-specific recommendations that may be helpful when planning and managing projects to support particular species or suites of species.

FIGURE 3.2 Abbreviated Habitat Support Function Matrix

	Shallow Bay or Channel	Tidal Flat	Lagoon	Beach	Rocky Shore	Low Tidal Marsh	Mid Tidal Marsh	High Tidal Marsh	Muted Tidal Marsh	Diked Wetland	Agricultural Baylands	Salt Pond	Storage or Treatment Pond	Riparian Forest	Willow Grove	Grassland	Oak Woodland	Mixed Evergreen Forest
Fish and Related Invertebrates																		
Chinook salmon	F	F				RF	R.F	RF										
Steelhead	F																	
White sturgeon	F	F				RF												
Striped bass	F	F				F	F	F										
Sacramento splittail	RF	RF				RFB	RFB	RFB										
Pacific herring	FB	FB																
Northern anchovy	FB																	
Arrow goby	RFB	RFB				RF												
Bay goby	RF																	
Delta smelt	F					RFB												
Jacksmelt	FB	FB																
Topsmelt	FB	FB				F	F	F										
Longfin smelt	F																	
Pacific staghorn sculpin	RF	FB				F	F	F										
Prickly sculpin						F	F	RFB										
Rainwater killifish						RFB		RFB										
Plainfin midshipman	RFB	RFB																
Shiner perch	FB	F																
Tule perch						RFB	RFB	RFB										
Threespine stickleback						RFB	RFB	RFB										
White croaker	FB	F					F											
Leopard shark	FB	F																
Bat ray	RF	RF				RF												
Brown rockfish	RF																	
California halibut	RF	RF																
Starry flounder	RF	RF				F												
Longjaw mudsucker		RFB				RFB	FB	FB										
Dungeness crab	RF	RF				RF												
Rock crab	RFB				RF	RF												
Mud crab	FB	FB				FB	RF	RF										
California bay shrimp	RF	RFB				RF												
Blacktail shrimp	RF	RFB				RF												
Opossum shrimp	F					F	F											
Softshell clam		RFB			RFB													
Japanese littleneck clam		RFB			RFB													
Ribbed horsemussel							RFB	RFB										
California horn snail		RFB				RFB	RFB	RFB										
Amphipods	RFB	RFB			RFB	RFB	RFB	RFB										

Key: R = Resting, F = Foraging, B = Breeding, ! = Uses vernal pools in this habitat, * = Uses artificial structures in this habitat.

FIGURE 3.2 *(continued)*

	Shallow Bay or Channel	Tidal Flat	Lagoon	Beach	Rocky Shore	Low Tidal Marsh	Mid Tidal Marsh	High Tidal Marsh	Muted Tidal Marsh	Diked Wetland	Agricultural Baylands	Salt Pond	Storage or Treatment Pond	Riparian Forest	Willow Grove	Grassland	Oak Woodland	Mixed Evergreen Forest
Other Invertebrates																		
Franciscan brine shrimp												RFB						
Conservancy fairy shrimp																RFB!		
Fairy shrimp																RFB!		
California vernal pool tadpole shrimp																RFB!		
Reticulate water boatman			RFB					RFB	RFB	RFB	RFB							
Delphacid planthopper						RFB												
Cixiid planthopper								RFB	RFB	RFB	RFB							
Tiger beetle (*C. oregona*)						RFB	RFB	RFB	RFB									
Tiger beetle (*C. senilis*)								RFB	RFB			RFB						
Tiger beetle (*C. haemorrhagica*)								RFB	RFB	RFB								
Diffuse water scavenger beetle								RFB	RFB	RFB	RFB							
Minute moss beetle								RFB	RFB	RFB	RFB							
Western tanarthrus beetle								RFB				RFB						
Leaf beetle						RFB	RFB	RFB	RFB	RFB	RFB							
Inchworm moth							RF	RFB	RFB	RFB	RFB							
Pygmy blue butterfly								RFB	RFB	RFB	RFB							
Summer salt marsh mosquito			RFB				RFB	RFB	RFB	RFB	RFB			RF		RFB		
Winter salt marsh mosquito			RFB				RF	RFB	RFB	RFB	RFB					RFB		
Washino's mosquito														RFB	RFB			
Western encephalitis mosquito			RFB					RFB	RFB	RFB	RFB		RFB	RFB		RFB		
Winter marsh mosquito									RFB	RFB	RFB		RFB	RFB		RFB		
Grodhaus's midge			RFB				RFB	RFB		RFB	RFB					RFB		
Flower fly			RFB				RFB	RFB	RFB	RFB	RFB	RFB						
Cinereus brine fly						RFB	RFB	RFB		RFB		RFB						
Millbrae brine fly						RFB	RFB	RFB		RFB		RFB						
Riparian shore fly														RFB	R			
Brine fly (*L. slossonae*)							RFB	RFB		RFB		RFB						
Jamieson's compsocryptus wasp							RF	RF	RFB	RFB		RF						
Amphibians																		
California tiger salamander										RFB	RFB			RFB		RFB	RF	RF
California toad			RFB			F	RFB	RFB	RFB	RFB	RFB		RF	RFB	RFB	RFB	RF	RF
Pacific treefrog			RFB			F	RFB	RFB	RFB	RFB	RFB		RF	RFB	RFB	RFB	RF	RF
California red-legged frog			RFB				RFB	RFB	RFB	RFB	RFB			RFB	RFB	RFB		F
Reptiles																		
Western pond turtle			RF			RF	RF	RF	RF	RFB	RFB		RFB	RFB	RB	RFB	RB	RB
California alligator lizard			RF			RF	RFB	RFB	RFB	RFB	RFB		RFB	RFB	RFB	RFB	RFB	RFB
Central coast garter snake			RF			F	RFB	RFB	RFB	RFB	RFB		RFB	RFB	RFB	RFB		
Coast garter snake			RF			F	RFB	RFB	RFB	RFB	RFB		RFB	RFB	RFB	RFB	RFB	RFB
San Francisco garter snake			RF			F	RFB	RFB	RFB	RFB	RFB			RFB		RFB		

Key: R = Resting, F = Foraging, B = Breeding, ! = Uses vernal pools in this habitat, * = Uses artificial structures in this habitat.

FIGURE 3.2 *(continued)*

	Shallow Bay or Channel	Tidal Flat	Lagoon	Beach	Rocky Shore	Low Tidal Marsh	Mid Tidal Marsh	High Tidal Marsh	Muted Tidal Marsh	Diked Wetland	Agricultural Baylands	Salt Pond	Storage or Treatment Pond	Riparian Forest	Willow Grove	Grassland	Oak Woodland	Mixed Evergreen Forest
Mammals																		
Salt marsh harvest mouse			RFB			RF	RFB	RFB	RFB	RFB	RF							
California vole			RFB				RFB	RFB	RFB	RFB	RF		RFB			RFB	RFB	
Salt marsh wandering shrew						F	RFB	RFB	RFB	RFB	RFB							
Suisun shrew						F	RFB	RFB		RF	RF							
Ornate shrew									RFB	RFB	RFB		RFB			RFB	RFB	
North American river otter	F		RFB	R	R	RFB	RFB	RFB	RFB				RF	RFB				
Southern sea otter	RFB	F		RF														
Harbor seal	F	RB	F	R	RB	RF												
California sea lion	RF			R	R													
Waterfowl																		
Tule white-fronted goose	RF		RF	R		RF	RF	RF		RF	RF		RF			RF		
Mallard	RF	F	RF	R		F		RFB	RF	RFB	RFB	RF	RFB	RFB		RFB		
Northern pintail	R		RF			F		RFB	RF	RFB	RFB	RF	RFB			RFB		
Canvasback	RF	F	RF						RF	RF		RF	RF					
Surf scoter	RF																	
Ruddy duck	RF	F	RF			RFB	RFB	RFB	RF	RFB	RFB	RF	RFB					
Shorebirds																		
Western snowy plover		F		RF								RFB						
Marbled godwit		RF	RF	RF	R	RF	RF	RF	RF	RF	RF	R	R			F		
Black turnstone		RF	R	R	RF	R	R	R	R									
Red knot		RF	R	R	R	RF	RF	RF	RF			RF	R					
Western sandpiper		RF	RF	RF	R	RF	RF	RF	RF	RF	RF	RF	RF					
Long-billed dowitcher		RF	RF	R	R	RF	RF	RF	RF	RF	RF	RF	RF			F		
Wilson's phalarope		F	RF	R						RF	RF	RF	RF					

Key: R = Resting, F = Foraging, B = Breeding, ! = Uses vernal pools in this habitat, * = Uses artificial structures in this habitat.

In addition to the information summarized in the species profiles, the MARI, Other Baylands Birds, and Shorebirds and Waterfowl focus teams assembled data on species distribution and abundance and displayed them on various kinds of maps. The MARI team displayed the distribution of many of its species on printed maps of the EcoAtlas. The bird teams used the EcoAtlas to analyze data and to prepare maps.

Focus Team Recommendations

The next step in the process required the focus teams to formulate habitat recommendations. The teams differed markedly in their approach to this step — some teams prepared acreage recommendations, some indicated specific habitat locations, and some described habitat arrangements or features. The MARI and Other Baylands Birds focus teams summarized their habitat recommendations on EcoAtlas maps. The Shorebirds and Waterfowl, Plants, and Fish teams did not illustrate their goals on maps; instead, they reviewed and commented on the maps

FIGURE 3.2 *(continued)*

	Shallow Bay or Channel	Tidal Flat	Lagoon	Beach	Rocky Shore	Low Tidal Marsh	Mid Tidal Marsh	High Tidal Marsh	Muted Tidal Marsh	Diked Wetland	Agricultural Baylands	Salt Pond	Storage or Treatment Pond	Riparian Forest	Willow Grove	Grassland	Oak Woodland	Mixed Evergreen Forest
Other Bayland Birds																		
Eared grebe	RF	F	RF			RF		RF		RFB		RF	RF					
Western/Clark's grebe	RF	F	RF							RFB		RF						
American white pelican		R	RF	R					F	RF		RF	RF					
Brown pelican	R*F	R	RF	R		RF			R	RF		RF		RF				
Double-crested cormorant	RFB*	R	F	R	R	RF			F	F		RFB	RF					
Snowy egret		F	F	RF	RB	RF	RF	RFB	RFB	RFB	F	RF	RFB	RFB	B		B	
Black-crowned night heron	RF	F	RF	RF	RF	RF	RF	RF	RF	RFB	F	RF	F	RFB	B		RB	RB
Northern harrier		F	F			F	F	RFB	RF	RFB	R.F.B	F	F		RF	RFB		
Peregrine falcon	RFB*	RF	F	F	F	R*F	F	R*FB	F	R*FB	F	R*FB	F		RF	F	RF	
California clapper rail		F				RFB	RFB	RFB	RF	R								
California black rail							F	RFB										
Common moorhen								RFB	RFB	RFB								
California gull	RF	RF	RF	RB	R	F			RF	RF	RF	RFB	RF			RF		
Western gull	R*FB	RF	RFB	RF	RF	RFB		RFB	RFB	RF	RF	RFB	RF			F		
California least tern	RF	RF	RFB	RB		F	F	F	RF	F		RFB	F					
Forster's tern	RFB	RF	RF	R		F	F	F	RFB	RFB		RFB	F					
Caspian tern	F	RF	RFB	R	R	F			RFB	RB		RFB	F					
Burrowing owl								F	RFB	RFB	R.F.B	RFB				RFB		
Belted kingfisher	RF	F	RF			RF			RF	RF		RF	RF	RFB				
Horned lark										RF	RF					RFB		
Yellow warbler							F	F						RFB		RF		
Salt marsh common yellowthroat			RFB			F	RFB	RFB	RF	RFB	RFB			RFB				
Savannah sparrow						F	F	RFB	RFB	RFB	RFB	RF				RFB		
Song sparrow						F	RF	RFB	RFB	RF	RF	RF						
Red-winged blackbird							RF	RFB	RF	RFB	RFB		RFB	RF	RFB	RFB		
Western meadowlark								RFB		RFB	RFB	RF				RFB		
Barn swallow	RF	F	RFB			RF	RF	RFB	RFB	RFB	RFB	RFB	RF	RFB	RF	F		

Key: R = Resting, F = Foraging, B = Breeding, ! = Uses vernal pools in this habitat, * = Uses artificial structures in this habitat.

produced by the two other teams. Each of the focus teams ultimately produced preliminary recommendations that reflected the habitat needs of its species.

Formulating preliminary recommendations enabled the focus teams to begin sharing their perspectives with each other. To facilitate this, the focus teams asked the RMG to organize a series of joint team meetings. Most of these meetings involved pairs of teams, but as many as four teams attended some meetings. After a couple of meetings, the HAT joined the discussions to help the teams better understand physical habitat controls. These meetings proved to be extremely valuable as they enabled the focus teams and the HAT to discuss their views, and to identify potential conflicts. They also enabled the teams to begin modifying their recommendations to accommodate other key species.

By the end of 1997, the focus teams had completed their joint meetings and prepared final recommendations. Their recommendations ranged from very general to very specific, and while many were complementary, some were in

The Use of Data

Data are systematic observations. When data are interpreted in the context of other appropriate information, they can lead to understanding.

Tables of measurements of such things as species population size and location are one kind of data. Other kinds may include descriptions of animal behavior, unwritten recollections, or sightings of a species. Many kinds of data are potentially useful.

While the quality of data is important, its interpretation is equally significant. The scientists who collect and analyze data frequently understand more than the data directly show, and the knowledgeable scientist will draw on experience to help interpret the information and draw reasonable conclusions.

The Goals Project relied on many kinds of data. The recommendations in this document reflect not only the data used, but also the collective understanding of the scientists who participated in the Project.

conflict. Besides recommendations for habitat placement and acreage, there also were suggestions regarding habitat design and management, needed research, and a host of other related topics, such as the use of dredged materials, control of non-native invasive species, and restoration phasing. In total, the focus team materials contained nearly 200 recommendations. Appendix C contains the focus team recommendations and information prepared by the HAT.

Integrating the Recommendations

The final step in preparing draft Goals required blending all of the focus team recommendations into a conceptual vision that balanced, to the extent possible, the competing needs of the many baylands species. Originally, the RMG had planned to undertake this task independently, using the information provided by the focus teams. However, since many of the teams had already begun integrating their recommendations through their joint meetings, the RMG decided to continue this process by working with the focus teams. To do this, they planned an all-hands integration workshop where all Project participants could consider the collective recommendations and help craft them into a unified vision.

To prepare for the integration workshop, the RMG reviewed the species and community profiles, focus team recommendations, and the MARI and Other Bayland Birds focus team maps. It then endeavored, using the MARI and Other Bayland Birds maps as a starting point, to display all of the recommendations on a single "integration map." The RMG consulted with the focus team members when recommendations were unclear, and referred to the Project's guiding principles to help resolve conflicts. When the RMG completed the draft integration map, the Estuary Institute entered it into the EcoAtlas. In this way, the RMG was able to calculate acreage for each of the key habitats and to prepare tables comparing the proposed future acreage to the historic and modern acreage.

The integration workshop spanned five days in early 1998 and was attended by 30 to 35 participants each day. During the first workshop day, the focus teams presented their recommendations and the HAT gave an overview of

Scientists come to terms.

Elise Brewster

Are the Goals Scientific?

An important precept of the Project was that the Goals should be based on the best available science. The RMG acknowledged that the Goals were not developed through experimental testing of scientific hypotheses — the data were too thin for this approach. Rather, the Goals were developed using the best available data, reasonable inference based on these data, and the collective best professional judgment of the regional community of environmental scientists and managers.

The Goals were *developed by scientists and are based on scientific information*; to this extent they are scientific.


Elise Brewster

Howard Cogswell...

important physical considerations. Participants then developed descriptions of high quality habitat, and recommendations for design and management practices to optimize habitat functions. They also discussed and described ways that the various habitat types should be arranged on the landscape.

During the next three workshop days, participants reviewed recommendations for each of the Project subregions and critiqued the RMG's integration map. They also made additional habitat recommendations, many of them very specific. Recommendations that received general support with no emphatic objections were recorded for inclusion in the Goals. The RMG developed two main products from these sessions — a revised integration map (Appendix D), and a listing of potential habitat improvement sites with corresponding maps (Appendix E).

On the final workshop day, participants discussed many issues relevant to implementing the Goals and made recommendations on several topics. During the final workshop session, they reviewed the revised integration map and the list of habitat improvement sites, and agreed on how to present the Goals in the draft report.

...his maps speak volumes.


Howard Cogswell

Preparing the Goals Report

Following the integration workshop, Project staff and the RMG summarized the information and recommendations provided by the participants in an administrative draft report. Project participants (including the Science Review Group) reviewed this report in April 1998. The RMG revised the report, based on the comments received, and released a public draft report in June 1998.

In July 1998, the RMG presented the draft Goals at four public workshops. After the close of the public comment period following the workshop, the RMG considered the verbal and written comments and prepared this final report.

Science Review

The RMG established a Science Review Group (SRG) to provide critical review of the Project's process and products. It carefully selected the SRG members to assure a strong review panel with expertise in a broad range of disciplines including ecosystem analysis, integrated resource planning, and conservation biology. The

Robin Grossinger

Public truthing sessions helped to improve the EcoAtlas.

RMG considered this sort of "big picture" critiquing an essential complement to the scientific peer review provided by the focus teams.

The SRG convened in February 1997 (20 months into the process), at about the time the focus teams had completed selecting species and habitats and were beginning to formulate their recommendations. The RMG asked the SRG to review past Project activities and to help chart a course for future action. In response, the SRG provided many helpful suggestions.

In reviewing the Project activities, the SRG confirmed that the Project's species-based approach was generally sound. It also agreed that it was reasonable to rely on the collective knowledge of local scientific experts. The SRG encouraged the RMG to develop Project tenets and principles to help assure more cohesive goals and to have the Hydrogeomorphic Advisory Team immediately begin working with the focus teams. It also recommended presenting draft Goals to the public for comments before finalizing them, and suggested presenting the Goals as maps and text. The SRG also made recommendations on other issues including the habitat classification system, the proposed timeline for completing the Goals, and the role of consensus and public comment.

The SRG made many significant contributions that helped to improve the process and resulted in more technically sound and useable Goals.

Public Outreach

During the Project's early stages, the Administrative Core Team developed a public outreach program to inform the public about the Project. The outreach program included a series of workshops, meetings, brochures, and reports. It also provided an opportunity for the public to communicate with the RMG. This section summarizes the main public outreach events.

At the Project's kick-off workshop in June 1995, organizers presented a Project overview and introduced the participants. Nearly 100 persons representing local, state, and federal agencies, environmental groups, landowners, and other interests attended this two-day workshop. Many of the environmental scientists that attended were later asked to join the Project. The RMG and Administrative Core Team used comments from this workshop to revise the Project's process.

Participants provided a Project update at a second public workshop in October 1995. An information package distributed at the workshop included Project background information, a list of Project participants, and details of the process. The Administrative Core Team asked the attendees for input on the proposed public outreach program and used comments received to help improve the program.

An informational brochure produced in May 1996 presented the Project history, explained public participation opportunities, and described some potential uses for the Goals. Over the next two years the Estuary Project and Administrative Core Team distributed thousands of brochures throughout the Bay Area.

During June and July 1997, RMG members and Project staff made some 30 presentations to local planning departments, resource conservation districts, environmental organizations, mosquito abatement districts, and park districts. Presentations included general information about the Project and the potential uses of the final Goals.

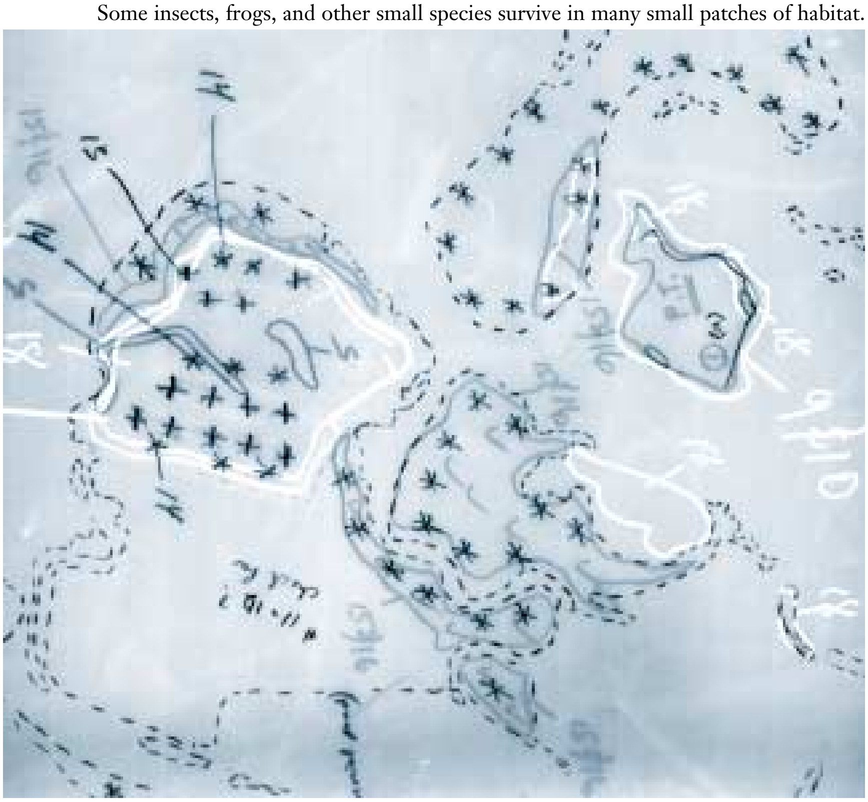
The RMG provided another Project update and presented its guiding principles at evening workshops in July 1997. The focus teams also described their work and presented their preliminary recommendations. A progress report distributed at the workshops listed the key species and habitats and introduced the Project's habitat typology. In response to RMG questions, the attendees commented on the Project's guiding principles and expressed their preferences for the format and level of specificity of the Goals.

The RMG presented the draft Goals report at a series of public workshops in July 1998. The workshops were held in the evenings and in each of the four subregions to encourage attendance by landowners and others who might not have been able to attend during the day. More than 150 persons attended the workshops, many provided comments or asked questions, and more than 60 individuals, groups, and agencies subsequently submitted written comments. The RMG and Project staff considered these comments before preparing the final report.

Public outreach also included seeking comments on technical materials; for example, the Estuary Institute invited the public to review and comment on draft versions of the EcoAtlas. This enabled many important corrections of habitat designations and boundary locations.

Public outreach for the Goals Project was extensive and provided many benefits. These benefits included a better sense of the issues of concern, improved technical products, and ideas on how to present the Goals in a way that would make them most useful.

Some insects, frogs, and other small species survive in many small patches of habitat.



Wes Maffei and Mark Jennings

Key Habitats of the Baylands Ecosystem

Large-scale habitat restoration and enhancement requires a thorough understanding of habitat features and functions. Without this understanding, one cannot expect to improve habitat conditions for a particular species or group of species. This chapter describes the Project's key habitats and identifies some of the plant and animal species that inhabit them.

An important step in understanding the similarities and dissimilarities of various habitats involves organizing the habitats into a conceptual framework. In the Goals Project, the RMG and the Estuary Institute undertook this step with considerable input from the focus teams.

The RMG considered various ways to organize the list of key habitats and recognized that each habitat contains many important components. For example, seasonal ponds occur within agricultural baylands; within a seasonal pond, the bottom substrate, water column, and edge each provide unique habitats essential to the survival of some key species. Likewise, tidal marsh contains channels of various dimensions, and each channel type has several important habitat components. This perspective led to the development of a hierarchical classification or "typology" of baylands in which habitat components of one level are nested within the next higher level. In developing the typology, Project participants identified the varied habitat support provided by each of the major habitat types and its components. **Figure 4.1** shows a very abbreviated typology of the baylands ecosystem habitats. Although this typology was appropriate and useful for the purposes of establishing regional habitat goals, it may be appropriate to modify it as more information is developed on the distribution and function of various wetlands and related habitats of the baylands ecosystem. **Table 4.1** compares the Project's habitat classification with the classification used by the San Francisco Estuary Project and the general framework for habitats developed by Cowardin et al. (1979).


Bruce Orr

Managed marsh changes through the seasons.

FIGURE 4.1 **Abbreviated Typology**

Baylands Ecosystem

Bay
- Deep Bay
- Deep Channel
- Shallow Bay
- Shallow Channel

Baylands

Tidal
- Tidal Flat
- Tidal Marsh
  - Salt Marsh
  - Brackish Marsh
- Lagoon

Diked
- Diked Wetland
  - Managed Marsh
  - Diked Marsh
- Agricultural Bayland
- Salt Pond
- Storage/Treatment Pond

Adjacent Habitats
- Riparian Forest
- Willow Grove
- Grassland
  - Non-native Annual Grassland
  - Moist Grassland
  - Grassland/Vernal Pool Complex
  - Coastal Prairie
- Oak Woodland
  - Coastal Live Oak Woodland
  - Valley Oak Woodland
  - Foothill Oak Woodland
- Mixed Evergreen Forest

Elise Brewster

The tide reaches across many habitats.

Please note that one of the habitats — agricultural bayland — actually is a kind of land use rather than a type of wetland or related habitat. It was included in the habitat typology because it represents a major part of the baylands ecosystem and provides a variety of important ecological support functions for baylands species. It also has habitat components — non-tidal salt marsh, non-tidal brackish marsh, and seasonal ponds — that could be described with existing information. Also, "agricultural bayland" or "farmed bayland" are regional terms that have been in common use for years.

Different types of habitats often blend, or intergrade, with one another in a transition zone called an ecotone. Ecotones can vary in width from a few feet, as at the upper edge of a riprapped shoreline, to hundreds of yards, as at the boundary of high tidal marsh and adjacent grassland. In the baylands, there are ecotones from deep bay to shallow bay, shallow bay to tidal flat, tidal flat to tidal marsh, and so forth. There are also ecotones between the components within a habitat type, and between the saltwater and freshwater extremes of the salinity gradient. The beaches, rocky shoreline, levees, and tidal reaches of adjacent streams are all part of the ecotone from the baylands to the adjacent uplands. Ecotonal areas are important because they support especially diverse groups of plants and animals.

Salt marsh builds against the hills.

The following section describes the key habitats of the baylands ecosystem and notes some of the organisms that use them. It presents the habitats in three groups — Bay Habitats, Baylands Habitats, and Adjacent Habitats — in accordance with the Project's typology. **Table 4.2** and **Figure 4.2** indicate some sites where one can observe good examples of the habitats. Chapter 7 presents information on the design and management of many of the habitats. For more thorough descriptions of the structure and associated biota of these habitats, please refer to the Goals Project's *Species and Community Profiles* (Goals Project 2000) and other appropriate materials listed in the References section of this report.

TABLE 4.1 Comparison of Wetland Classification Systems

Cowardin et al. (1979) (System/Subsystem)	S.F. Estuary Project (Category)	Goals Project (Key Habitats)
Estuarine/Subtidal	Open Water Shallow Bay & Channel	Deep Bay & Channel Shallow Bay & Channel
Estuarine/Intertidal	Mudflat Rocky Shore Tidal Channel Tidal Marsh	Tidal Flat Tidal Marsh (& channels) Lagoon
Riverine	Tidal River Nontidal River Perennial & Intermittent Creeks	Lowland Creek
Lacustrine	Perennial Lakes & Ponds Salt Evaporator Crystallizer Bittern pond	Storage/Treatment Pond Salt Pond
Palustrine	Diked Vegetated Wetlands Seasonal & Permanent Vegetated Wetland Seasonal Pond Farmed Wetland Freshwater Marsh	Diked Wetland Agricultural Bayland
	Riparian Forest	Riparian Forest/Willow Grove
	Adjacent Upland	Grassland Oak Woodland Mixed Evergreen Forest

For a more detailed comparison of the Cowardin habitat classifications and the San Francisco Estuary Project's wetlands and related habitat categories, please refer to Meiorin et al. (1991), page 23.

Bay Habitats

Bay habitats are intricately tied to the baylands and are components of the baylands ecosystem. They are especially important for aquatic organisms, sea birds, and some mammals that move back and forth between deep and shallow waters. Bay habitats are divided into two categories: areas of deep water (Deep Bays and Channels) and areas of shallow water (Shallow Bays and Channels).

Deep Bay and Channel

Deep bays and channels are the parts of the Project area that are deeper than 18 feet below Mean Lower Low Water (MLLW). They include the deepest portions of the Bay and the largest tidal channels.

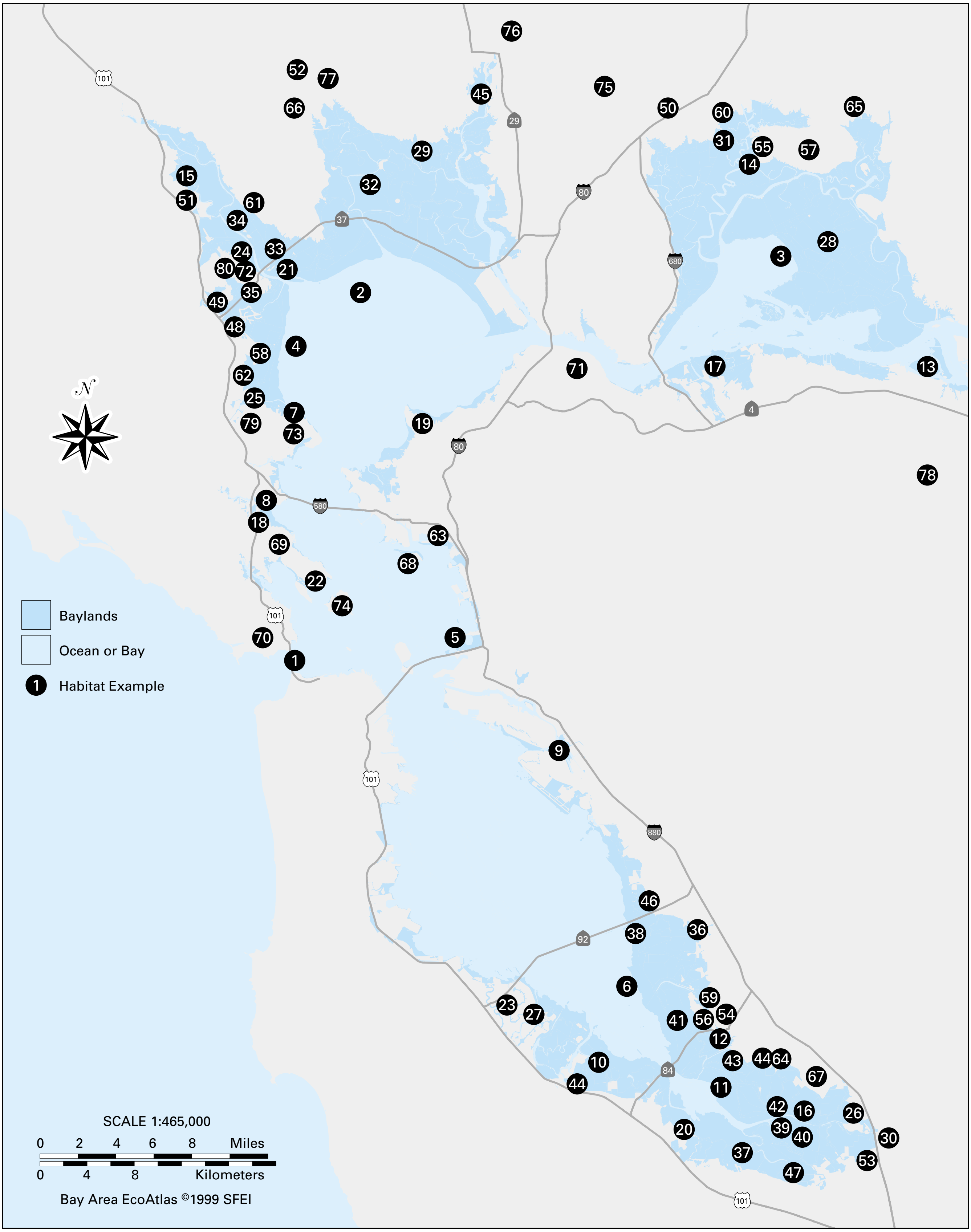
The sediments of deep bay and channel habitat vary widely in character, from coarse sand to very fine clays and silts. In the parts of the Bay where currents are strong, especially as in the deeper reaches of San Pablo Bay and Central Bay, the bottom is mostly coarse sand. In Suisun Bay and South Bay, however, most of the bottom is covered with mud, a mixture of material with more than 80 percent silt and clay (Nichols and Thompson 1985).

TABLE 4.2 List of Habitat Example Sites

Habitat Type	Site	Location
Deep Bay/Channel	1.	Golden Gate (CB)
Shallow Bay/Channel	2.	San Pablo Bay (NB)
Tidal Flat	3.	Grizzly Bay (S)
	4.	Marin Shoreline (NB)
	5.	Emeryville Crescent (CB)
	6.	South Bay (SB)
Tidal Salt Marsh	7.	China Camp (NB)
	8.	Heerdt Marsh (CB)
	9.	Arrowhead Marsh (CB)
	10.	Greco Island (SB)
	11.	Mowry Slough (SB)
	12.	Upper Newark Slough (SB)
Tidal Brackish Marsh	13.	Brown's Island (S)
	14.	Rush Ranch (S)
	15.	Petaluma Marsh (NB)
	16.	Triangle Marsh (SB)
Muted Tidal Marsh	17.	Pacheco Slough (S)
	18.	Marta's Marsh (CB)
	19.	Point Pinole (NB)
	20.	Charleston Slough (SB)
Lagoon	21.	Sonoma Baylands (NB)
	22.	Belvedere Lagoon (CB)
	23.	Foster City (SB)
Diked Wetland	24.	Western Marsh and Central Low-lands at Bahia (NB)
	25.	Gallinas Creek (NB)
	26.	Fremont Airport (SB)
	27.	Area H, Redwood Shores Peninsula (SB)
	28.	Suisun Marsh (S)
	29.	Huichica Unit, Napa-Sonoma Marsh (NB)
	30.	Santa Clara Valley Water District Pond (SB)
Agricultural Bayland	31.	Suisun Marsh (S)
	32.	Skaggs Island (NB)
	33.	Leonard Ranch (NB)
	34.	Twin House Ranch (NB)
	35.	Black Point (NB)
	36.	Oliver Hayfield, Hayward (SB)
Salt Pond, low salinity	37.	Pond B1/B2, Mtn. View (SB)
	38.	B10 Baumberg (SB)
	39.	Pond A9, Alviso (SB)
Salt Pond, mid salinity	40.	Ponds A10-A14, Alviso(SB)
	41.	Ponds 2-8, Coyote Hills (SB)
	42.	Ponds 2-6, Mowry Slough/Coyote Creek (SB)
Salt Pond, high salinity	43.	Ponds 10 and 26, Newark (SB)
	44.	Crystallizers, Newark and Redwood City (SB)
Storage/Treatment Pond	45.	Napa (NB)
	46.	Hayward (SB)
	47.	Sunnyvale (SB)
	48.	Ignacio Pond (NB)
	49.	Hahn Flood Basin (NB)
Riparian Forest	50.	Suisun Creek (S)
	51.	San Antonio Creek (NB)
	52.	Sonoma Creek (NB)
	53.	Coyote Creek (SB)
Willow Grove	54.	Coyote Hills Regional Park (SB)
Native Grassland	55.	Rush Ranch (S)
Community (Remnants)	56.	Coyote Hills (SB)
Non-native Annual	57.	Potrero Hills (S)
Grassland	58.	Hamilton Field (NB)
	59.	Coyote Hills (SB)
Moist Grassland	60.	Near Fairfield (S)
	61.	Petaluma River Area (NB)
	62.	St. Vincent's/Silveira Ranch (NB)
	63.	Richmond Field Station (CB)
	64.	Upper Reach Mowry Slough (SB)
Grassland/Vernal Pool	65.	Near Fairfield (S)
Complex	66.	Sonoma Creek Area (NB)
	67.	Warm Springs (SB)
Coastal Prairie	68.	Brooks Island (CB)
	69.	Ring Mountain Preserve (CB)
	70.	Golden Gate National Recreation Area (CB)
Coast Live Oak	71.	Carquinez Strait (S)
Woodland	72.	Black Point to Rush Creek (NB)
	73.	China Camp (NB)
	74.	Angel Island (CB)
Valley Oak Woodland	75.	Green Valley Creek Area (S)
	76.	Lower Napa River Area (NB)
	77.	Sonoma Creek Area (NB)
Foothill Oak Woodland	78.	Black Diamond Mine Regional Park (S)
Mixed Evergreen Forest	79.	San Pedro Ridge (NB)
	80.	Black Point to Rush Creek (NB)

S = Suisun, NB = North Bay, CB = Central Bay, SB = South Bay

FIGURE 4.2 Map of Habitat Example Sites




NASA 1995/96

Bays deepen.

Deep bays and channels are important for large aquatic invertebrates including California bay shrimp, Dungeness crab, and rock crab, and for fishes such as white sturgeon and brown rockfish. They also are migratory corridors through which pass anadromous fishes including Chinook salmon and steelhead.

Deep bays and channels are habitat for several species of water birds including brown pelican, double-crested cormorant, greater and lesser scaup, surf scoter, and Caspian tern. Marine mammals such as harbor seal and California sea lion are also found here.

This habitat accounts for about one-third of the Bay's area and occurs in all four subregions. The deepest portion is in Central Bay at the Golden Gate.

Shallow Bay and Channel

Shallow bays and channels include the portion of the Project area where the bottom is entirely between 18 feet below MLLW and MLLW.

The sediments of shallow bays and channels are primarily mud. An exception is a large portion of the eastern side of South Bay, which is covered with shell fragments, remnants of the native and introduced oysters that once occurred in the area (Nichols and Pamatmat 1988).

Shallow bays and channels are important for many invertebrates, fishes, and water birds. This rich environment is an especially productive feeding area for many fishes including Pacific herring, splittail, northern anchovy, and jacksmelt. It is also an important migratory corridor for anadromous fishes such as Chinook salmon and steelhead.

A few of the many bird species that occur in this habitat include western grebe, American wigeon, canvasback, Forster's tern, and least tern. Some of the mammals found here are the harbor seal and California sea lion.

Eelgrass is a particularly important plant species found in the upper reaches of shallow bays and on mudflats in Central Bay. The Bay's only rooted seagrass, eelgrass provides feeding, escape, or breeding habitat for many species of invertebrates, fishes, and some waterfowl. The economically important Pacific herring spawns in eelgrass beds, and least terns forage on small fishes that are found there. Eelgrass also has been found to be an obligate food for black brant along the Pacific flyway (Einarsen 1965).

Shallow bays and channels account for about two-thirds of the Bay's area, and they occur in all four subregions. A good example of this habitat type is at the northern edge of San Pablo Bay.

Bayland Habitats

Bayland habitats include the parts of the Project area that lie between MLLW and the highest observed tide. As described in Chapter 2, the baylands' boundaries and areal extent have changed over the years as a result of sedimentation, diking, and filling.

Bayland habitats support a broad variety of plants and animals and provide areas for feeding, breeding, nesting, roosting, resting, and other functions. The discussion below divides bayland habitats into two categories: Tidal Baylands and Diked Baylands.

What is an Ecosystem?

The ecosystem concept was developed by research scientists so that a patch of the earth, of any convenient size, could be studied to see how life worked there. The boundaries drawn around ecosystems are arbitrary and selected for convenience in studying each system. Thus, an ecosystem can be a planet, a tropical rain forest, an ocean, a fallen log, a puddle of water, or a culture of bacteria in a petri dish.

Generally, an ecosystem is a natural community of living organisms that interact with each other and with their physical environment in a way that perpetuates the community.

adapted from G. T. Miller, Jr., (1985), *Living in the Environment*

Tidal Baylands

The key habitats within tidal baylands are tidal flat, tidal marsh, and lagoon.

Tidal Flat

Tidal flat habitat includes mudflats, sandflats, and shellflats. It occurs from below MLLW (at the elevation of the lowest tides) to Mean Tide Level (MTL) and supports less than 10 percent cover of vascular vegetation, other than eelgrass. About 90 percent of intertidal flat habitat occur on the edges of the Bay, and the remainder is associated with shallow tidal channels. Historically, a greater proportion of tidal flat occurred along the edges of tidal marsh channels (Bay Area EcoAtlas 1998).

Mudflats comprise the largest area of tidal flat habitat. These expanses of fine-grained silts and clays support an extensive community of diatoms, worms, and shellfish, as well as algal flora including green algae, red algae, and sea lettuce. Eelgrass, described previously under shallow bay and channel habitat, can also be a component of mudflats.

During the twice-daily high tides, Bay water inundates tidal flats and provides foraging habitat for many species of fishes including longfin smelt, staghorn sculpin, and starry flounder. During low tides, tidal flats are the major feeding areas for many species of shorebirds; mudflats, in particular, are rich in shorebird food items. Shorebird species that feed on tidal flats include semipalmated plover, American avocet, willet, marbled godwit, western sandpiper, and dunlin. Few mammals, however, frequent tidal flats; the harbor seal is the most notable exception (Fancher and Alcorn 1982).

Tidal flat habitat occurs in each of the Bay's four subregions, but there naturally tends to be less in brackish or freshwater areas compared to more saline areas. This is because, under fresher conditions, marsh vegetation grows lower in the intertidal zone (Atwater 1979, Grossinger 1995). As a result, there is little tidal flat habitat in Suisun, the subregion with the freshest water. About one-third of the Bay's tidal flat habitat is in North Bay, and more than one-half is in South Bay. Given the South Bay's large acreage of tidal flats, most biologists consider it to be the region's most important area for shorebirds.

Tidal flat, East Bay.

Josh Collins

Examples of tidal flat exist in Grizzly Bay, along the Marin shoreline, at the Emeryville Crescent, and throughout much of South Bay.

Tidal Marsh

Tidal marsh is vegetated wetland that is subject to tidal action. It occurs throughout much of the Bay from the lowest extent of vascular vegetation to the top of the intertidal zone (at the maximum height of the tides). Tidal marsh also exists in the tidal reaches of local rivers and streams. In the fresher parts of the Estuary it occurs at lower elevations in the intertidal zone.

Tidal marsh plant communities vary markedly from one part of the Estuary to another. This variation correlates strongly to salinity patterns and to other factors such as substrate, wave energy, marsh age, sedimentation, and erosion.

In the more saline parts of North, Central, and South bays, tidal marsh is referred to as tidal salt marsh. In the more brackish areas, where there is significant freshwater influence — as in Suisun, along the middle reaches of the Petaluma and Napa rivers, and at the mouths of several streams in South Bay — it is referred to as tidal brackish marsh. Because the plant communities of these two general marsh types differ, tidal marshes in different parts of the Bay look very different. For example, a tidal marsh on Montezuma Slough in Suisun (with tall tules and cattails along the channels) looks very different compared to a tidal marsh on the Palo Alto bayfront (with low-growing pickleweed and Pacific cordgrass along the channels).

Three general zones of vegetation, each of which is related to tidal elevation and distance from shore, typically characterize both tidal salt marsh and tidal brackish marsh. Low tidal marsh occurs between the lowest margin of the marsh and Mean High Water (MHW). Middle tidal marsh occurs between MHW and Mean Higher High Water (MHHW). High tidal marsh occurs between MHHW and the highest margin of the marsh.

The high marsh vegetation in a tidal salt marsh or tidal brackish marsh typically intergrades with upland plant species in the marsh/upland ecotone. The width of this zone is determined primarily by the slope of the land; in flatter areas, such as in Suisun, it may be hundreds of yards wide, whereas in Central Bay, with its relatively steep shorelines, the zone is usually much narrower. The marsh/upland ecotone is very important ecologically as it is characterized by a diverse assemblage of vegetation and may provide especially valuable habitat for many species of wildlife.

Tidal marshes have a variety of important components including tidal channels and, sometimes, pans. Large tidal channels and their smaller tributaries form drainage networks that distribute tidal waters throughout the marsh. Where the marsh plain is fairly level, channels tend to be sinuous, but where it slopes more steeply, they tend to be straighter. Channel density (i.e., the amount of channel habitat per area of marsh plain) is directly related to tidal prism, the volume of water that flows into and out of the marsh. A high marsh with a small tidal prism typically will have fewer channels than a low marsh with a larger tidal prism. Also, channel density may be related to salinity; salt marshes generally have denser networks of tidal channels than do brackish marshes (Grossinger 1995).

Tide goes out in shallow channels.

Josh Collins

Marsh pans, referred to as pannes in some references, are typical features of extensive, well-developed tidal marshes. The term refers to natural ponds that form in the marsh plain. These ponds, usually less than one foot in depth, fill with tidal water only during very high tides. They may be hypersaline in late summer, but they do not develop thick deposits of salts as do natural or commercial salt ponds. Most pans are unvegetated, but some support wigeongrass and green macroalgae. There tend to be fewer but larger pans in brackish marshes compared to salt marshes (Grossinger 1995).

Mark Barnby

Pans sit on the marsh top.

Pans also occur at the backshore edge of marshes at the tidal marsh/ upland ecotone, where they receive infrequent tidal flows. Here, they tend to be elongate, with the long axes parallel to the marsh/upland boundary. Local influences of topography, microclimate, groundwater, and freshwater runoff affect the salinity of these pans, which is highly variable. Examples of pans exist at the base of Potrero Hills at Rush Ranch in Suisun, at the eastern end of the tidal marsh that fringes Highway 37 in North Bay, at the edge of the Emeryville Crescent in Central Bay, and near Mowry Slough in South Bay.

A microtidal marsh is a tidal marsh that receives less than full tidal flow because of a physical impediment; locally, the term "muted" is frequently used to describe this kind of marsh. An impediment to tidal flow may be natural (such as a sand spit) or man-made (such as a culvert, tide gate, or other water control structure). Muted tidal marshes exhibit many of the same features as fully tidal marshes, but they often lack a full range of plant diversity. Although muted tidal marshes may be very important to some wildlife groups (particularly for shorebirds during the fall migration), muting typically excludes some species. Examples of muted tidal marsh include the marshes near the mouth of Pacheco Slough in Suisun, Marta's Marsh in North Bay, Point Pinole in Central Bay, and Charleston Slough in South Bay.

Development in the baylands has severely affected tidal marshes, especially high marsh zones and high marsh/upland ecotones. Filling marshes and isolating the remnants from sediment and natural freshwater flows has greatly reduced tidal marsh plant diversity. Past floral accounts of the Bay note a much greater diversity of marsh plants than exists today; research by the Project's Plants Focus Team indicates that more than 50 plant species found in the Bay marshes at the turn of this century are now extinct or exist only in isolated populations (Goals Project 1999). Most of these plant species resided in the high marsh or in the marsh/upland ecotone. Locally extinct species include Point Reyes bird's-beak, sea-pink, salt marsh owl's clover, and smooth goldfields (all extirpated in the South Bay); and California sea-blite and California saltbush (extirpated throughout the estuary). Today, rare plant species of tidal marsh include Point Reyes bird's-beak, soft bird's-beak, Suisun thistle, Mason's lilaeopsis, and Delta tule pea.

High-quality tidal marshes provide a complex habitat for many fish and wildlife. In Suisun Bay, splittail, Delta smelt, Chinook salmon, and longfin smelt occur in the marsh channels. Common fishes of Central Bay and South Bay tidal marshes include topsmelt, arrow goby, yellowfin goby, and staghorn sculpin. In North Bay, tidal marshes support gobies, sculpins, and three-spined stickleback. Some bird species associated with tidal marshes include snowy egret, northern harrier, California clapper rail, California black rail, willet, short-eared owl, salt marsh yellowthroat, Alameda song sparrow, San Pablo song sparrow, and Suisun song sparrow. Small mammal species that rely primarily on tidal marsh include salt

"The habitat of an organism is the place where it lives, or the place where one would go to find it."
— E. Odum 1971

marsh wandering shrew, Suisun shrew, and salt marsh harvest mouse. Red fox, coyote, and other predators prey on these species in middle and high marsh. Harbor seals utilize tidal marsh, especially areas adjacent to sloughs in South Bay, as resting or haul-out sites during high tides.

Tidal marsh occurs throughout the Project area, but the largest patches are on the northern edge of San Pablo Bay and along the Petaluma River. Suisun Bay, too, supports a substantial acreage of tidal marsh, while Central Bay supports relatively little.

Tidal Salt Marsh — Pacific cordgrass and common pickleweed are the dominant plant species in tidal salt marsh. Pacific cordgrass is usually the primary colonizer on broad tidal mudflats that fringe tidal marsh plains, and it occurs in virtually pure stands in low marsh between about MTL and MHW. Midway within this tidal range, it intermixes with annual pickleweed, especially in depressions in the marsh plain.

In middle tidal salt marsh, at elevations near and above MHW, Pacific cordgrass yields to common pickleweed. A perennial succulent, pickleweed dominates salt marsh plains around the Bay. In high tidal salt marsh, between about MHW and the maximum extent of the tides, common pickleweed is found in association with peripheral halophytes including saltgrass, fathen, and alkali heath.

Additional plant species on tidal marsh plains include fat hen, marsh rosemary, alkali heath, and jaumea. Dodder, a parasite on common pickleweed, is often a dominant species of salt marshes; it is widespread and abundant in North Bay and South Bay. Levees within tidal marshes support coyote brush and gumplant.

Recent research indicates that hybrid cordgrass (a cross between native Pacific cordgrass and smooth cordgrass) is a new dominant in many East Bay salt marshes (Antilla et al. 1998). As described in Chapter 6, this new species has a potential for affecting the structure and function of tidal marshes and is spreading to other parts of the Bay.

Examples of tidal salt marsh are found at China Camp, Heerdt Marsh at Corte Madera Ecological Reserve, Arrowhead Marsh, Greco Island, Mowry Slough, and Upper Newark Slough.

Tidal Brackish Marsh occurs in parts of the Bay where freshwater reduces salinities. Salinities vary markedly from season to season and from year to year, depending largely on rainfall patterns, and the marsh plant communities reflect these changes.

In tidal brackish marsh, cattails, California bulrush, and alkali bulrush dominate low marsh. A diverse assemblage of plant species including bulrushes, spike rush, Baltic rush, silverweed, and salt grass dominates middle marsh. Common pickleweed, saltgrass, gumplant, and alkali-heath characterize the plants of the high marsh.

Tidal brackish marsh exists throughout the Suisun subregion and along the middle and upper tidal reaches of the larger rivers and streams of the three other subregions. The most natural examples of this habitat type are at Brown's Island near the confluence of the Sacramento and San Joaquin rivers, Rush Ranch at First Mallard Slough in Suisun Marsh, Petaluma Marsh near the confluence of the Petaluma River and San Antonio Creek, and Triangle Marsh in South Bay.

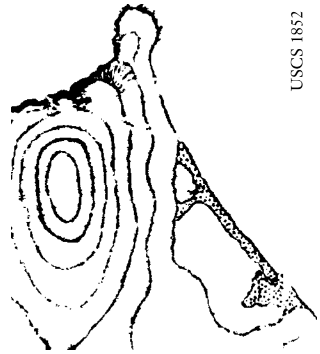
Lagoon

A lagoon is an impoundment of water that is subject to at least occasional or sporadic connection to full or muted tidal action. The impoundment may or may not receive a stream or other form of uplands runoff, and it can be natural (e.g., formed behind a barrier beach along an indented shoreline) or artificial.

Lagoons support many of the same species of aquatic invertebrates and fishes that occur in nearby shallow bays and channels. They also provide feeding or loafing habitat for a variety of water birds such as brown pelican, canvasback, greater and lesser scaup, bufflehead, and ruddy duck.

Recent information indicates that lagoons may be sites of early colonization by introduced aquatic species (Cohen 1995).

Historically, natural lagoons occurred in Central Bay on the Marin shoreline and along the San Francisco Peninsula. Today, no historical natural lagoons remain in the Bay, but artificial ones occur in North Bay, Central Bay, and South Bay. Examples are the lagoons at Tolay Creek, Sonoma Baylands, Belvedere Lagoon, and Foster City. Nearby, but outside of the Project area, natural lagoons occur in Tomales Bay and at Drakes Estero.



USCS 1852

Lagoons form behind beaches.

Diked Baylands

Diked baylands exist in parts of the Bay that once were tidal but are now isolated from the tides. Their physical origins are generally similar in that most were initially diked or "reclaimed," beginning in the mid-1800s, for some kind of agricultural use or for salt production. Reclamation typically involved the construction of earthen levees along the margins of the marsh plains where they bordered mudflats or large tidal channels. Today, diked baylands consist of several major habitats. In this report, key diked bayland habitats include diked wetland, agricultural bayland, salt pond, and storage/treatment pond.

Diked Wetland

Diked wetlands are areas of historical tidal marshes that have been isolated from tidal influence by dikes or levees, but which maintain primarily wetland features. In this report, diked wetlands are differentiated from diked agricultural baylands in that they typically support much more wetland vegetation and they produce no agricultural crops. For purposes of developing habitat recommendations, the Project divided diked wetlands into two general categories: managed marsh and diked marsh.

The plant communities of diked wetlands vary greatly from site to site and can resemble those of local tidal salt marsh, tidal brackish marsh, non-tidal perennial freshwater marsh, or seasonally wet grasslands. Some also have characteristics similar to components of tidal marshes that are now regionally scarce or extinct, such as tidal marsh pans and alluvial high marsh/upland ecotones. However, they usually have fewer native species than their analogous natural tidal plant communities, and often a larger component of exotic plant species. Common native plant species of diked wetlands include common pickleweed, saltgrass, alkali bulrush, bulrush, and cattail.

Managed marsh is habitat for many waterfowl species.

Josh Collins

Managed marsh is diked wetland habitat that is managed for wildlife, primarily waterfowl. It accounts for about 80 percent of the diked wetland habitat in the Project area. Managed marshes are located in private duck clubs and on publicly owned wildlife management areas and refuges. Fresh to brackish tidal water taken from streams or sloughs is the primary water source for managed marshes; this water is delivered through tide gates and along artificial channels. Specific management objectives determine the timing, duration, depth, and extent of water ponding in a managed marsh. They also influence the vegetation management practices.

Marshes traditionally managed for waterfowl have been designed to favor alkali bulrush, barley, brass buttons, fat hen, and sago pondweed (Miller et al. 1975). Wigeongrass and watergrass commonly occur on ponds within these marshes. In the more brackish managed areas, Baltic rush, saltgrass, and pickleweed occur; other species that have colonized these wetlands include goosefoot, dock, celery, sea purslane, and pepper grass.

Suisun Marsh is the largest managed marsh in the Estuary and is managed primarily to provide wintering feeding habitat for migratory waterfowl (Rollins 1981, Arnold 1996). This marsh has a great diversity of habitats due to water and land management practices. Marsh management is usually designed to favor mixtures of shallow submerged mud, perennial and seasonal open ponds, and floating and rooted emergent vegetation. Other managed marshes, although much smaller than Suisun Marsh, also exist in North Bay and South Bay. Vegetation in North Bay marshes includes many of the same species that are in Suisun Marsh. In South Bay, however, managed marsh vegetation is mostly that of the salt marsh community.

Managed marshes typically provide excellent habitat for many species of waterfowl such as mallard, northern shoveler, northern pintail, and blue-winged teal. They also provide habitat for many species of other birds, mammals, reptiles, amphibians, and invertebrates; for example, more than 20 species of shorebirds occur in Suisun Marsh, along with many species of hawks and owls. Some of the many mammal species that occur in Suisun Marsh include opossum, weasel, river otter, mink, salt marsh harvest mouse, beaver, striped skunk, red fox, coyote, and tule elk.

Examples of managed marsh are Suisun Marsh, the Huichica Unit of the Napa-Sonoma Marsh, and the Santa Clara Valley Water District pond adjacent to Coyote Creek.

Diked marsh usually occurs in low areas adjacent to levees or dikes that have no or poor drainage. This kind of wetland is not actively managed for wildlife, although many diked marshes may have been subject to some kind of management (including agriculture) in the past. Because rainfall and, in some areas, runoff from adjacent lands are their primary water sources, diked marshes are seasonal wetlands. Annual rainfall patterns determine the timing, duration, depth, and extent of ponding and soil saturation. In some years, they are ponded continuously for weeks or months; in other years, they are alternately dry and wet; and in some years, they may remain nearly dry.

Although diked marshes are not intensively managed, they may provide important habitat for a variety of wildlife, especially waterfowl, shorebirds, and small mammals. Where they are located near or adjacent to tidal marshes, they can be especially valuable as high tide refugia for small mammals and as roosting habitat for shorebirds and waterfowl. Sites which pond water in winter months often are good foraging and roosting habitat for shorebirds.

Examples of diked marsh are at the Western Marsh and Central Lowlands at Bahia near the Petaluma River, Gallinas Creek, the abandoned Fremont Airport, and Area H on the Redwood Shores Peninsula.

Agricultural Bayland

Agricultural bayland consists of diked, former tidal marshes that are intensively cultivated for agricultural production (primarily oat hay) or are grazed by cattle, sheep, or horses. This habitat type also includes ruderal areas where agricultural production ceased relatively recently. Most agricultural baylands support shallow, seasonally ponded wetlands and some upland plants, and would support a more diverse array of wetland and upland plants if active agricultural management were to cease.

During the wet season, large areas of agricultural baylands become waterlogged or inundated. The patterns of waterlogging and inundation depend principally on the relict tidal marsh topography, the extent and effectiveness of artificial drainage, soil permeability, and the amount and seasonal distribution of rainfall. Successfully raising a crop such as oat hay in these areas requires careful management of ground water levels, soil salinity, and levees.

Until the middle part of this century, farmers controlled water levels on agricultural baylands with gravity-driven systems of drainage ditches. Subsurface and surface water flowed from fields to adjacent marshes through these ditches via one-way flapgates. These systems had limited efficiency, and low places in the fields (relict tidal channels and pans) often remained poorly drained well into the crop-growing season. Today, diked agricultural baylands have subsided to the point at which gravity-driven drainage systems are ineffective, and farmers must pump water from their fields. Although pumping is relatively expensive, it allows farmers more control over water levels in their fields.

After many years of intensive draining and flushing with rainwater, baylands soils tend to become subsaline to nonsaline and support a variety of marsh plants in addition to cultivated crops. Agricultural fields that are disked annually typically support a mixture of native annual wetland plants (e.g., popcornflower, toadrush), and non-native annuals (e.g., loosestrife, brass buttons, barley) and perennials (e.g., birdsfoot trefoil, coyote thistle, and Pacific bentgrass).

Agricultural baylands provide habitat for many species of wildlife. They are important as roosting and feeding habitat for wintering shorebirds including greater yellowlegs, long-billed curlew, least sandpiper, dunlin, and long-billed dowitcher. They may be especially important for smaller shorebirds, whose size prevents them from foraging on nearby tidal mudflats during each tidal cycle for as long as longer-legged larger species (Page, pers. comm.). Waterfowl such as mallard and northern pintail use fields when they pond. Other bird species commonly found on farm fields include snowy egret, black-crowned night heron, northern harrier, horned lark, savannah sparrow, red-winged blackbird, and western mead-

Water ponds on farmed baylands.

Ruth Pratt

owlark. Some of the mammal species that use this habitat are California vole, California ground squirrel, striped skunk, coyote, and black-tailed deer.

Within agricultural baylands, areas of shallow seasonal ponds are the most important habitats for shorebirds and waterfowl. These ponds, typically less than six inches deep, have feathered edges and a minimum of emergent vegetation. The areal extent and duration of ponding vary markedly from year to year and are highly influenced by pumping and rainfall patterns. Areas with the highest habitat values are those that pond every year and which are frequently or continuously inundated during the wet season.

Pastures in grazed agricultural baylands, especially those that are not frequently cultivated or mowed, provide abundant cover and food for wildlife. They also allow year-round use by more wildlife species than do intensively farmed areas. As most pastures are allowed to pond more extensively and for longer periods than oat hay fields, they often provide better wintering habitat for shorebirds and waterfowl. And because grazing reduces dense plant cover, it improves access for birds.

Ruderal areas — uncultivated and ungrazed — support more upland grasses and other vegetation than do cultivated fields. Wild mustard, fennel, and poison hemlock are dominant members of the plant community. Some ruderal areas, especially the wetter lower portions of some sites, support a variety of amphibians, reptiles, birds, and small mammals.

Nearly all of the agricultural baylands are in the North Bay subregion, although some agricultural production occurs in Suisun Marsh and in South Bay. Examples of this major habitat type are at the northwestern edge of Suisun Marsh, Skaggs Island, Leonard Ranch, Twin House Ranch, Black Point, and Oliver West.

Salt Pond

Salt ponds are large, persistent hypersaline ponds that are intermittently flooded with Bay water. They occur within the historical areas of tidal salt marsh in North Bay and South Bay.

Historically, there were natural salt ponds along the eastern edge of South Bay, primarily near San Lorenzo Creek and Mt. Eden Slough near Hayward (Ver Planck 1951, 1958). Native Americans obtained salt from these ponds for their own use and for trade; later, so did the region's Spanish and other settlers. The largest pond complex, extending over some 1,000 acres, was called Crystal Pond. In the mid-1800s, as the demand for salt rose, the first artificial salt ponds were developed in the East Bay as extensions and improvements of the natural salt ponds. Today, artificial salt ponds have entirely displaced their natural forerunners and no natural salt-crystallizing ponds remain in the Bay.

Salt appears in a salt pond.

Bob Walker

The process of making salt in the artificial ponds involves moving Bay water through a series of ponds, known as concentrators or evaporators, over a period of six or seven years. During this time, solar evaporation increases the water's salinity from about 35 parts per thousand (ppt) to more than 180 ppt. The precipitation of sodium chloride salt from the highly saline water, or brine, takes place in ponds known as crystallizers (Ver Planck 1958). The salinity of any given salt pond is determined by management practices rather than by its location.

The Project's bird focus teams described and compared habitat functions of salt ponds according to salinity. Their salinity categories differed somewhat from those of another recently developed salt pond classification system (Javor 1989) because they were based on observations of birds rather than of plants and microinvertebrates. In the Project's classification system, low-salinity ponds usually have salinities less than 60 ppt, medium-salinity ponds usually have salinities between 60 and 180 ppt, and high-salinity ponds usually have salinities greater than 180 ppt, with crystallizer salinities approaching 360 ppt at saturation.

Salt ponds support a distinctive and highly specialized salt-tolerant to salt-loving biota consisting of microalgae, photosynthetic bacteria, and invertebrates (e.g., brine fly and brine shrimp). The dominant species are single-celled green alga and numerous species of blue-green and other bacteria. Ponds with salinities closer to marine salinities support macroalgae, such as sea lettuce, and marine plankton.

Salt ponds, especially those with low to mid-salinities, provide important habitat for many species of wildlife, particularly birds. They are of primary importance to migratory shorebirds and waterfowl, and they also provide year-round foraging habitat for a number of resident species such as American avocet, black-necked stilt, and western snowy plover. These and several other species — California gull, western gull, Forster's tern, and Caspian tern — nest on partly dry salt ponds, on levees, and on salt pond islets and islands. In all, more than forty species of birds are common on salt ponds. Ponds managed as crystallizers provide habitat for wildlife including shorebirds, gulls, and other water birds; however, given their comparatively high salinities, their habitat quality for most species of birds is not as high as the lower-salinity ponds.

The construction of artificial salt ponds in the Bay enabled increased populations of several bird species. These species include eared grebe, white pelican, bufflehead, western snowy plover, black-necked stilt, American avocet, Wilson's phalarope, red-necked phalarope, California gull, Caspian tern, and Forster's tern (Harvey et al. 1988). Eliminating artificial salt pond habitats without concomitantly restoring natural salt ponds and tidal salt marshes with pans could reduce or even extirpate some of these species from the Bay.

All salt ponds that are actively producing salt for commercial purposes are in South Bay, south of the San Mateo Bridge. In North Bay, none of the salt ponds west of the Napa River is managed to produce salt. The California Department of Fish and Game manages these "inactive" ponds for wildlife purposes.

As currently managed, examples of low-salinity salt ponds are Pond B1/B2 in Mountain View, Pond 1 at Mowry Slough, and Pond A9 at Alviso. Examples of mid-salinity salt ponds are Ponds A10–A14 at Alviso, Ponds 2–8 at Coyote Hills, and Ponds 2–6 at Mowry Slough/Coyote Creek. Examples of high-salinity salt ponds are Ponds 10 and 26 at Newark and the crystallizers at Newark and Redwood City.

Sewage treatment pond.

NASA 1995/96

Storage/Treatment Pond

The storage/treatment pond designation refers to diked, perennial shallow or deepwater pond habitat that has been constructed to store or treat runoff, sewage, or industrial discharges. These ponds support relatively little vascular vegetation. Most of them are parts of municipal wastewater treatment works that store treated effluent before it is recycled or discharged to the Bay. As they are similar in many respects to lagoons, they tend to support many of the same species, especially with regard to birds. Ponds typically provide habitat for mallard, northern shoveler, pied-billed grebe, scaup, bufflehead, and American coot.

Examples of storage/treatment ponds are at the wastewater treatment facilities in Napa, Hayward, and Sunnyvale. Other examples are Ignacio Pond in Novato and the Hahn flood basin in Corte Madera.

Adjacent Habitats

There are several key habitats that are part of the baylands ecosystem, but which occur mostly outside of the baylands. These include riparian forest, willow grove, grassland, oak woodland, and mixed evergreen forest, and they are described below.

Riparian Forest

Riparian habitats border the edges of rivers and streams. They comprise the ecotone between the river or stream and the rest of its watershed. Natural riparian habitats are characterized by steep and variable gradients of moisture and light, lush vegetation, and very high biological diversity. Of all the riparian habitats in the Bay Area, riparian forests are the most complex and support the greatest total number of plant and animal species.

The species composition of the riparian forests differs among the subregions. In South Bay, the list of common native riparian trees includes western sycamore and cottonwood. In North Bay, the list includes ash and California bay laurel, and box elder is locally abundant. Some species of willow (red willow, arroyo willow) and oak (coast live oak, valley oak) are common riparian trees. Non-native trees, like acacia and eucalyptus, occur in the riparian forests of urban and suburban landscapes. Common riparian understory species are elderberry, wild rose, and blackberry.

In the Bay Area, natural riparian habitats tend to be long and narrow. Historically, this was because the natural rivers and streams were entrenched within their canyons and valleys, such that the active flood plains were below the valley floors. The downstream reaches of some of these rivers and streams have since filled with sediment, so that the valleys sometimes flood, but the lateral extent of the riparian habitat is usually constrained by adjacent land use or flood control levees. Therefore, the riparian forests on either side of a river or stream are typically less than a few trees wide. In urban settings, riparian forest often is unnaturally broken into a number of short segments, most of which are less than a block long. There are only a few remaining examples of riparian forests that extend from the upper reaches of local watersheds all the way to the Bay.

A creek floods.

Laurel Collins

Riparian forest is often reported to be among the most valuable habitats available to wildlife (SFEP 1992). The complexity of microhabitats created by the layering of trees, shrubs, and herbaceous and aquatic vegetation promotes very high wildlife species diversity. For example, of all the wildlife habitat types surveyed in the Sacramento-San Joaquin Delta, just upstream of the Project area, researchers have found that riparian vegetation supports the greatest diversity of wildlife species (Madrone Associates et al. 1980). It also enhances the functions of in-stream habitats, and adjacent upland habitats such as grasslands or farm fields, and is most valuable when it exists in an unbroken corridor throughout the length of a watershed.


Josh Collins

Willows shade a managed marsh.

A few representative wildlife species that use riparian forest include Pacific treefrog, California newt, ring-necked snake, ornate shrew, broad-footed mole, deer mouse, opossum, striped skunk, raccoon, coyote, and black-tailed deer. Bird species that occur in this habitat include wood duck, great-horned owl, downy woodpecker, tree swallow, northern oriole, scrub jay, and song sparrow.

Examples of riparian forest exist along Suisun Creek, San Antonio Creek adjacent to Petaluma Marsh, Sonoma Creek, and Coyote Creek.

Willow Grove

A willow grove is a patch of willow trees that is associated with groundwater discharge, perennial ponds, or seasonal ponds. In some instances, particularly in South Bay, willow groves also occur where intermittent streams terminate before reaching the Bay. The dominant species is arroyo willow and associated species include California blackberry and silverweed.

Willow groves support many species of amphibians, birds, and small mammals that also frequent the baylands or occur in riparian forests. Representative species include Pacific treefrog, snowy egret, black-crowned night heron, northern harrier, raccoon, and striped skunk.

In the Bay Area, willow groves were historically associated with springs and areas of groundwater discharge along the margins of the Bay, especially in the South Bay subregion. One of the few remaining examples of willow grove is at Coyote Hills Regional Park.

Grassland

Vegetation dominated by grasses and sedges was widespread along the shores of the Bay prior to European settlement. Native perennial grassland predominated near the Bay on valley floors and on hillslopes with southwest aspects. These grasslands were composed primarily of perennial bunch grasses and rhizomatous grasses, and were dominated by purple needlegrass and creeping wild rye. Example remnants of this community are at Rush Ranch in Suisun and Coyote Hills near Newark.

Today, grasslands are still widespread in the Bay Area, although their botanical makeup differs markedly from historical conditions. The Project's Plants Focus Team organized them into three general groups: non-native annual grassland, moist grassland, and grassland/vernal pool complex.

Robin Grossinger

Ducks rest in moist grassland.

Non-native annual grassland — The introduction of European grazing and agriculture in the 1800s shifted the region's grassland communities from native perennials to Eurasian non-native annuals. Dominant species of these communities are wild oats, soft chess, ripgut brome, and Italian ryegrass. Non-native annual grassland occurs in the interior valleys surrounding the baylands, on the unforested hillslopes with southwest aspect, and on the alluvial plains. Examples of non-native annual grassland exist at Potrero Hills, Hamilton Field, and Coyote Hills.

Annual grasslands adjacent to the baylands are frequented by many species of wildlife. In summer, amphibians such as the tiger salamander aestivate in grassland soil to avoid heat stress. Reptiles associated with grasslands include racer, coachwhip, and gopher snake. In winter, grasslands provide important foraging habitat for sandhill crane, Canada geese, and many species of migratory shorebirds. Some of the other bird species commonly associated with grasslands include turkey vulture, black-shouldered kite, red-tailed hawk, northern harrier, American kestrel, burrowing owl, western meadowlark, and savannah sparrow. Mammals that reside in grasslands include ornate shrew, broad-footed mole, coyote, California ground squirrel, botta pocket gopher, western harvest mouse, and California vole. Many of these species occur in the baylands year-round, and others move into the baylands at certain times of the year, primarily to forage.

Moist grassland — Much of the landscape adjacent to the baylands was formed by water-deposited sediments and is therefore nearly flat. The soils that have evolved here (e.g., Dublin adobe soils, Clearlake adobe clay, Zamora adobe clay, Lindsey clay loam, Yolo silty clay loam, and others) are composed primarily of clay and silt. These tight soils slow the downward movement of surface water. As a result, they tend to be saturated for relatively long periods and frequently support moist grassland and depressional seasonal wetlands. Dominant moist grassland species include Italian ryegrass, Baltic rush, iris-leaved rush, Santa Barbara sedge, and creeping wildrye.

Many of the wildlife species that occur in non-native annual grasslands also utilize moist grasslands. Overall, however, moist grasslands, especially areas that have seasonal wetlands, attract more species than drier grasslands. Representative species include western toad, western skink, meadowlark, horned lark, savannah sparrow, and western harvest mouse.

Historically, moist grasslands existed in large expanses near Suisun Marsh, in the upper reaches of Sonoma Creek and the Petaluma River, and adjacent to much of the baylands in South Bay. Today, examples of large areas of this habitat exist near Fairfield and in the Petaluma River area. Smaller areas of moist grasslands with seasonal wetlands are in Marin at St. Vincent's/Silveira Ranch. In South Bay, development has destroyed most of the historical moist grasslands; notable exceptions exist east of Coyote Hills in the Ardenwood area and near the upper reach of Mowry Slough in Newark.

Flowers bloom in vernal pools.

Grassland/Vernal Pool Complex is an area of annual grassland where there are vernal pools. Vernal pools are surface depressions usually less than 6 inches deep that are underlain by an impervious substrate of natural materials. They are ponded by direct rainfall or nearby runoff during the wet season, and desiccated by evapotranspiration early in the dry season. Typical native vernal pool species include goldfields, popcornflower, *Navarretia*, and *Downingia*.

Some wildlife species associated with vernal pools include fairy shrimp, tadpole shrimp, California tiger salamander, western spadefoot toad, common garter snake, black-necked stilt, and American avocet. Some waterfowl, especially mallard and cinnamon teal, nest in this habitat where there are pools. Small mammals, including California vole and black-tailed hare, also occur here.

Historically, large areas of grasslands with vernal pools occurred in the Project area in only three areas: adjacent to Suisun Marsh, along Sonoma Creek, and in the Warm Springs area in South Bay. Although they have been degraded by farming and filling, vernal pool complexes still exist in these areas.

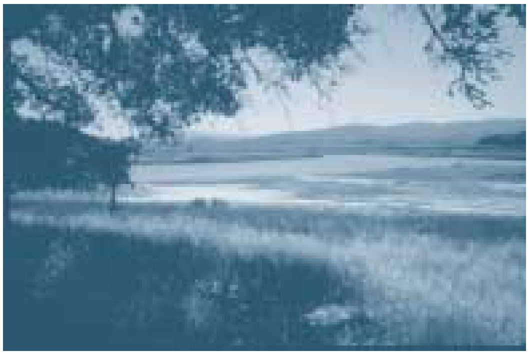
Coastal prairie is a type of grassland that occurs in limited distribution near the Bay in areas that are frequently exposed to moist marine air and which have clay soil. Dominant species include Douglas iris, reedgrass, oatgrass, and hairgrass. Examples occur at Brooks Island, at Ring Mountain Preserve, and at the Golden Gate National Recreation Area.

Oak Woodland

Vegetation with an overstory dominated by oak trees is common throughout California's valleys, foothills, and lower mountain ranges. In the Bay Area, there are three recognized types of oak woodland, based on species dominance: Coast live oak woodland, Valley oak woodland, and Foothill oak woodland.

Oak woodlands are an integral part of the baylands ecosystem as they provide important foraging, roosting, and breeding habitat for many species of amphibians, reptiles, birds, and small mammals that frequent the baylands. Some representative species associated with oak woodlands include ensatina, southern alligator lizard, gopher snake, red-tailed hawk, California quail, acorn woodpecker, western scrub jay, California ground squirrel, Audubon's cottontail, and black-tailed deer.

Coast live oak woodland occurs on hillslopes where there are thin soils and moderate to large amounts of rainfall. The dominant species is coast live oak. Associated species include madrone, California blackberry, creeping snowberry, cream bush, and poison oak. Examples exist on the north-facing slopes along the Carquinez Strait, on the ridge between Black Point and Rush Creek near Novato, at China Camp, and on Angel Island.



Elise Brewster

Tidal marsh reaches oaks.

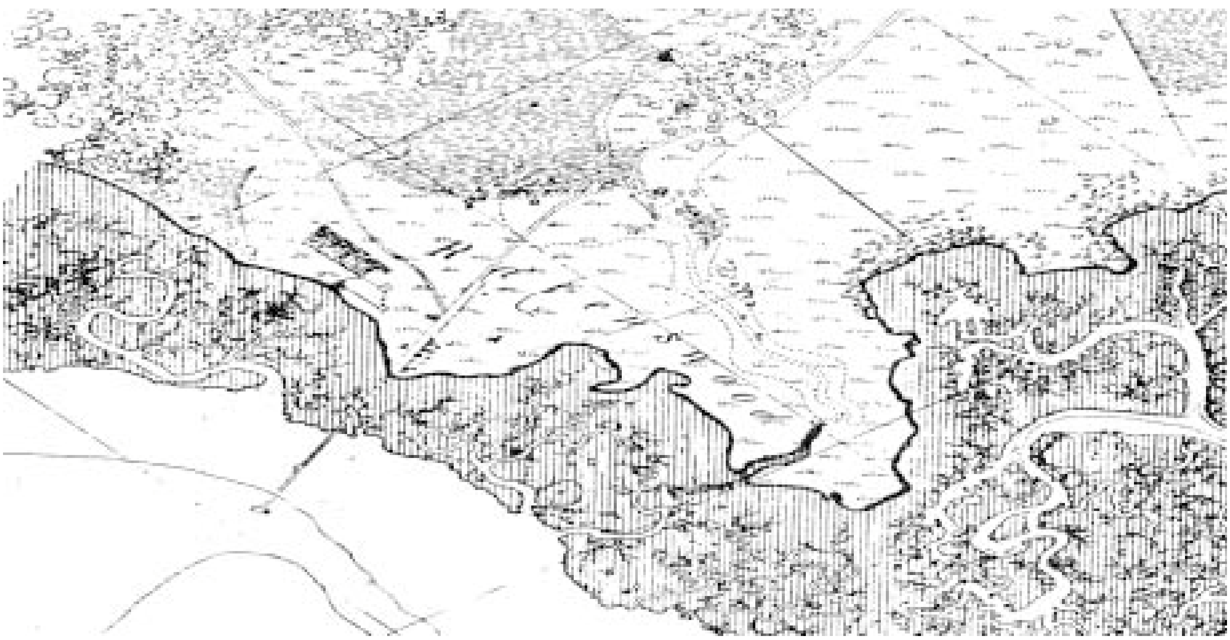
Valley oak woodland occurs in a few places on the alluvial plains, valleys, and piedmonts adjacent to the baylands. Valley oak is the dominant species. Associated species include creeping wild rye and Santa Barbara sedge. This community is not widespread in the Bay Area. Examples exist along Green Valley Creek near Cordelia, along the lower Napa River, and along Sonoma Creek near Schellville.

Foothill oak woodland occurs on hillslopes with deep soils and small to moderate amounts of rainfall. The dominant species is blue oak. Associated species include digger pine, manzanita, deerbrush, coffeeberry, and pink-flowered currant. This community is not widespread on the lands near the Bay. An example exists at Black Diamond Mine Regional Park near Antioch.

Mixed Evergreen Forest

Mixed evergreen forest is mostly restricted to north-facing hillslopes in the North Bay and Central Bay areas. The dominant species include California bay laurel, bigleaf maple, and madrone. Associated species are coyote brush, California huckleberry, and poison oak.

This vegetation complex provides habitat for a variety of wildlife that also occurs in the baylands. Some representative species are common garter snake, western fence lizard, Cooper's hawk, Nuttall's woodpecker, wrentit, dark-eyed junco, hermit thrush, purple finch, dusky-footed woodrat, brush rabbit, and gray fox. Examples of mixed evergreen forest occur in the headward reaches of north-facing draws of San Pedro Ridge near China Camp and on the northern side of the ridge between Black Point and Rush Creek.



USCS 1857

Habitat boundaries are habitats too.

Habitat Goals

According to the process adopted by the RMG, Project participants were to develop habitat goals only after assembling and analyzing many kinds of data about the baylands ecosystem. In this way, participants worked together for nearly two years before they began making habitat recommendations. It was hoped that this methodical approach would produce Goals that were appropriate and technically sound. The recommendations in this chapter are based on the best available information and the best professional judgment of the Project participants. They should be reviewed periodically in the coming years and modified as needed to reflect new understanding.

This chapter presents the Goals, first as a general regional perspective — or "big picture" — of how the baylands and adjacent habitats should appear in the coming decades. It then provides more detailed recommendations of the habitat changes for each of the four subregions.

Please remember that the regional perspective is a view of the distant future. It describes the general arrangement and kinds of wetlands and associated habitats that Project participants believe should exist. But it is not a precise prescription or blueprint that must be followed exactly. There are several, perhaps many, ways to provide a sufficient mix of tidal and diked habitats in each of the subregions. Likewise, the more detailed recommendations are flexible and not necessarily comprehensive. Anyone interested in restoring or enhancing the baylands ecosystem should use the Goals — and also the list of potential habitat improvement sites in Appendix E — as starting places, not end points, in their planning deliberations.

The recommendations in this chapter should not overshadow one fundamental tenet: there should be no additional loss of wetlands within the baylands ecosystem. Furthermore, as filled or developed areas within the baylands become available, their potential for restoration to wildlife habitat should be fully considered.

The Goals — A Regional Perspective

The main objective of the Goals Project was to provide a picture of the types, amounts, and distribution of wetlands and related habitats needed to restore and sustain a healthy baylands ecosystem. This section describes the habitats that should exist in and around the Bay within the next several decades. It attempts to address the competing habitat needs of the Estuary's many species, especially those species that are dependent on tidal marsh, salt ponds, or diked seasonal wetlands.

At the most general level, the baylands and adjacent areas should be a diverse mosaic of habitats. This mosaic should include:

- Many large patches of tidal marsh connected by corridors to enable the movement of small mammals and marsh-dependent birds.
- Several large complexes of salt ponds managed for shorebirds and waterfowl.
- Extensive areas of managed seasonal ponds.
- Large expanses of managed marsh.
- Continuous corridors of riparian vegetation along the Bay's tributary streams.
- Restored beaches, natural salt ponds, and other unique habitats.
- Intact patches of adjacent habitats including grasslands, seasonal wetlands, and forests.

This regional perspective embodies several ecological design considerations that are described in detail in Chapter 6. Key among these are that tidal marsh restoration should strive for large (1,000+ acres) connected patches of habitat that are centered, where possible, around existing populations of species of special concern (e.g., salt marsh harvest mouse and California clapper rail). Tidal marsh should be restored along the salinity gradients of the Estuary and its tributaries to enable species to follow shifts in habitat location due to variations in freshwater flows. Tidal marsh restoration should be emphasized along the Bay edge and where streams enter the baylands to maximize benefits for fish and other aquatic animals. Wherever possible, restored tidal marsh should include natural features such as pans and large tidal channels, as these significantly increase the habitat's ability to support large numbers of many species of fish, shorebirds, and waterfowl.

Where possible, natural transitions from tidal flat through tidal marsh to upland should be reestablished. There also should be natural transitions between diked wetlands and adjacent uplands. Restoring these natural transitions is critical for reestablishing bayland-edge plant communities. In all cases, buffers should be provided on undeveloped adjacent lands to protect habitats from disturbance.

Restoring large areas of tidal marsh will reduce the acreage of some other existing habitats, especially salt ponds, agricultural bayland, and managed marsh. To offset the loss of salt pond area, the remaining salt ponds should be managed to maximize wildlife habitat functions, particularly for shorebirds, waterfowl, and other water birds. There should be salt pond complexes in North Bay and in South Bay adjacent to important shorebird foraging areas. Each complex should be managed to maintain a range of salinities and water depths that favor the desired bird species. To offset the loss of agricultural bayland habitat, agricultural areas that are not restored to tidal marsh should be managed as seasonal pond habitat to improve habitat functions for shorebirds, waterfowl, and other water birds. To offset the conversion of managed marsh habitat to tidal marsh, the remaining managed marshes should be managed more intensively.

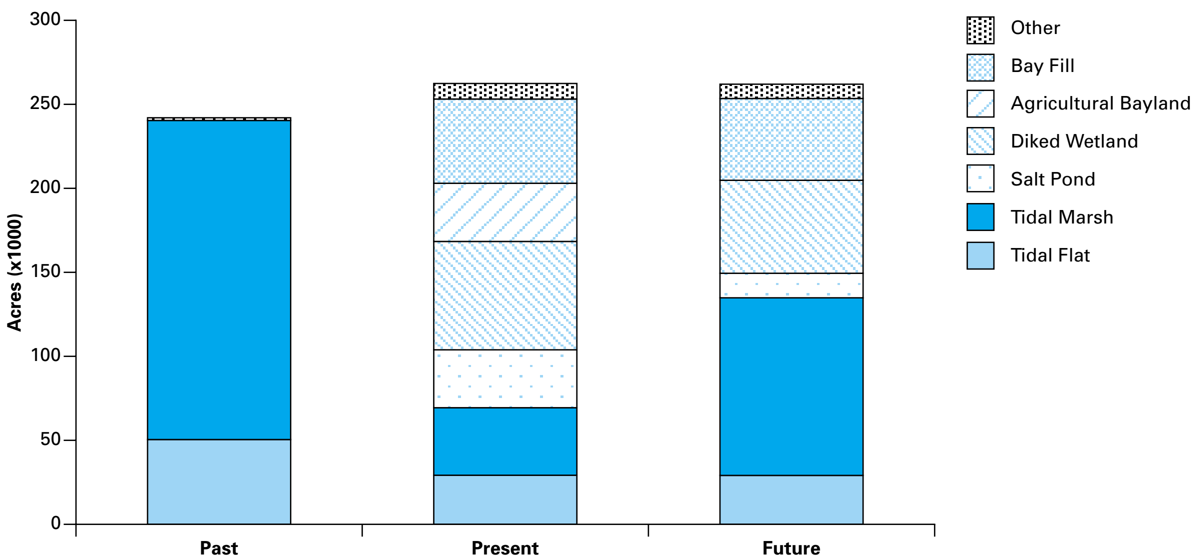
Although the Goals recommend reducing the acreage of some major habitat types in most of the subregions, they call for increasing the region's overall ability to support shorebirds, waterfowl, mammals, and other wildlife. In essence, the Goals shift some habitat functions from one subregion to another.

Figure 5.1 shows the approximate regional acreage goals for the key bayland habitats, along with past and present acreage. As the figure indicates, the Goals call for increasing the total area of tidal marsh from the existing 40,000 acres to about 95,000 to 105,000 acres. This would entail reducing the area of all major diked habitats.

In each of the subregions except Central Bay, where the options for restoration are relatively limited, there is ample flexibility regarding habitat arrangement, Appendix D shows one possible example. The Goals include this kind of flexibility because the Project participants recognized that it will be necessary to accommodate implementation constraints such as land availability or construction or maintenance costs. Additional examples could be shown that would favor the support of one species or group of species over another. For example, more tidal salt marsh would provide additional support for species of small mammals at the expense of salt ponds managed for shorebirds and waterfowl. The Goals strive to strike a balance between the needs of the various species.

Achieving the Goals regionwide would have major environmental benefits. A primary anticipated benefit would be the recovery of the baylands many species of special concern. For example, if the tidal marsh restoration goals were achieved, populations of the salt marsh harvest mouse and the California clapper

FIGURE 5.1 Past, Present, and Recommended Future Bayland Habitat Acreage for the Region



rail would be expected to rebound, removing the need to protect them as endangered species. If the diked marsh enhancement goals were realized, the regional and subregional support of migratory birds would be enhanced because of improved habitat quality and availability. In addition to the many benefits for wildlife, restoring large amounts of tidal marsh also would improve the Bay's natural filtering system and enhance water quality.

Subregional Habitat Recommendations

This section presents the Goals in greater detail. It includes recommendations for each of the four subregions and for portions, or segments, of each subregion. There are 20 segments and each is identified alphabetically (**Figure 5.2**). The subregional recommendations are more specific than those presented in the preceding section, but they are still fairly general. The segment recommendations, however, are quite specific.

Each segment presentation includes maps of past and present conditions, a description of major or unique features, unique restoration opportunities and benefits, and a list of possible constraints. Unique restoration opportunities describe the kinds of habitat changes that may be possible, given a segment's past and present conditions; as used in this chapter, the term "opportunity" is meant to imply ecological potential. Although there are many kinds of constraints to habitat restoration, the "possible constraints" listed for each segment are primarily infrastructure constraints.

The habitat acreage goals for each subregion are presented as bar graphs. They were derived from the recommendations described below and from the integration map in Appendix D. To put these acreage goals into perspective, the bar graphs are shown beside similar graphs of past and present habitat acreage. Please note that the graphs of habitat goals depict general acreage targets and do not represent the same level of certainty as do the graphs of the past and present habitats.

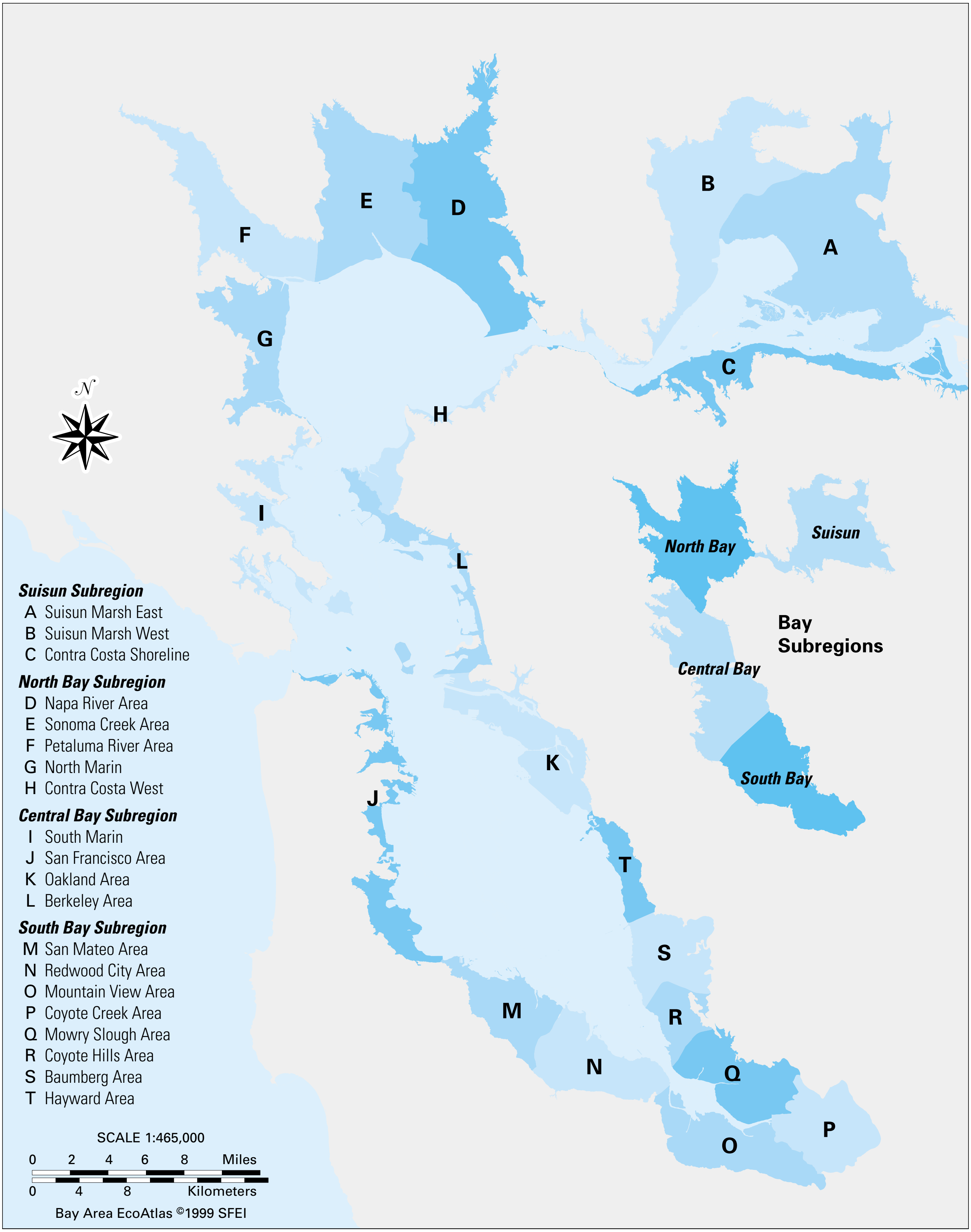
Appendix E lists 124 sites that have some potential for habitat improvement. This list and the accompanying maps do not represent all potential sites, but they indicate places where projects should at least be considered.

Suisun Subregion

The overall goal for this subregion is to restore tidal marsh on the northern and southern sides of Suisun Bay, Grizzly Bay, and Honker Bay, and to restore and enhance managed marsh, riparian forest, grassland, and other habitats.

In Suisun Marsh, there should be a continuous band of restored tidal marsh from the confluence of Montezuma Slough and the Sacramento/San Joaquin rivers to the Marsh's western edge. This band of tidal marsh should extend in an arc around the northern edge of the Marsh and should blend naturally with the adjacent grasslands to provide maximum diversity of the upland ecotone, especially for plant communities. A broad band of tidal marsh also should be restored along the southern edge of Suisun Marsh and around Honker Bay, in large part to improve fish habitat.

FIGURE 5.2 **Project Area with Subregions and Segments**



On the majority of lands within Suisun Marsh, the long-standing practice of managing diked wetlands primarily for waterfowl should continue. These brackish marshes should be enhanced, through protective management practices, to increase their waterfowl carrying capacity. On the periphery of the Marsh, moist grasslands with vernal pools should be enhanced, as should riparian vegetation along the tributary streams.

On the Contra Costa shoreline, full tidal action should be restored to many of the marshes that currently are diked or that receive muted tidal flow. Restoration should incorporate broad transition zones to foster a higher diversity of plant communities and associated animals, and buffers to protect these populations from adjacent disturbance. Also, riparian vegetation should be restored along as many stream corridors as possible.

In the northern part of this subregion, achieving the Goals will depend largely on the willingness of private duck club owners to convert managed marsh to tidal marsh. On the Contra Costa shoreline, achieving them will depend on the willingness of corporate, military, and private landowners to restore many marshes to full tidal action.

Figure 5.3 shows the approximate acreage goals for the key bayland habitats in this subregion, along with past and present acreage. As the graphs indicate, the Goals recommend significant changes in habitat acreage. In general, the Goals for the subregion call for increasing the area of tidal marsh from about 13,000 acres to about 30,000 to 35,000 acres, while maintaining approximately 32,000 to 37,000 acres of diked wetlands. With this change, about 65% of the existing managed marsh acreage would be retained.

The Suisun subregion consists of Segments A, B, and C. Recommendations for achieving the Goals in each of these segments are described beginning page 100.

FIGURE 5.3 Past, Present, and Recommended Future Bayland Habitat Acreage for Suisun Subregion

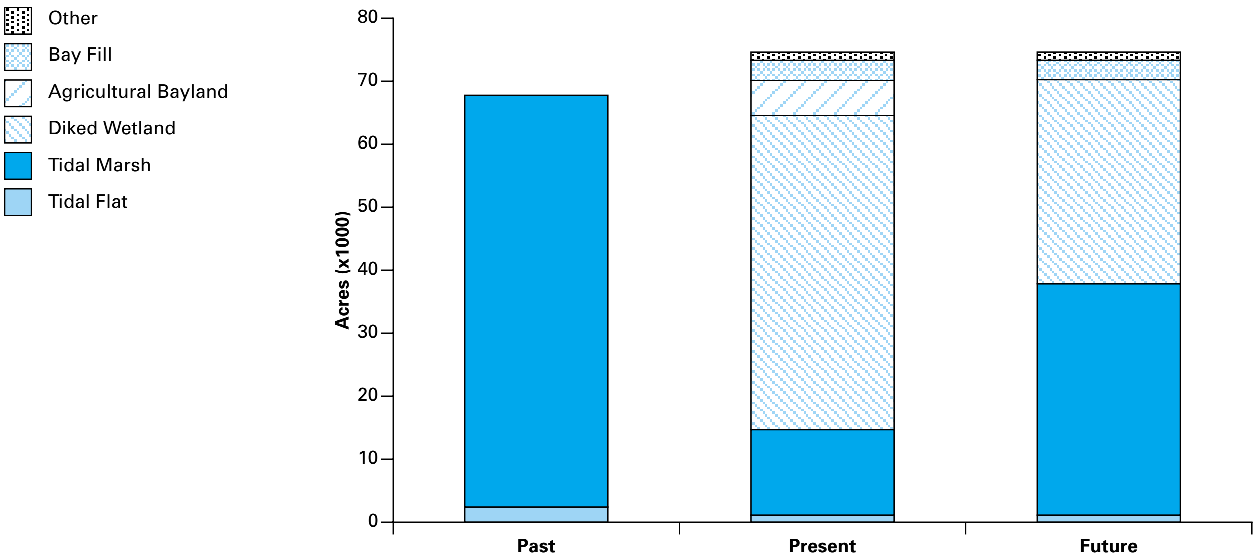
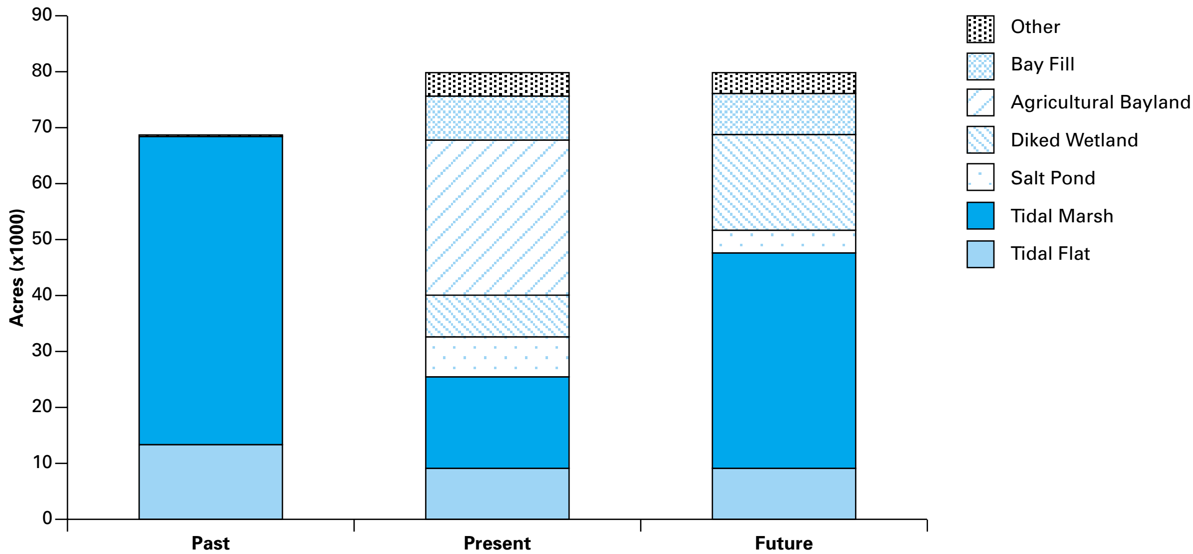


FIGURE 5.4 **Past, Present, and Recommended Future Bayland Habitat Acreage for North Bay Subregion**



North Bay Subregion

The overall goal for North Bay is to restore large areas of tidal marsh and to enhance seasonal wetlands. Some of the inactive salt ponds should be managed to maximize their habitat functions for shorebirds and waterfowl, and others should be restored to tidal marsh. Tributary streams and riparian vegetation should be protected and enhanced, and shallow subtidal habitats (including eelgrass beds in the southern extent of this subregion) should be preserved or restored.

Tidal marsh restoration should occur in a band along the bayshore, extending well into the watersheds of the subregion's three major tributaries — Napa River, Sonoma Creek, and Petaluma River. Seasonal wetlands should be improved in the areas that currently are managed as agricultural baylands. All remaining seasonal wetlands in the uplands adjacent to the baylands should be protected and enhanced.

In much of this subregion, achieving the Goals will depend on the willingness of farmers to convert agricultural baylands to tidal marsh and to allow the remaining areas to be managed as seasonal pond habitat.

Figure 5.4 shows the approximate acreage goals for the key bayland habitats in this subregion, along with past and present acreage. In total, the Goals for the North Bay subregion call for increasing the area of tidal marsh from the existing 16,000 acres to approximately 38,000 acres, and creating about 17,000 acres of diked wetlands managed to optimize their seasonal wetland functions.

The North Bay subregion includes Segments D through H. Actions for achieving the Goals in each of these segments are described beginning on page 106.

Central Bay Subregion

The overall goal for Central Bay is to protect and restore tidal marsh, seasonal wetlands, beaches, dunes, and islands. Natural salt ponds should be restored on the East Bay shoreline. Shallow subtidal habitats (including eelgrass beds) should be protected and enhanced. Tributary streams and riparian habitats should be protected and enhanced.

Tidal marsh habitats should be restored wherever possible, but particularly at the mouths of streams (where they enter the baylands) and at the upper reach of dead-end sloughs. Tidal marsh restoration in urban areas is encouraged.

Although topography and urban and industrial development limit the potential for large-scale habitat restoration in this subregion, there are many opportunities to restore relatively small tidal marshes and other habitats, and these should be pursued. Even small disconnected patches of tidal marsh would provide habitat islands for migrating native wildlife species and improve overall habitat conditions. Even the smallest restoration efforts should try to incorporate transitions from intertidal habitats to adjacent uplands, as well as upland buffers. Shorebird roosting sites should be protected and enhanced.

Of particular importance in this subregion, especially in the southern half, is the need to control smooth cordgrass. This issue is described in greater detail in Chapter 6.

In this subregion, achieving the Goals will depend largely on the willingness of many private and public landowners to undertake habitat restoration and enhancement in the most urbanized portion of the baylands.

Figure 5.5 shows the approximate acreage goals for the key bayland habitats in this subregion, along with past and present acreage. Given the limitations of this subregion, the Goals recommend only a few hundred acres of tidal marsh restoration.

FIGURE 5.5 Past, Present, and Recommended Future Bayland Habitat Acreage for Central Bay Subregion

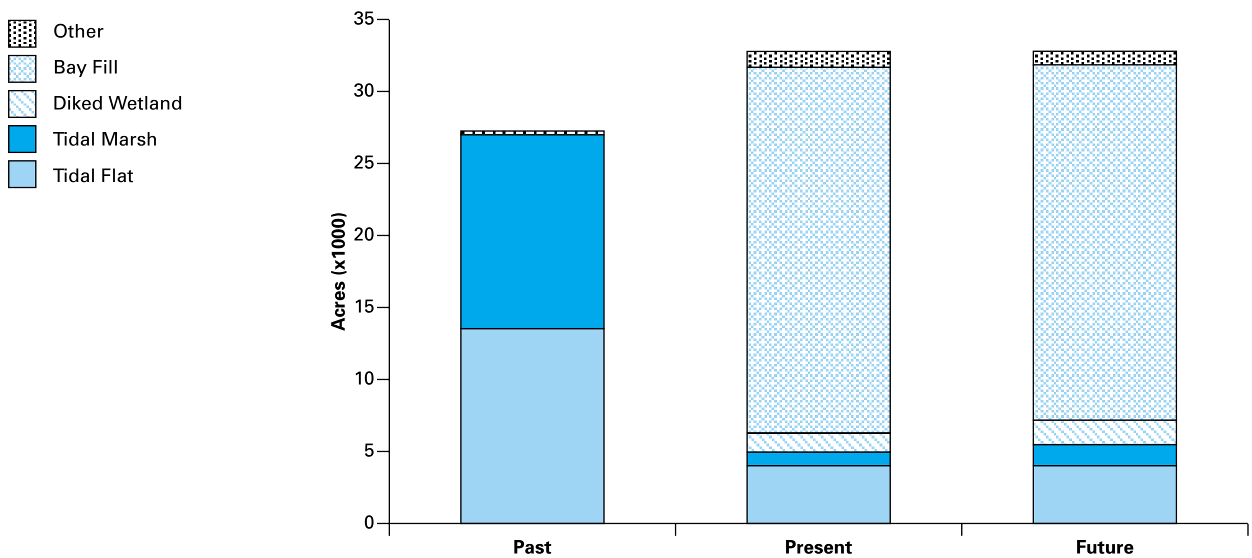
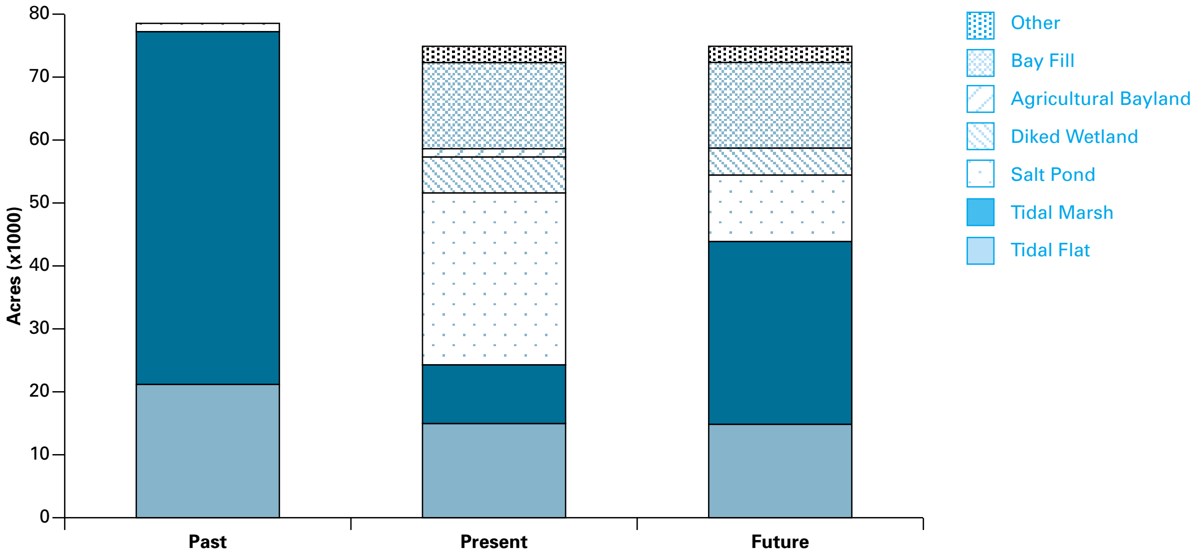


FIGURE 5.6 Past, Present, and Recommended Future Bayland Habitat Acreage for South Bay Subregion



The Central Bay subregion includes Segments I through L. Actions for achieving the Goals in each of these segments are described beginning on page 116.

South Bay Subregion

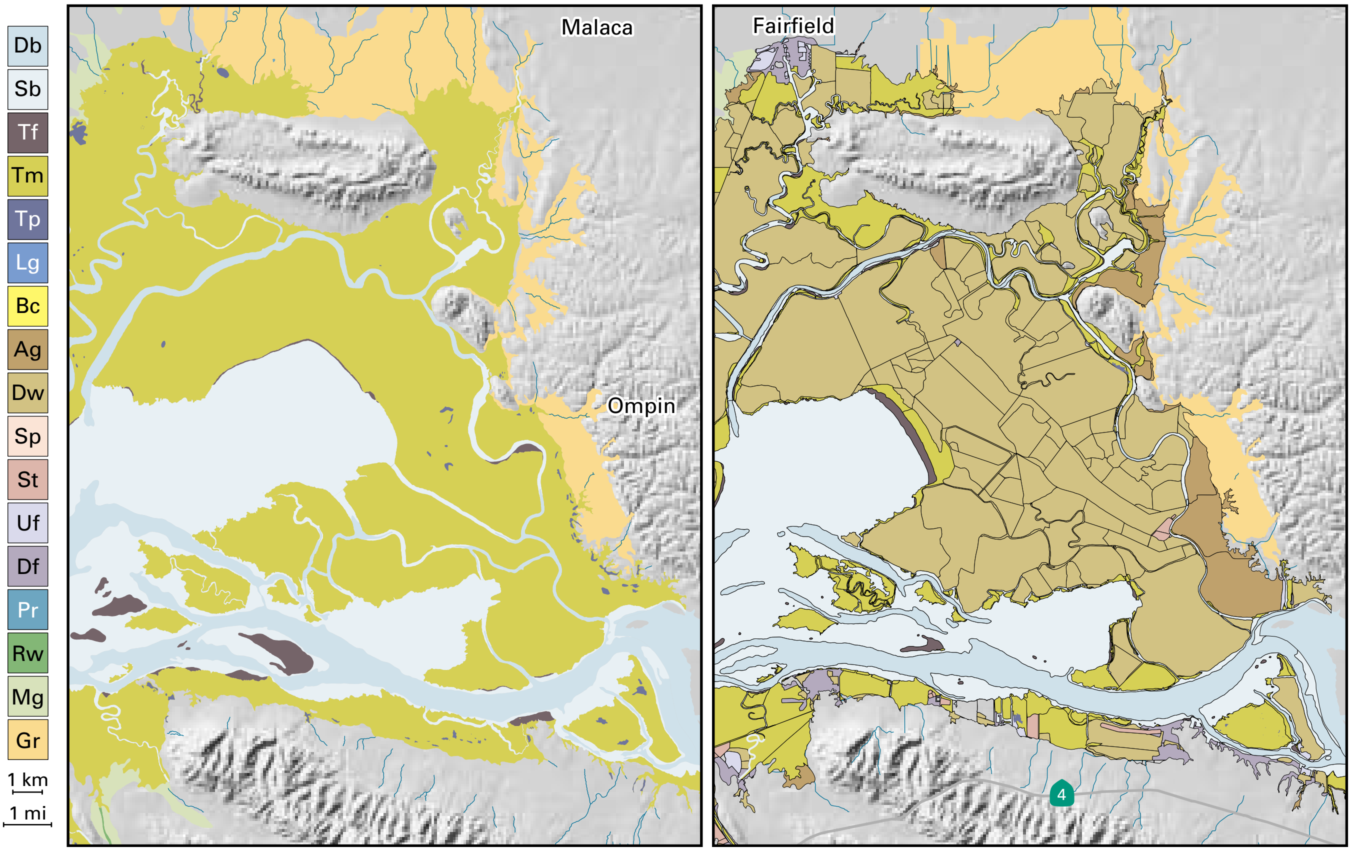
The overall goal in the South Bay subregion is to restore large areas of tidal marsh connected by wide corridors of similar habitat along the perimeter of the Bay. Several large complexes of salt ponds, managed to optimize shorebird and waterfowl habitat functions, should be interspersed throughout the subregion, and naturalistic, unmanaged salt ponds (facsimiles of historical, hypersaline backshore pans) should be restored on the San Leandro shoreline. There should be natural transitions from mudflat through tidal marsh to adjacent uplands, wherever possible. Adjacent moist grasslands, particularly those with vernal pools, should be protected and improved for wildlife. Riparian vegetation and willow groves should be protected and restored wherever possible.

Of particular importance in this subregion, especially in, Segments R, S, and T, is the need to control smooth cordgrass.

In this subregion, achieving the Goals will depend largely on the willingness of the Cargill Salt Division to undertake major changes in its operations or to cease commercial salt production. It also will depend on the efforts of many other private and public landowners.

Figure 5.6 shows the approximate acreage goals for the key bayland habitats in this subregion, along with past and present acreage. As the graphs indicate, the Goals call for increasing the area of tidal marsh from about 9,000 acres to between 25,000 and 30,000 acres. They also recommend managing for wildlife somewhere between 10,000 acres and 15,000 acres of salt pond habitat.

The South Bay subregion consists of Segments M through T. Recommendations for achieving the Goals in each of these segments are described beginning on page 124.



Past

Present

Segment area: 38,538 acres

Segment A — Suisun Marsh East

Subregion: Suisun

Location: Eastern portion of Suisun Marsh.

Major or Unique Features: Historically, this area was predominantly tidal fresh and brackish marsh, arrayed as low-lying islands in Suisun Bay and as wide plains between the Bay and the adjacent uplands. Inside this broad expanse of marshes were sloughs, channels, ponds, and small bays. Except for parts of Suisun Bay, the segment had relatively few areas of tidal flat. Adjoining the baylands, especially along Montezuma Slough and near Potrero Hills, were extensive areas of moist grasslands with vernal pools. The relatively steep topography of Potrero Hills provided a unique and narrow marsh/upland transition.

Today, this segment is one of the least developed areas of the baylands ecosystem. There are extensive tidal flats in Grizzly Bay. Most of the marshes are diked and are managed as duck clubs, but some tidal marsh occurs in Suisun Bay, along the edge of Grizzly Bay, and in many of the sloughs. There are alkaline/saline vernal pool complexes in the surrounding grasslands that grade into the upper tidal marsh zone. Water salinity throughout the diked areas and in many of

The maps for this and other segments use an abbreviated legend. To see the full legend, please refer to the inside front cover.

the sloughs is managed in ways that reduce natural variability of marsh salinity. For example, the salinity control gates in Montezuma Slough are operated to maintain channel salinity levels similar to levels that would have occurred before the start of water diversions from the Delta. There is considerable localized freshwater influence from Denverton Creek in the northeast corner.

Unique Restoration Opportunities: This segment's large size, current protected status, and relative isolation make it an ideal location for habitat protection, enhancement, and restoration. Because of its location in the upper reach of the estuary, this segment offers a good opportunity to restore large areas of tidal marsh along the full salinity gradient.

Restoring tidal marsh at the periphery of Suisun Marsh would provide opportunities to reestablish the range of the endangered soft bird's-beak. There also are opportunities to restore vernal pools with tadpole shrimp in the adjacent uplands. Many diked wetlands in this segment are well suited for continued management for waterfowl and other species.

Recommendations:

- Restore tidal marsh at sites adjacent to Honker Bay, along the eastern side of Montezuma Slough, in the Nurse Slough area, and near Denverton Creek.
- Provide a tidal marsh corridor along the base of Potrero Hills between Nurse Slough and the marshes to the west.
- Provide natural transitions to adjacent uplands (with protective buffers wherever possible) for all existing and restored tidal marshes.
- Protect and enhance existing vernal pools and other seasonal wetlands adjacent to Montezuma Slough, in the Nurse Slough area, and north of Potrero Hills.
- Enhance managed marshes in the Grizzly Island area to improve and diversify managed wetlands.

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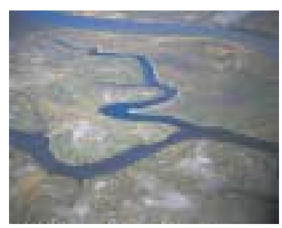

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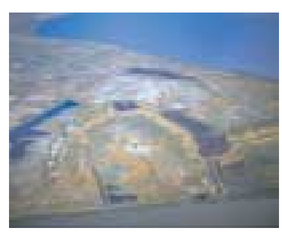

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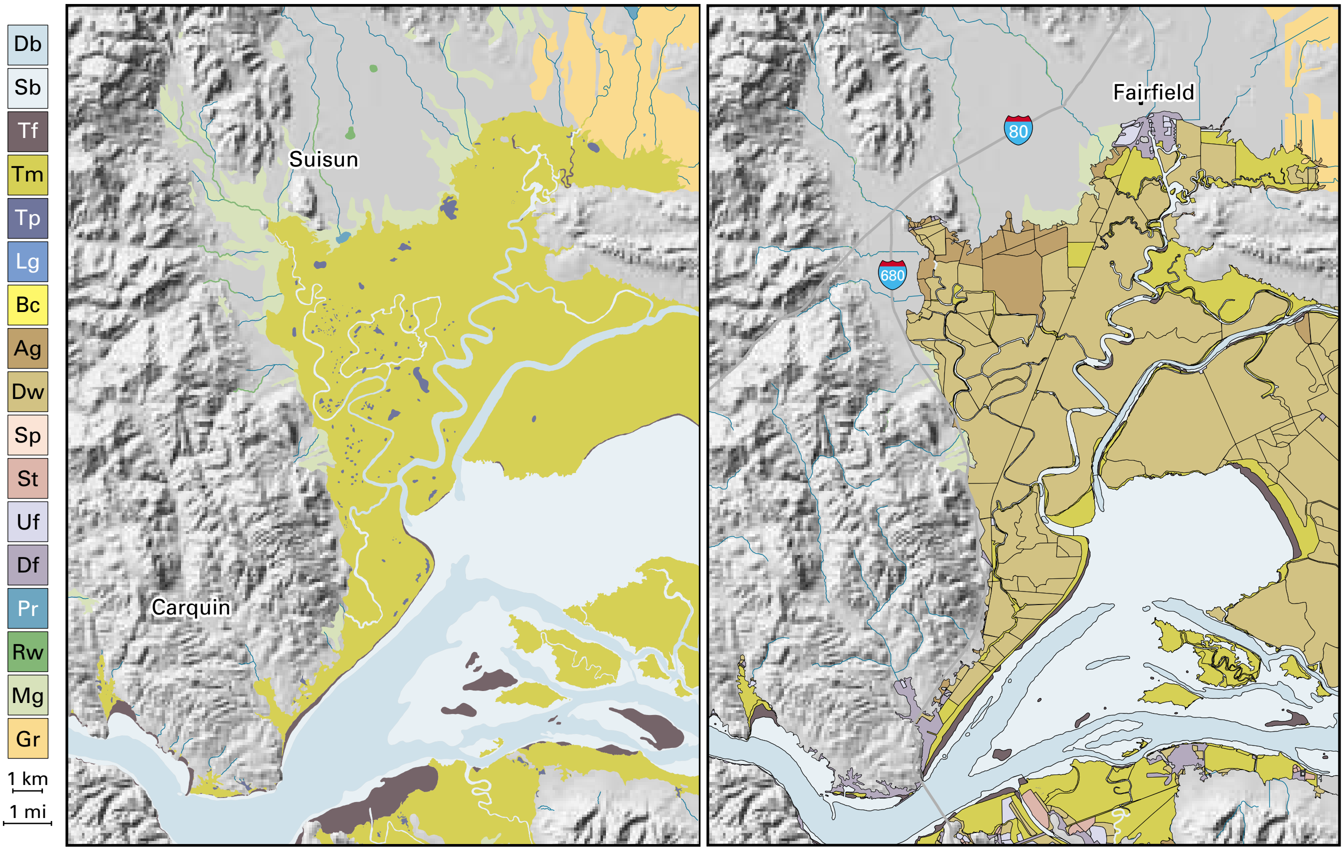
Unique Restoration Benefits: Restoring tidal marshes in this segment would benefit black rail, Suisun song sparrow, and other tidal marsh species. It also would increase detrital input to this very productive part of the estuary and increase habitat for aquatic organisms including Delta smelt, striped bass, out-migrating salmon, and other fishes. Restoring large amounts of tidal marsh along the Montezuma and Suisun sloughs would increase tidal flow and thus improve water circulation and reduce the need for dredging. Expanding tidal marsh along the tidal/upland ecotone would provide opportunities for restoring plant communities. Enhancing vernal pools and other seasonal wetlands on the periphery of the Marsh would help restore their declining plant and animal communities. Improving managed marsh would benefit waterfowl, other water birds, songbirds, and a variety of mammals.

Possible Constraints: Flood control considerations, levee maintenance, sedimentation of tidal creeks, water salinity management, and water quality impacts.



Past

Present

Segment area: 25,353 acres

Segment B — Suisun Marsh West

Subregion: Suisun

Location: Western portion of Suisun Marsh.

Major or Unique Features: Historically, this part of Suisun Marsh was relatively fresh to brackish marsh, with marsh conditions more saline in the western portion. The marshland extended from Potrero Hills westward to the upper end of Carquinez Strait. Myriad channels and sloughs meandered through the marsh, and along the western side there were many large tidal marsh pans. Adjacent to the tidal marshes north of Potrero Hills were large areas of moist grassland with vernal pools; scattered patches of moist grassland occurred along the base of the hills to the west. Riparian forest lined several of the larger creeks that flowed into the marshes from the north. Like the eastern part of Suisun Marsh, this segment had few areas of tidal flats.

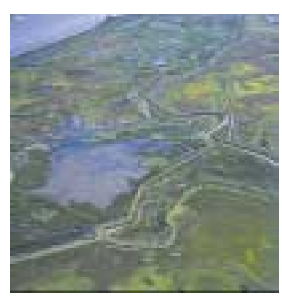
Today, this segment is nearly all diked wetland that is managed as seasonal waterfowl habitat. An area in the northwestern portion is agricultural bayland and is managed primarily for pheasant hunting. Tidal marshes are limited and are generally confined to areas along Hill, Peytonia, Montezuma, Suisun, and Cutoff sloughs and to First and Second Mallard Branch. None of the historical marsh ponds remain, except in low areas in diked baylands, and the tidal channels have narrowed markedly or disappeared. Water regimes are highly managed, primarily to regulate salinity. Only remnants of the moist grasslands and areas of vernal pools remain, and most have been degraded by years of grazing. The area is a stronghold for endangered soft bird's-beak and the site of the only known population of Suisun thistle.

Unique Restoration Opportunities: This segment provides opportunities to restore large patches of tidal marsh adjacent to areas of moist grasslands and vernal pools and to provide wide natural transitions between these habitat types. There is an opportunity to expand an existing large tract of tidal marsh at Rush Ranch. There also are opportunities to restore and enhance riparian vegetation along streams, several of which support steelhead, that flow into the Marsh from the north. There are opportunities to improve management of diked wetlands for waterfowl and other water birds. As with the Marsh's eastern segment (Segment A), this area's large size, current protected status, relative isolation, and location on the estuarine salinity gradient all increase its overall restoration value.

Recommendations:

- Restore large areas of tidal marsh in the Hill Slough and upper Suisun Slough areas, and on Morrow Island south of the confluence of Goodyear Slough and Suisun Slough.
- Connect these large areas of restored tidal marsh with a tidal marsh corridor. The location of this corridor is highly flexible, but establishing it along Cordelia Slough probably would facilitate water management on duck clubs in the area.
- Provide natural transitions to adjacent uplands, with protective buffers wherever possible.
- Enhance managed marsh areas that are not restored to tidal marsh to improve waterfowl habitat.
- Protect and restore tidal marsh at Southampton Bay.

Unique Restoration Benefits: Restoring tidal marshes in this segment would benefit many estuarine and anadromous fish species, including Chinook salmon, steelhead, and Delta smelt. It also would benefit the California clapper rail. Restoring natural marsh/upland transitions would improve conditions for endangered plant species such as the soft bird's-beak and Suisun thistle, especially along the segment's northern edge. Mammals that depend on transition areas for high water escape habitat also would benefit. The lower elevation tidal marshes would provide habitat and food web support for aquatic invertebrates, and habitat for diving ducks such as canvasback and redheads. The remaining managed marshes would continue to provide waterfowl and shorebird habitat, and habitat for small mammals. Restoring tidal action to the upper reaches of Cordelia Slough would enhance habitats, improve channel flood control capacity, and improve water conveyance to duck clubs.



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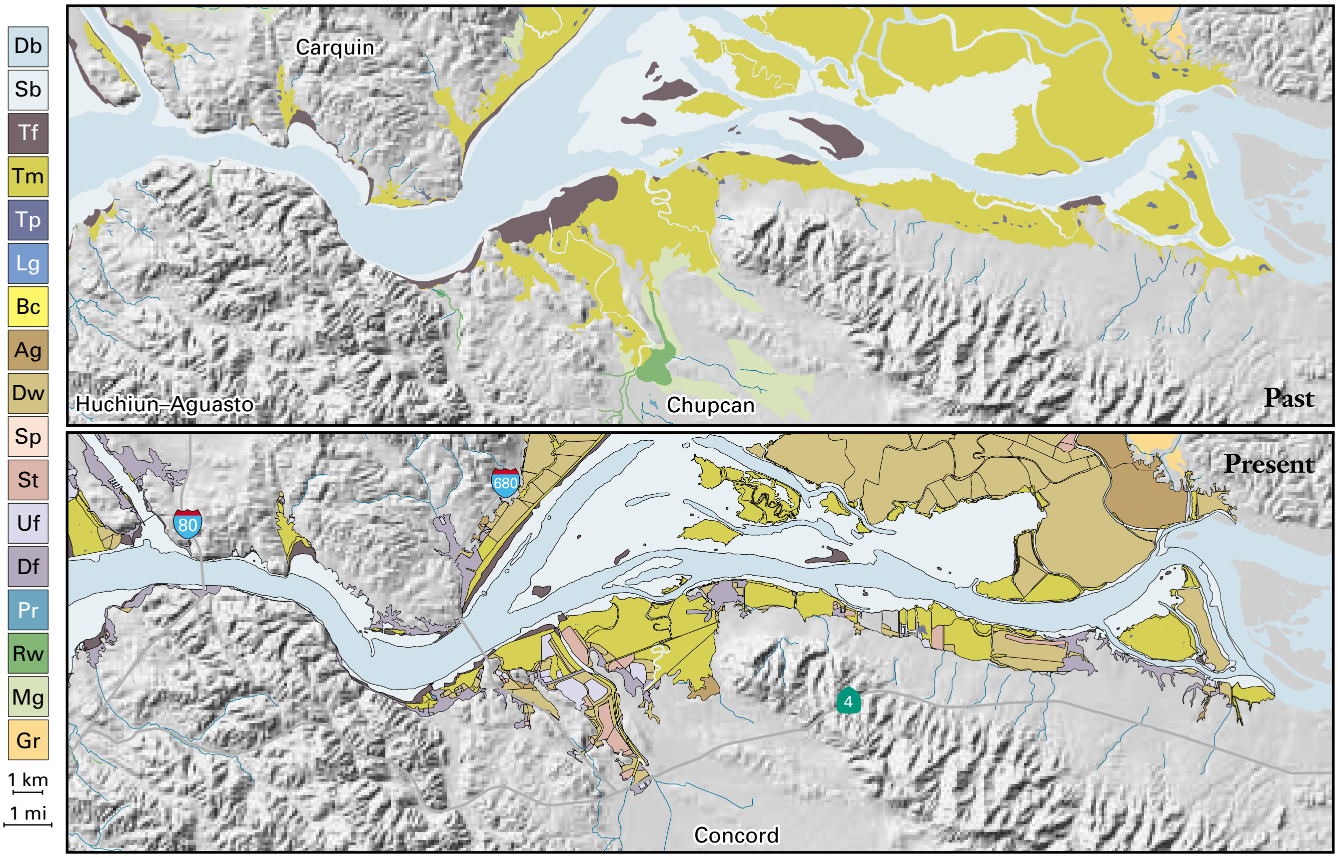
Possible Constraints: Southern Pacific railroad tracks, industrial areas in southwest portion, flood control considerations, levee maintenance, sedimentation of tidal creeks, water salinity management, and water quality impacts.



Segment area: 11,051 acres

Segment C — Contra Costa North

Subregion: Suisun

Location: Southern edge of Suisun Bay between Carquinez Bridge and Broad Slough/San Joaquin River.

Major or Unique Features: Historically, there was tidal brackish marsh along nearly the entire length of this segment except for a portion downstream along the Carquinez Strait. These tidal marshes extended into the lower reaches of several local steams, including Hastings Slough, Alhambra Creek, and Pacheco Creek. Tidal flats occurred near the mouth of Pacheco Creek and at a few locations on the shoreline upstream toward the Delta. Within the Walnut Creek watershed were several areas of moist grassland and large stands of willow groves and riparian forest.

Today, most of the tidal marsh in this segment has been diked, and there are several cities, numerous industrial plants, and a military facility on or near the shoreline. However, many tidal marshes remain, especially near Martinez and near Pittsburg. Although most of these are degraded, some have significant populations of soft bird's-beak and salt marsh harvest mouse. Only a few remnants of riparian forest remain.

Unique Restoration Opportunities: Many of the shoreline's historical tidal marsh areas, although degraded by years of grazing, agriculture, and other activities, are restorable to full tidal action. Likewise, several of the seasonal diked wetlands are suitable for tidal restoration or enhancement. Lands adjacent to many of the streams are still undeveloped and have high potential for riparian restoration and enhancement.

Recommendations:

- Restore large areas of tidal marsh in diked and muted tidal marsh areas.
- Where tidal marsh cannot be restored, improve water management to enhance diked wetlands.
- Ensure natural transitions between marshes and adjacent uplands, and protect and expand adjacent buffers where possible.
- Restore riparian vegetation along small and large streams.

Unique Restoration Benefits: Implementing these recommendations would improve habitat conditions for a variety of plants and animals. Restoring tidal marsh along the shoreline of Suisun Bay would improve habitats for estuarine and anadromous fishes, and would increase detrital input to the null zone. Restored marshes also would provide improved habitat for California clapper rail, black rail, and salt marsh harvest mouse. Restoring the marsh/upland ecotone would benefit populations of soft bird's-beak, Mason's lilaeopsis, and Delta tule pea. Reestablishing riparian vegetation along streams would provide corridors for amphibians, small mammals, and birds, thereby improving the ecological connections between the baylands and the adjacent watersheds.

Possible Constraints: Railroads and roadways, major pipelines, sewer lines, Concord Naval Weapons Station, adjacent heavy industry (e.g., Pacific Gas and Electric Company's Pittsburg power plant), and on-site contaminants.

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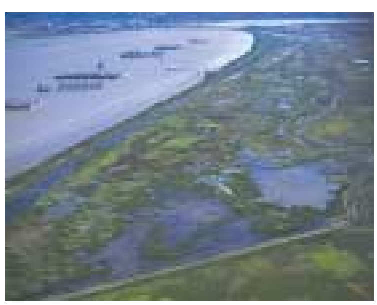

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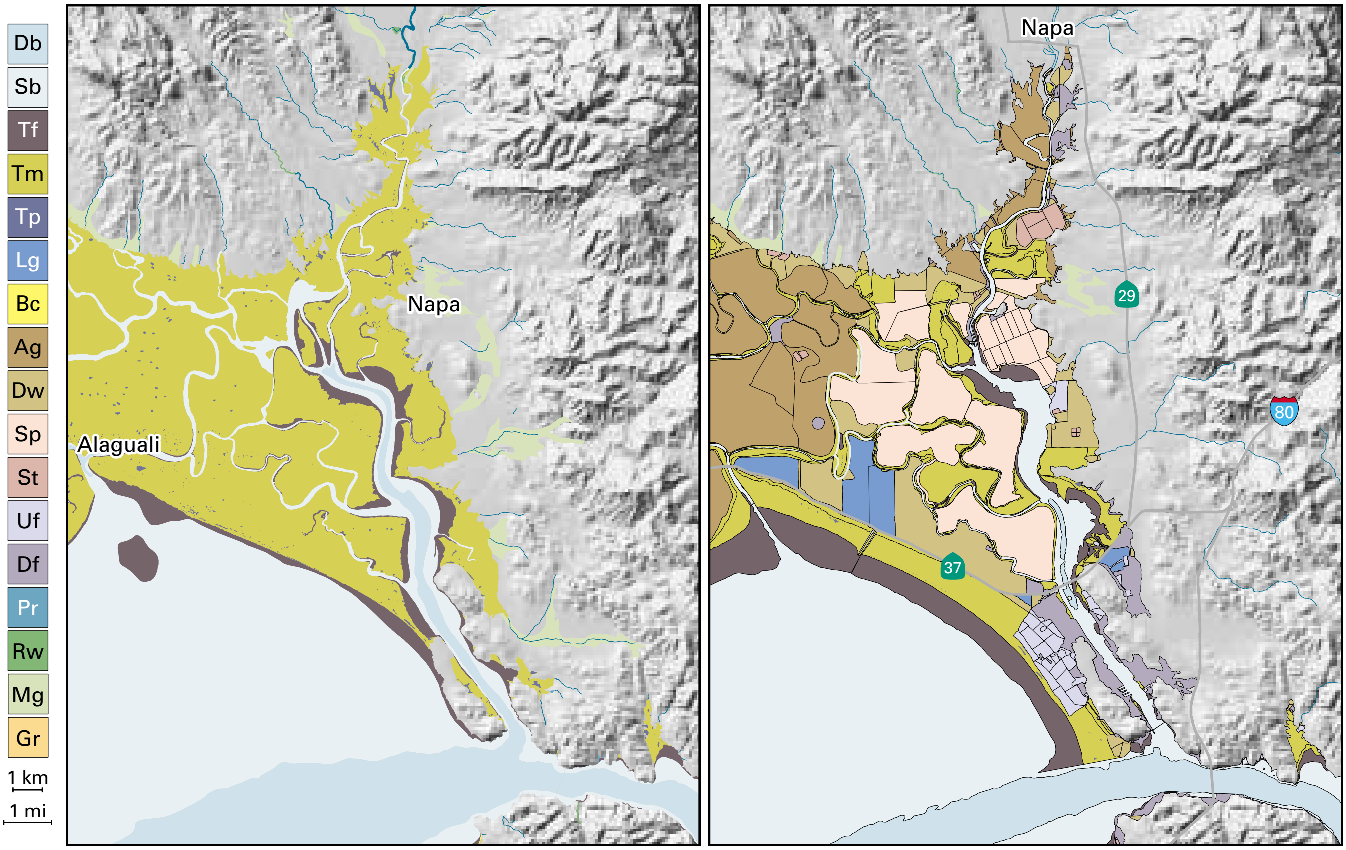


Past

Present

Segment area: 25,710 acres

Segment D — Napa River Area

Subregion: North Bay

Location: Northern side of San Pablo Bay extending from the Carquinez Bridge westward to the salt pond intake channel.

Major or Unique Features: Historically, this area was nearly all tidal salt marsh and tidal brackish marsh dominated by the hydrology of the lower Napa River. Extensive sloughs and channels connected it to the lower portion of Sonoma Creek to the west. Tidal salt marsh extended to the Bay, but there was very little bordering tidal flat except along the Napa River. Many of the tidal marshes along the eastern side of the Napa River reached into small valleys and swales and were bordered with moist grasslands.

Today, this segment remains relatively undeveloped, except for agriculture, and the inactive salt ponds on the western side of the Napa River dominate its landscape. Narrow strips of tidal marsh exist on the outboard sides of the levees that border these salt ponds, and also at several sites along the Napa River. The high salt marsh on the southern side of Highway 37 supports the largest population of salt marsh harvest mouse in North Bay. Significant populations of California clapper rail and black rail exist at Fagan Slough, Coon Island, and White Slough. Extensive tidal flats border the salt marsh south of Highway 37.

There are diked wetlands along the northern side of Highway 37 and along the base of the hills near Huichica Creek. At the bayland edge are many localities of rare or extirpated species of high marsh plants.

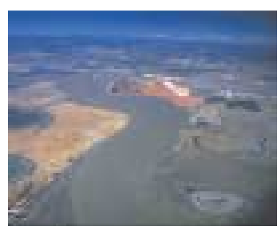
Unique Restoration Opportunities: This segment presents an excellent opportunity to restore several large patches of tidal marsh adjacent to a large riverine system. It also is a place where marsh can be restored around a major intact remnant historic tidal marsh (e.g., Fagan Slough and Coon Island). It is the only place in North Bay where inactive salt pond habitat can be improved for waterfowl, especially diving ducks. Along the bayland edge are opportunities (e.g., eastern side of Napa River near American Canyon) to ensure natural transitions between restored tidal marsh and the adjacent uplands. Also along the periphery of the segment, on both sides of the Napa River, are opportunities to improve seasonal wetlands.

Recommendations:

- Restore large areas of tidal marsh along both sides of the Napa River. This will entail restoring about half of the inactive salt ponds and Cullinan Ranch to tidal marsh.
- Manage the remaining acreage of inactive salt ponds on both sides of the Napa River as salt pond or shallow open water habitat to support waterfowl.
- Restore a continuous band of tidal marsh along the bayshore, and enhance existing marsh patches by improving tidal circulation.
- Manage diked wetlands and seasonal wetlands in the adjacent uplands to improve seasonal ponding.
- Where possible, enhance riparian vegetation and marsh/upland transitions and provide upland buffers.
- Enhance seasonal wetlands at the Mare Island dredged material disposal ponds to improve habitat for shorebirds.

Unique Restoration Benefits: Implementing these recommendations would improve habitat conditions for tidal marsh-dependent species, such as the salt marsh harvest mouse and California clapper rail, throughout the segment. It also would improve habitats for species associated with seasonal wetlands. Large-scale restoration would widen and deepen many of the tidal channels, and this would benefit fishes and diving ducks, as well as water circulation. Improving salt pond habitat also would provide valuable deepwater foraging and resting habitat for diving ducks. Restoring riparian vegetation would benefit many amphibians, birds, and small mammals. Enhancing marsh/upland transitions would improve conditions for several rare plants.

Possible Constraints: California Northern railroad tracks, Highway 37, communication cables and Pacific Gas and Electric Company power lines, discharge or disposal of salt and bittern from inactive salt ponds, and levee maintenance (including salt pond levees isolated from land-based access).



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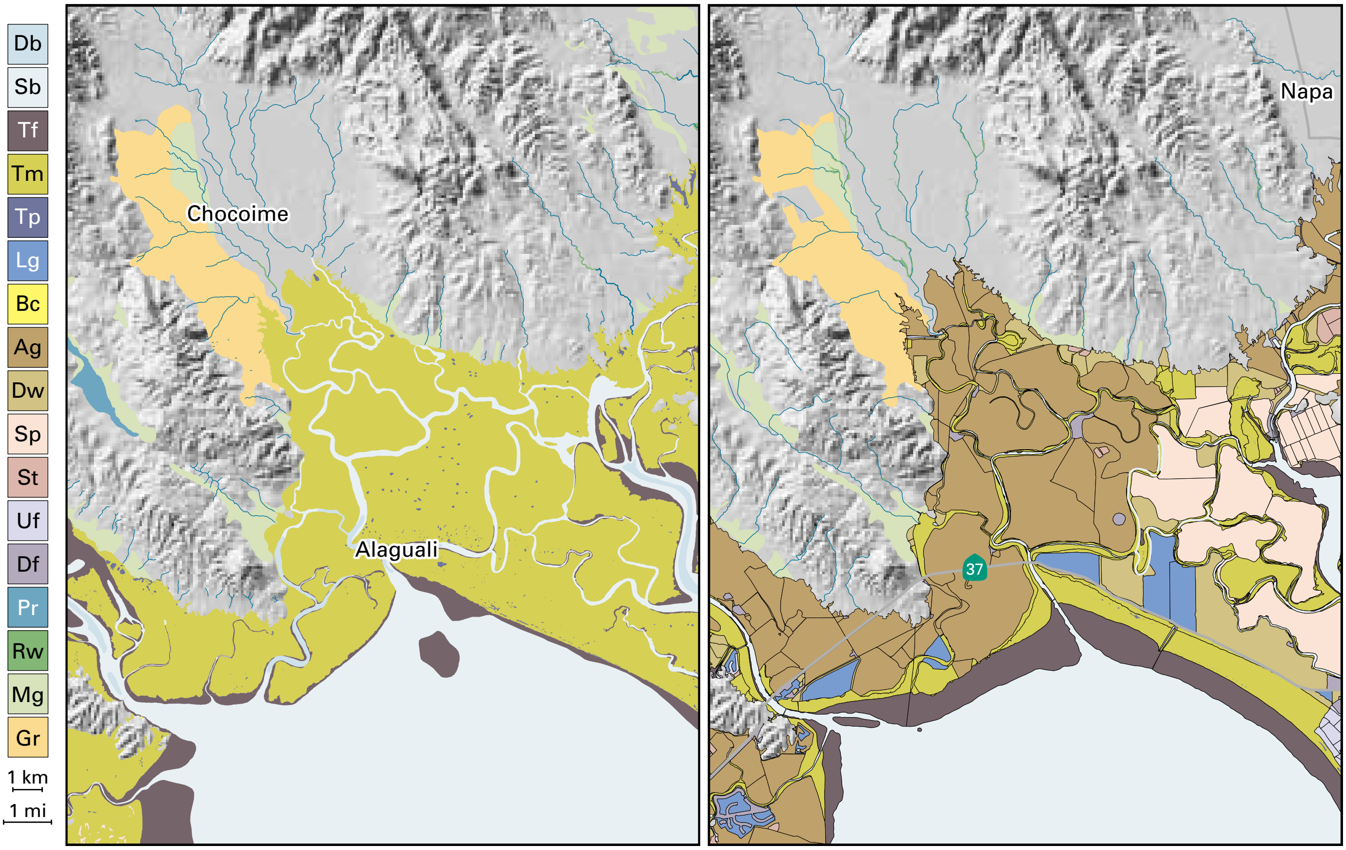


Past

Present

Segment area: 23,319 acres

Segment E — Sonoma Creek Area

Subregion: North Bay

Location: Northern side of San Pablo Bay extending from salt pond intake channel to just west of Tolay Creek.

Major or Unique Features: Nearly all of the lands within this segment once were tidal salt marsh or tidal brackish marsh. There were some limited areas of moist grasslands to the north and west, along upper Sonoma Creek, and in the drainages around and below Lake Tolay. A large area of vernal pool soils existed on the western side of upper Sonoma Creek.

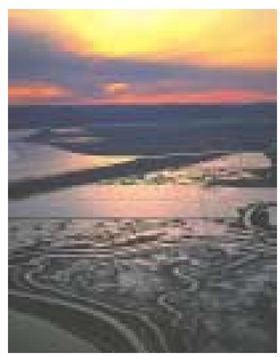
Today, this segment is relatively undeveloped and most of the baylands are farmed. There are several managed diked wetlands along the periphery of the segment, especially near the hills to the north and adjacent to Highway 37. Tidal marsh is limited to the Bay edge near Sonoma Creek and along the outboard sides of levees along the remaining channels. There are some muted tidal lagoons adjacent to Highway 37 and Tolay Creek. Spawning Chinook salmon have been observed in Sonoma Creek.

Unique Restoration Opportunities: This segment provides an excellent opportunity to restore large patches of tidal marsh, some as isolated marsh islands and others with natural transitions to the adjacent uplands. Also, there are large areas that are well suited to be managed as diked wetlands for shorebirds and waterfowl.

Recommendations:

- Restore large patches of tidal marsh along the entire shoreline of San Pablo Bay, particularly near the mouths of sloughs and major streams.
- Upstream of Highway 37, restore a broad plain of tidal marsh on both sides of Sonoma Creek. There is considerable flexibility in this area regarding the desired location of tidal and diked habitats; seasonal diked wetlands should be located in close proximity to tidal flats to provide high tide roosting habitat for shorebirds.
- Establish managed marsh or enhanced seasonal pond habitat (especially for shorebirds) on agricultural baylands that are not restored to tidal marsh. Landowners who wish to continue farming or grazing practices on the baylands in this segment are encouraged to consider implementing the recommendations on page 157.
- Enhance riparian habitat along Sonoma Creek in the Schellville area and upstream, and protect and restore Tolay Creek.
- Where possible, enhance marsh/upland transitions and provide buffers.

Unique Restoration Benefits: Restoring tidal marsh in this segment would greatly enlarge the area of shallow channel habitat for many fish species. Increased tidal prism would also enlarge existing deep channels to the benefit of fish and diving ducks. Increasing the area of tidal marsh would expand suitable tidal marsh habitat for endangered tidal marsh species such as the California clapper rail and the salt marsh harvest mouse. Restoring marsh at the periphery of the baylands, where natural transitions to adjacent uplands could develop, would benefit several rare plants, as well as birds, mammals, and amphibians that depend on the marsh/upland transition zone. Large amounts of tidal marsh can reestablish the hydrological gradients between Sonoma Creek and the Napa River, greatly improving water circulation. Large areas of managed diked wetlands would provide important roosting and foraging habitat for shorebirds and waterfowl.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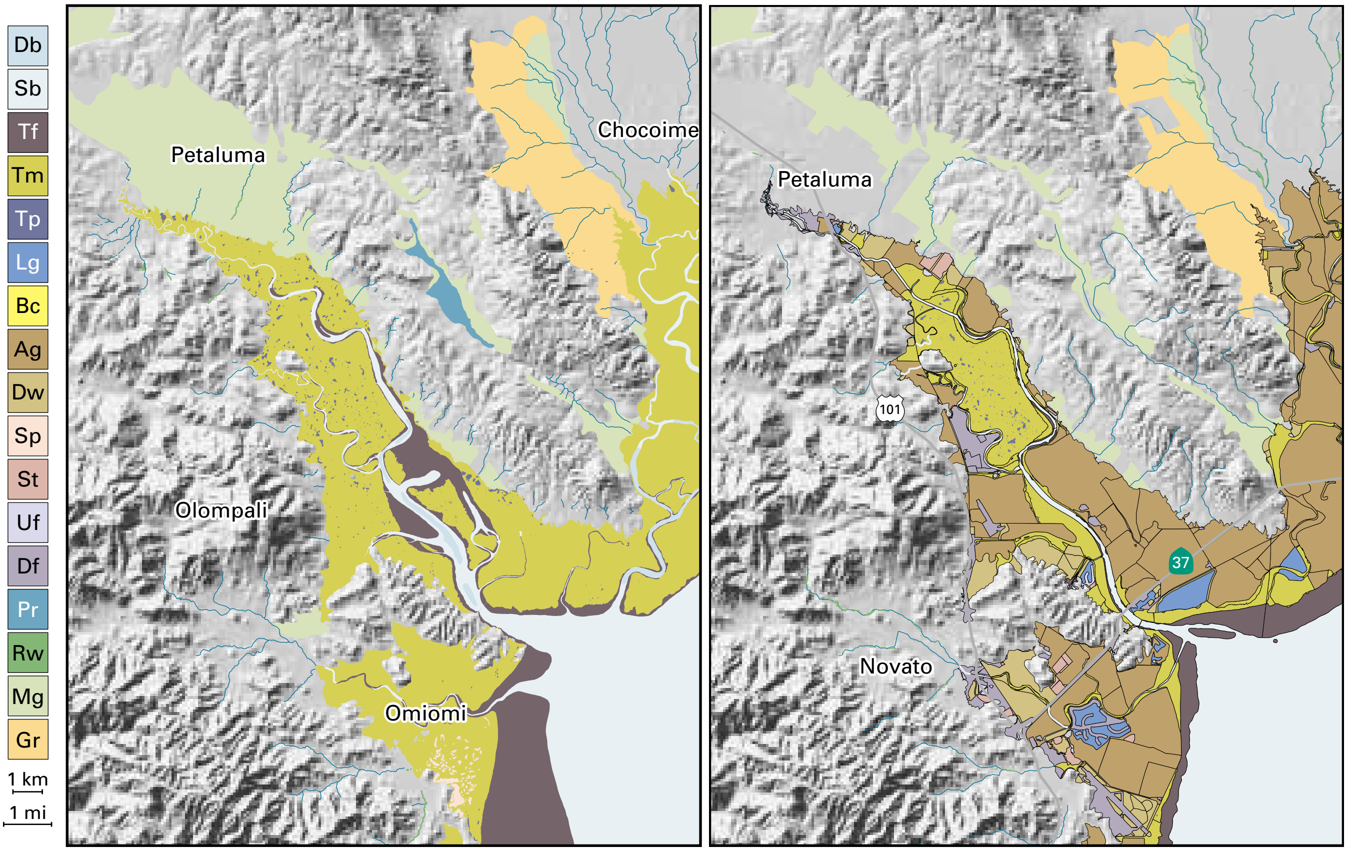
Possible Constraints: Northwestern Pacific railroad tracks, Pacific Gas and Electric Company transmission lines, Highway 37 and other highways, levee maintenance, and flood control considerations.



Past Present

Segment area: 15,647 acres

Segment F — Petaluma River Area

Subregion: North Bay

Location: Northwestern edge of San Pablo Bay and lands in the lower Petaluma River drainage.

Major or Unique Features: Tidal marsh once was the dominant habitat type in this segment. Salt marsh existed near the mouth of the Petaluma River, and became brackish upstream. There were relatively small tidal flats at the river mouth, but several large areas upstream at False Bay. Small patches of moist grassland occurred along the northeastern edge of the baylands, and a very large area of this habitat existed near Petaluma.

Today, this segment remains relatively undeveloped, and it contains the largest intact tidal marsh within the estuary, Petaluma Marsh. This marsh exhibits many of the features that were characteristic of the estuary's historical marshes — pans, a system of extensive channels, and natural transitions to adjacent uplands — but which are not readily apparent in most other Bay marshes. Adjacent to the baylands, the landscape retains much of the historical character of moist grassland bordered by oak woodland. The segment receives freshwater flows from San Antonio Creek, which supports extensive riparian habitat, and the Petaluma River and Adobe Creek, which support runs of steelhead.

Unique Restoration Opportunities: This segment provides opportunities to restore extensive tidal marsh and natural marsh/upland transitions near the subregion's largest brackish marsh. It also provides opportunities to expand remnant populations of rare plants, such as Point Reyes bird's-beak, into restored tidal marsh areas. There is the unique opportunity to enhance the stream/marsh ecotone between San Antonio Creek and tidal habitats, one of the few places where such restoration can take place. Opportunities also exist to significantly increase and enhance seasonal wetland habitat in the diked baylands and adjacent uplands, particularly on the eastern side of the Petaluma River. This segment also provides opportunities to restore and enhance tidal marsh/upland transitions, particularly with oak woodlands.

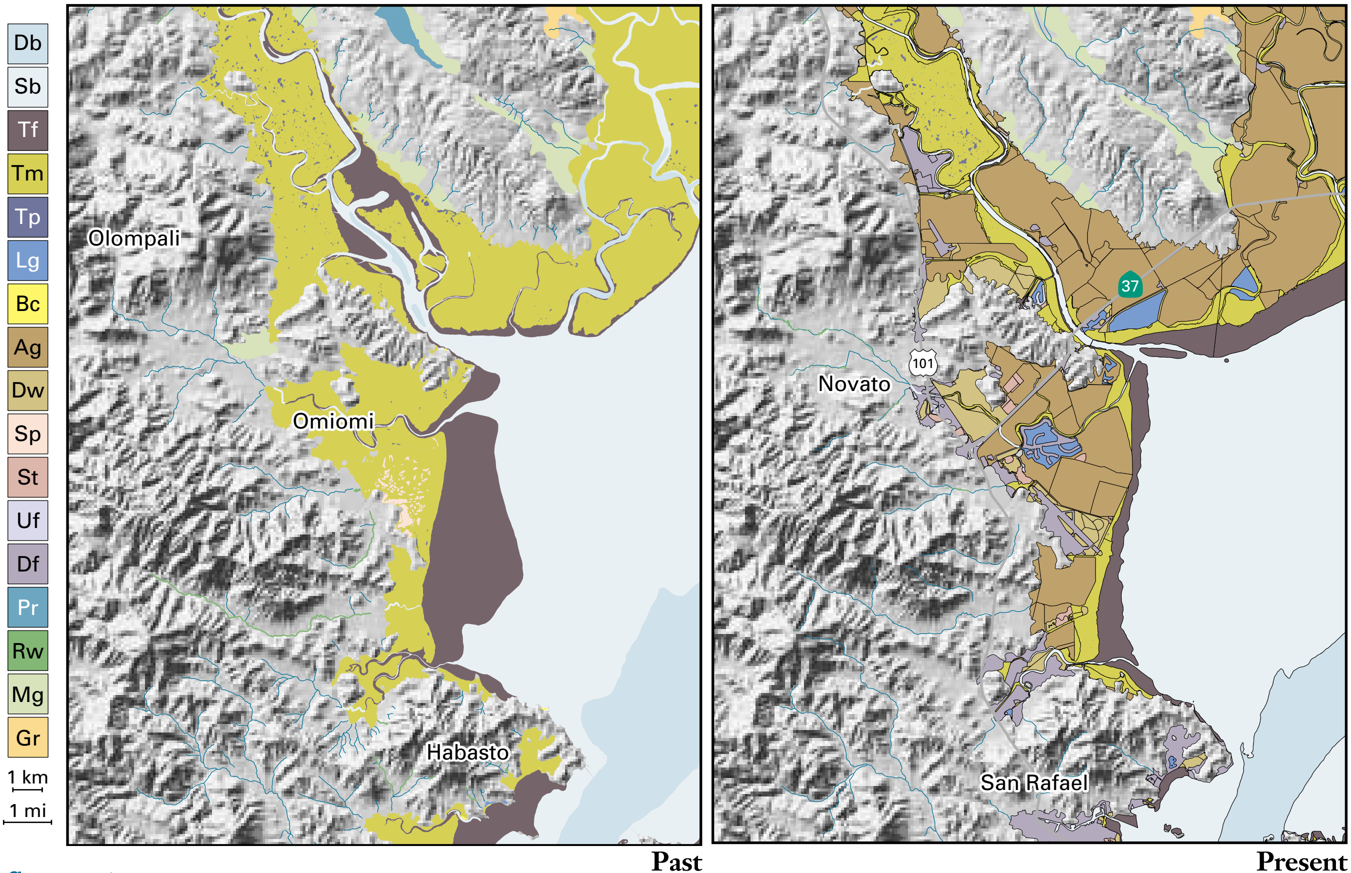
Recommendations:

- Restore a continuous, wide band of tidal marsh along the bayshore from Tolay Creek to the Petaluma River.
- Restore tidal marsh on both sides of the Petaluma River, particularly on the eastern side, between Highway 37 and False Bay.
- Establish managed marsh or enhanced seasonal pond habitat on agricultural baylands that are not restored to tidal marsh. Landowners who wish to continue farming or grazing practices on the baylands in this segment are encouraged to consider implementing the recommendations on page 157.
- Provide natural transitions at the marsh/upland ecotone and buffers in the adjacent uplands.
- Encourage seasonal wetlands and managed marsh creation at Burdell Ranch around Gnoss Airfield, and in areas constrained by infrastructure along the Highway 37 corridor between Sears Point and the Petaluma River.
- Protect and enhance moist grassland habitats on the eastern portion of this segment.
- Control pepper grass invasions in otherwise intact tidal brackish marsh to prevent loss of high marsh plant diversity.

Unique Restoration Benefits: Significant benefits for tidal marsh species such as the California clapper rail, black rail, and salt marsh harvest mouse, could be achieved in this segment. Restoring tidal marsh also would improve nursery habitat for salmon, steelhead, starry flounder, Dungeness crab, and other aquatic species. Restoring and enhancing fluvial/riparian/tidal marsh transitional habitats along San Antonio Creek and possibly Adobe Creek would benefit fish, amphibians and plants. Restoring tidal marsh/upland transitions would improve conditions for rare high marsh and ecotonal plant species.

Possible Constraints: Highway 37 corridor and Lakeville Highway east of the Petaluma River, Highway 101 west of the Petaluma River, Northwestern Pacific Railroad tracks, Pacific Gas and Electric Company transmission lines, subsided baylands, Gnoss Air Field, and flood control considerations.

USGS 1860



Segment area: 11,555 acres

Segment G — North Marin

Subregion: North Bay

Location: Western side of San Pablo Bay extending from the mouth of the Petaluma River to Point San Pedro.

Major or Unique Features: This segment supported large areas of tidal marsh that were bordered by extensive mudflats. These flats composed the majority of the mudflats in San Pablo Bay. Several tributary streams, the largest of which were Novato and Gallinas creeks, fed the marshes. These streams supported riparian habitats through which passed steelhead and possibly coho salmon. Upslope of the marshes, oak woodlands dominated the landscape. Large pans in the tidal marshes near present-day Novato supported abundant waterfowl populations.

Currently, much of the area near the Bay is cultivated for oat hay, and there are residential developments at Bel Marin Keys, at Hamilton Field (along with other military base infrastructure), and at several sites to the south. A fairly large remnant marsh remains at the mouth of Gallinas Creek, including China Camp, which supports what appears to be the largest population of clapper rails in North Bay. Large, permanent, freshwater emergent marshes are found along the western side of Novato Creek north of Highway 37 and at the Ygnacio Pond.

Unique Restoration Opportunities: This segment provides an opportunity to enhance tidal marsh in areas where natural marsh/upland transitions can be restored. It has areas to expand and reintroduce populations of rare plant species, such as Point Reyes bird's-beak and johnny-nip. It also has potential for major expansion of California clapper rail into very wide marshes, remote from predator outposts and corridors. Tidal marsh restoration could be used to enhance flood protection in the Novato Creek area by expanding tidal prism to maintain and enhance the existing channel which is currently dredged to maintain capacity. There are opportunities to restore riparian habitat along Gallinas and Novato creeks. Presence of treated wastewater provides the opportunity to develop freshwater managed wetlands for waterfowl in the area. Stream and riparian habitat could be enhanced on tributary streams for fish and amphibians.

Recommendations:

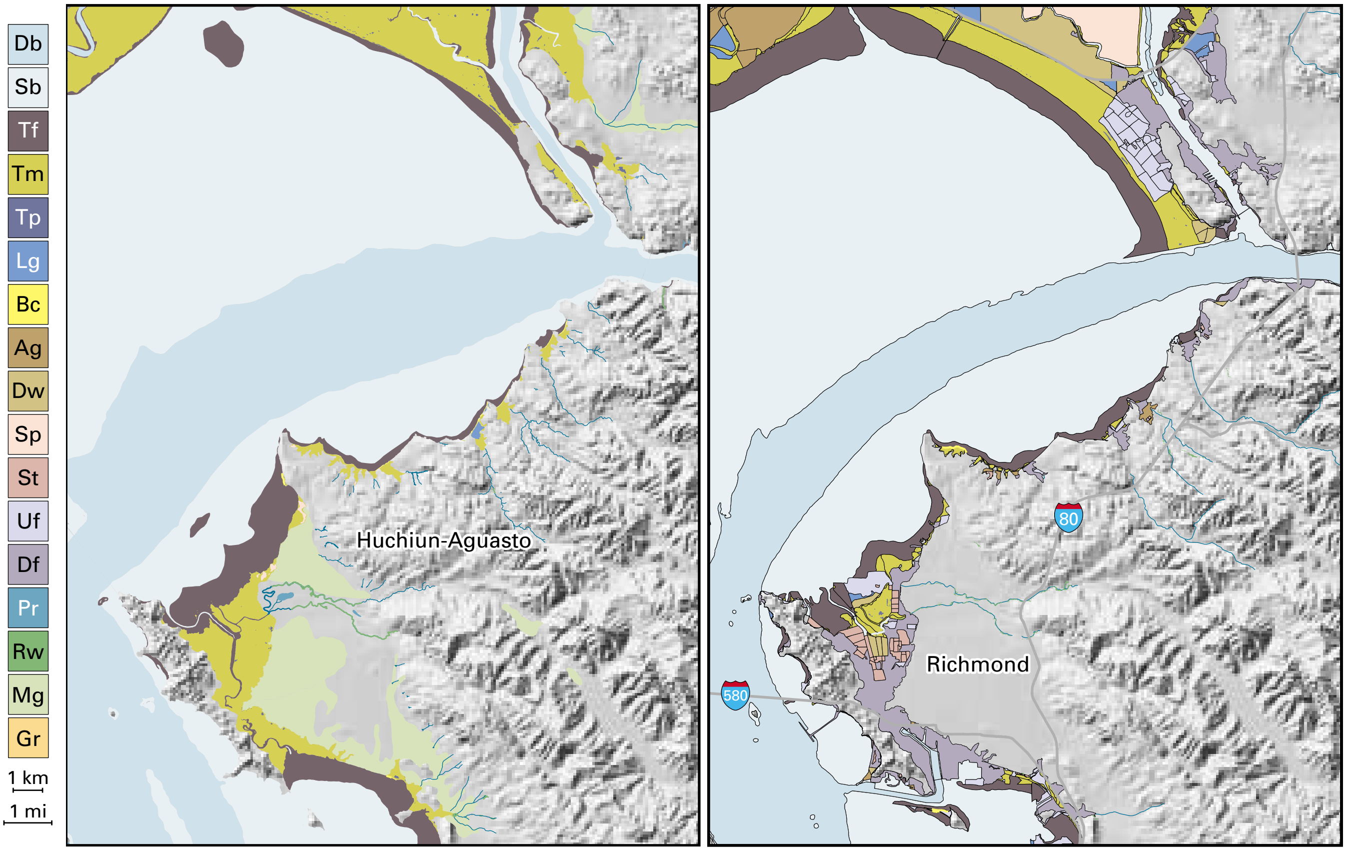
- Restore a wide, continuous band of tidal marsh along the bayfront between Black Point and Gallinas Creek, and along Gallinas Creek and Novato Creek. Ensure a natural transition to uplands throughout and provide an upland buffer outside the baylands boundary.
- Protect oak woodlands and mixed evergreen forest along the entire ridge and hillslopes from Black Point to Rush Creek, and protect the ecotone at the base of the slopes. Also protect oak woodlands at Deer Island and Hanna Ranch.
- Establish managed marsh or enhanced seasonal pond habitat on agricultural baylands that are not restored to tidal marsh. Landowners who wish to continue farming or grazing practices on the baylands in this segment are encouraged to consider implementing the recommendations on page 157.


Herb Lingl

Unique Restoration Benefits: Restoring tidal marshes on the bayshore and along lower reaches of streams would expand suitable habitat for many tidal marsh species, particularly California clapper rail. Providing wide transitions between these marshes and adjacent uplands would benefit many rare plant species. Restoring and improving tidal marsh along Novato Creek would improve flood protection and expand habitat for sensitive tidal marsh species. Protecting oak woodlands and mixed evergreen forest would ensure habitat for the many species of wildlife that utilize these areas and the adjacent baylands.


Herb Lingl

Possible Constraints: Flood protection considerations, Novato wastewater discharge, railroad right-of-way, and Hamilton Field.



Past Present

Segment area: 4,223 acres

Segment H — Contra Costa West

Subregion: North Bay

Location: Southeastern edge of San Pablo Bay between Point San Pablo and the Carquinez Bridge.

Major or Unique Features: A broad tidal flat once bordered most of the portion of this segment north of Point Pinole, except along the steep shoreline near Carquinez Strait. A string of small tidal marshes existed in small coves along this shoreline and at the entrances to Garrity, Pinole, Refugio, and Rodeo creeks. A large tidal marsh spanned much of the area between the San Pablo Peninsula and Point Pinole and extended the length of lower Castro Creek. There were extensive areas of moist grasslands bordering the upland edge of this tidal marsh.

Today, there is considerable industrial development in this segment. The Union Pacific railroad tracks lie within a few yards of the shore for the entire distance north of Point Pinole, and almost no tidal marsh remains in this area. Most of the tidal marsh in the Castro Creek basin has been filled for heavy industry (oil refinery and rail yard) and the Richmond sanitary landfill. Some tidal marshes remain to the north and south of this landfill at the mouths of San Pablo and Wildcat creeks. Tidal flats still exist throughout most of their historical distribution, and there are several sandy barrier beaches and lagoons. Some vernal pools remain in the adjacent uplands.

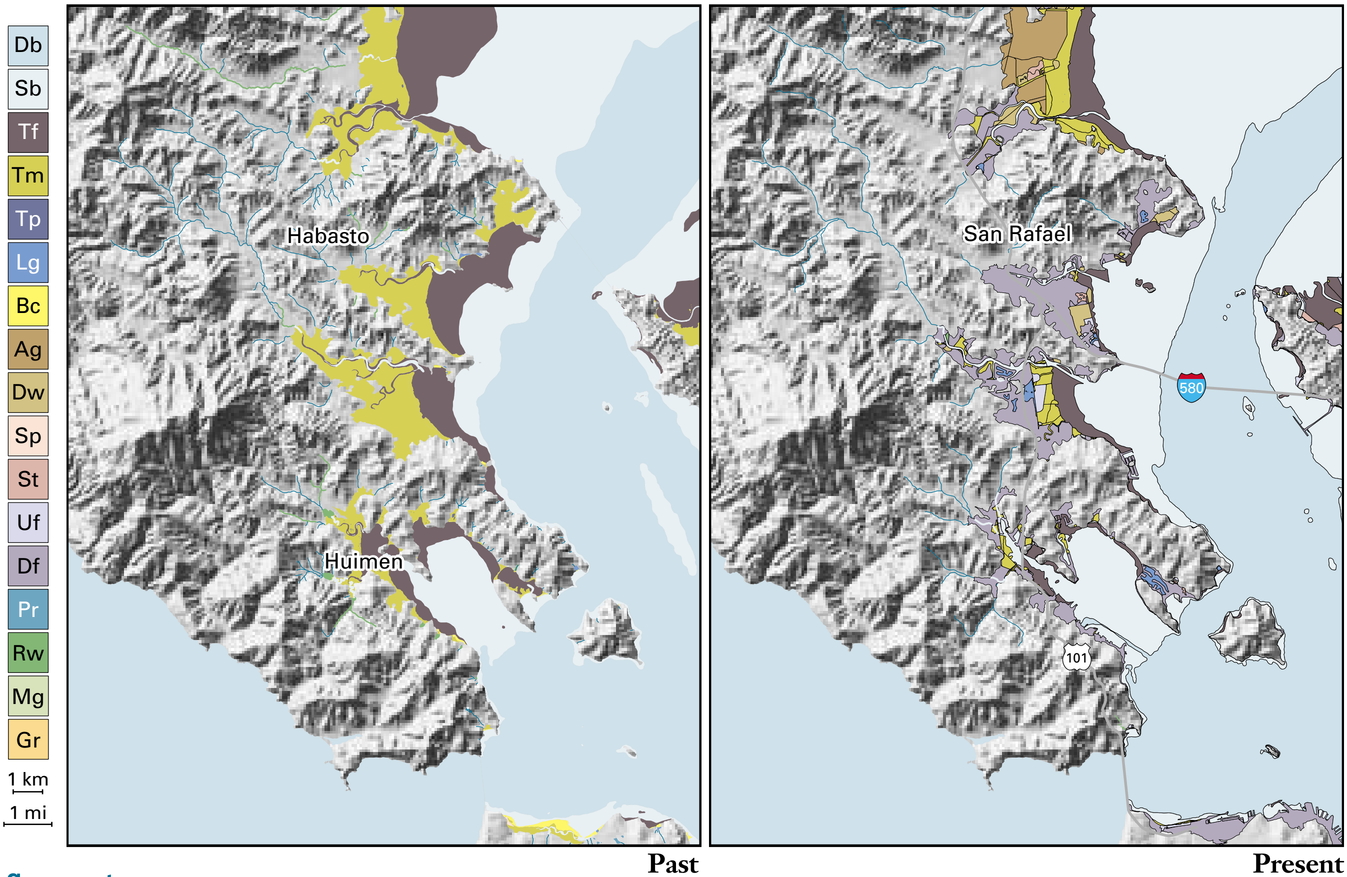
Unique Restoration Opportunities: There is potential to restore a corridor of tidal marsh between Wildcat Marsh and San Pablo Marsh, as well as riparian vegetation along the streams that flow into these marshes. There are opportunities to restore the lagoon on the eastern side of San Pablo Peninsula and vernal pools near the Bruener property. There also are opportunities to restore populations of tidal marsh plants, including soft bird's-beak, johnny-nip, and possibly Point Reyes bird's-beak near Point Pinole.

Recommendations:

- Protect and enhance existing tidal marshes, beaches, lagoons, and uplands.
- Restore a tidal marsh corridor along the eastern edge of the Richmond landfill to reconnect Wildcat Marsh and San Pablo Marsh.
- Protect and restore tidal marsh south of the Point Pinole Regional Shoreline at the Bruener property, and connect to Giant Marsh.
- Restore vernal pools in the adjacent uplands.
- Control rampant spread of pepper grass in rare high marsh plant associations, and prevent reemergence of invasive non-native Chilean cordgrass at Point Pinole.

Unique Restoration Benefits: Implementing these recommendations would improve habitat conditions for tidal marsh-dependent small mammals, such as the salt marsh harvest mouse. Many species of Bay fishes that use tidal marsh habitat also would benefit from any tidal marsh improvements in this segment. Reestablishing a tidal marsh corridor between the Wildcat and San Pablo marshes would link these existing areas, increase tidal marsh acreage, and reduce the isolation of small mammal populations. Restoring and improving high marsh/upland transitions would benefit populations of several rare plants.

Possible Constraints: Union Pacific railroad tracks, Richmond landfill, flood control considerations, and on-site contaminants.



Segment area: 6,309 acres

Segment I — South Marin

Subregion: Central Bay

Location: Western edge of Central San Francisco Bay extending from Point San Pedro to the Golden Gate.

Major or Unique Features: Historically, this segment's relatively steep bayshore topography limited large areas of tidal marsh to the lower reaches of San Rafael and Corte Madera creeks, and to the western part of Richardson Bay. In all of these areas, there also were broad expanses of tidal flats.

Today, much of the baylands within this segment is developed for urban, transportation, and residential uses. Only a few remnants of the original tidal marshes remain. Several of these marshes are muted, and some are adjoined by diked wetlands. Very little tidal flat remains. There are populations of rare Point Reyes bird's-beak near Mill Valley and Sausalito, and possibly elsewhere in this segment. There also may be populations of Marin knotweed near Corte Madera and Greenbrae.

Unique Restoration Opportunities: This segment provides opportunities to restore and improve tidal marsh and diked wetlands. Harbor seals use the Corte Madera Marsh and Strawberry Spit areas for resting and pupping, and these sites are among a few places in the Bay where these habitats can be enhanced. In or near

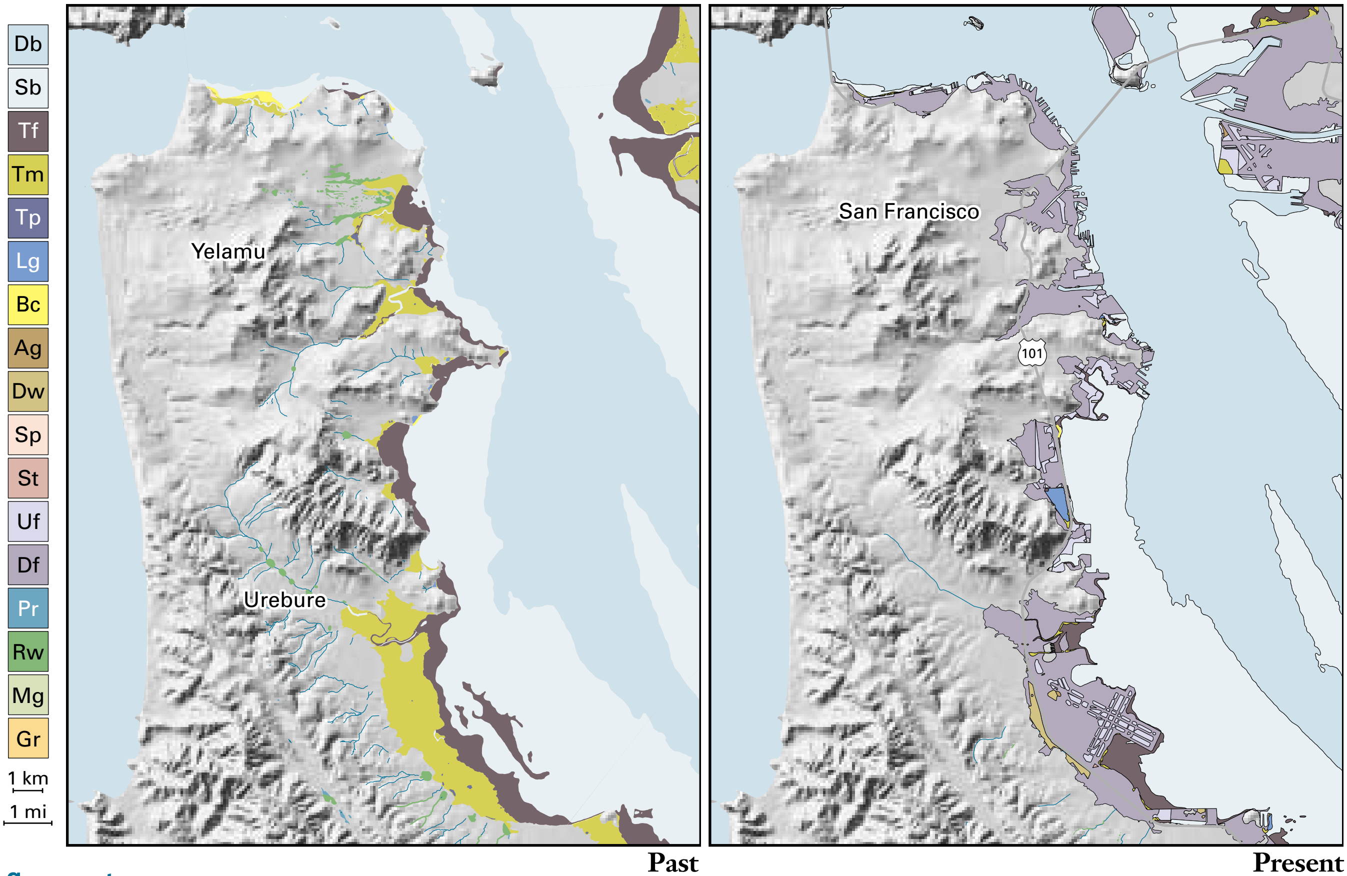
Richardson Bay are suitable sites for restoring and enhancing habitat for the endangered Point Reyes bird's-beak. On offshore islands, potential exists for enhancing colonial bird nesting areas.

Recommendations:

- Restore and enhance tidal marsh wherever possible.
- In the Corte Madera and San Rafael marshes, enhance seasonal wetland features in the marsh/upland transition zone and establish or improve upland buffers. Eradicate non-native cordgrass along Corte Madera Creek.
- Restore high marsh near populations of rare and uncommon salt marsh plants to enable their expansion.
- Enhance colonial nesting bird habitat on East and West Marin Islands.
- Protect and enhance harbor seal haul-out and pupping sites in Corte Madera Marsh and at Strawberry Spit.
- In Richardson Bay, restore and enhance fringing marsh along the northwest edge for Point Reyes bird's-beak.
- Enhance riparian and instream habitats on Corte Madera Creek.
- Control pepper grass to prevent its invasion into rare plant habitat.

Unique Restoration Benefits: Implementing the recommendations for this segment would improve habitat support for harbor seals, salt marsh harvest mice, and other mammals. Improving tidal salt marsh/upland transitions would benefit Point Reyes bird's-beak. Protecting and enhancing valuable nesting habitat on the Marin islands would benefit colonial birds, such as the double-crested cormorant, gulls, and egrets. Enhancing seasonal wetlands would provide improved high-tide roosting habitat for shorebirds. Enhancing riparian and instream habitats would benefit migratory songbirds and steelhead.

Possible Constraints: Highway 101, Northwestern Pacific railroad tracks, flood control considerations, and extensive stands of dense-flowered cordgrass in Corte Madera Creek.



Segment area: 9,976 acres

Segment J — San Francisco Area

Subregion: Central Bay

Location: Western side of Central San Francisco Bay between the Golden Gate and Coyote Point.

Major or Unique Features: Historically, there were many kinds of habitats in this segment. Barrier beaches and marshes existed in small coves between local headlands, and often in connection with the mouths of streams. Tidal marsh also occurred here, and along the lower reaches of streams and in several small embayments at sites, such as China Basin, Islais Creek, and Hunters Point. A wide band of tidal marsh extended from near Candlestick Point southward to Coyote Point. This area was one of the major historical localities of California sea-blite, now regionally extinct.

Today, most of this segment is intensively developed — cities, military bases, industrial sites, and port facilities line much of the shore. San Francisco International Airport is in the middle of a former, large tidal marsh. West of the airport is an area of seasonal wetlands and permanent freshwater marsh. At several sites along the modern shoreline, shell and sand beaches have re-formed naturally. The segment is a major center of spread for the non-native invasive smooth cordgrass.

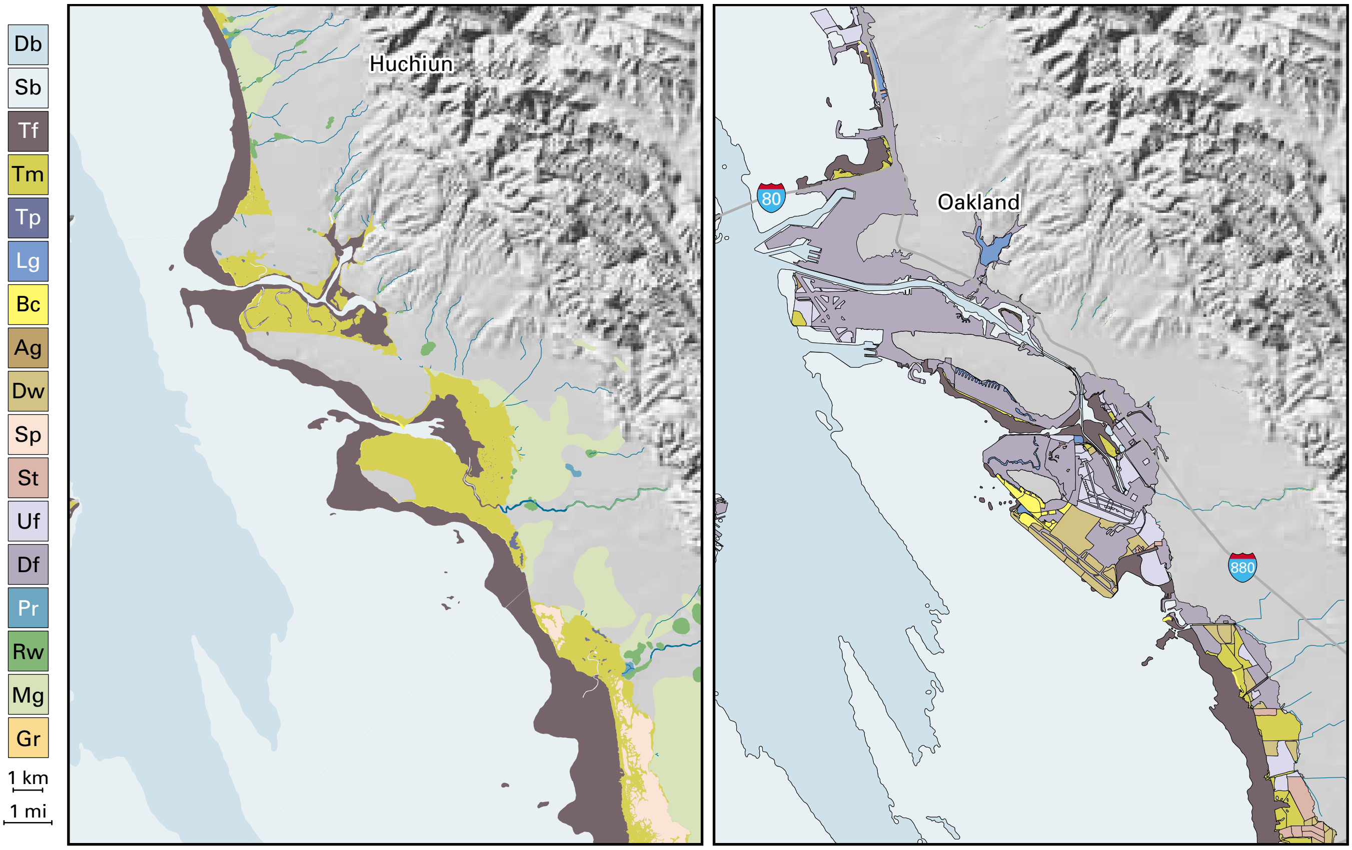
Unique Restoration Opportunities: This segment provides an opportunity to restore beach and sand dune habitats. There also are opportunities to restore or enhance tidal marshes at several sites south of San Francisco and to reestablish locally extirpated California sea-blite and associated rare or uncommon high marsh plant species. West of the airport, there are opportunities to enhance freshwater marshes and adjacent seasonal wetlands for the San Francisco garter snake and red-legged frog.

Recommendations:

- Restore beach, sand dune, and tidal marsh habitats at Crissy Field.
- Restore "pocket" tidal marshes along the Bay shoreline from China Basin southward using sandy berms and barrier beaches at several sites.
- Reestablish California sea-blite and associated high salt marsh plant species on the sandy edges of these areas.
- Enhance the existing freshwater marsh and seasonal wetland complex west of Highway 101 near the airport.
- Eradicate core populations and advancing-edge populations of smooth cordgrass.

Unique Restoration Benefits: Implementing these recommendations would improve habitat diversity throughout the segment by restoring beach, dune, and tidal marsh habitats. Restoring tidal marsh would facilitate the dispersal of tidal marsh-dependent birds, such as California clapper rail and black rail by providing roosting and foraging habitat. Restoring tidal marsh/upland transitions would benefit several plant species. Enhancing the habitats west of Highway 101 near the airport would benefit the San Francisco garter snake and red-legged frog. Eradicating smooth cordgrass in this segment would reduce its potential to spread to other areas.

Possible Constraints: Extensive urban infrastructure including port and military facilities, Highway 101, wastewater treatment facilities, San Francisco International Airport, Union Pacific railroad tracks, many large shoreline fills, on-site contaminants, utility corridors, exotic predators (e.g., rats and foxes), and smooth cordgrass.



Past

Present

Segment area: 11,570 acres

Segment K — Oakland Area

Subregion: Central Bay

Location: Eastern edge of Central San Francisco Bay between the San Leandro Marina and Oakland Outer Harbor.

Major or Unique Features: Historically, this area was predominantly tidal flat and tidal salt marsh. Most of the baylands in the Oakland estuary were tidal flat, tidal wetlands fringed by sandy beaches, or open bay. The estuary extended well into the current site of Lake Merritt. Most of the area surrounding Bay Farm Island was tidal flat and tidal wetlands fringed by sandy beaches. Oakland, Alameda, and Bay Farm Island were major strongholds for the now-extinct California sea-blite. Large areas of oak woodland existed on the higher lands near the estuary, and moist grassland bordered the tidal marsh in the southern half of the segment. Perennial ponds, riparian zones, and willow groves also occurred here.

Today, this segment is highly developed with urban, industrial, and transportation uses, and many of its historical and unique habitat features are gone. Most of the tidal flats and marshes along the bayshore have been filled to allow the development of railroad, military base, port, shipyard, and other facilities. Lake Merritt is an urban wildlife refuge, ringed by concrete walkways. Water levels in Lake Merritt are controlled with tide gates, and the Lake is managed primarily as a flood retention basin. The marshes and other habitats near Bay Farm Island have been filled and are the site of the Oakland Airport.

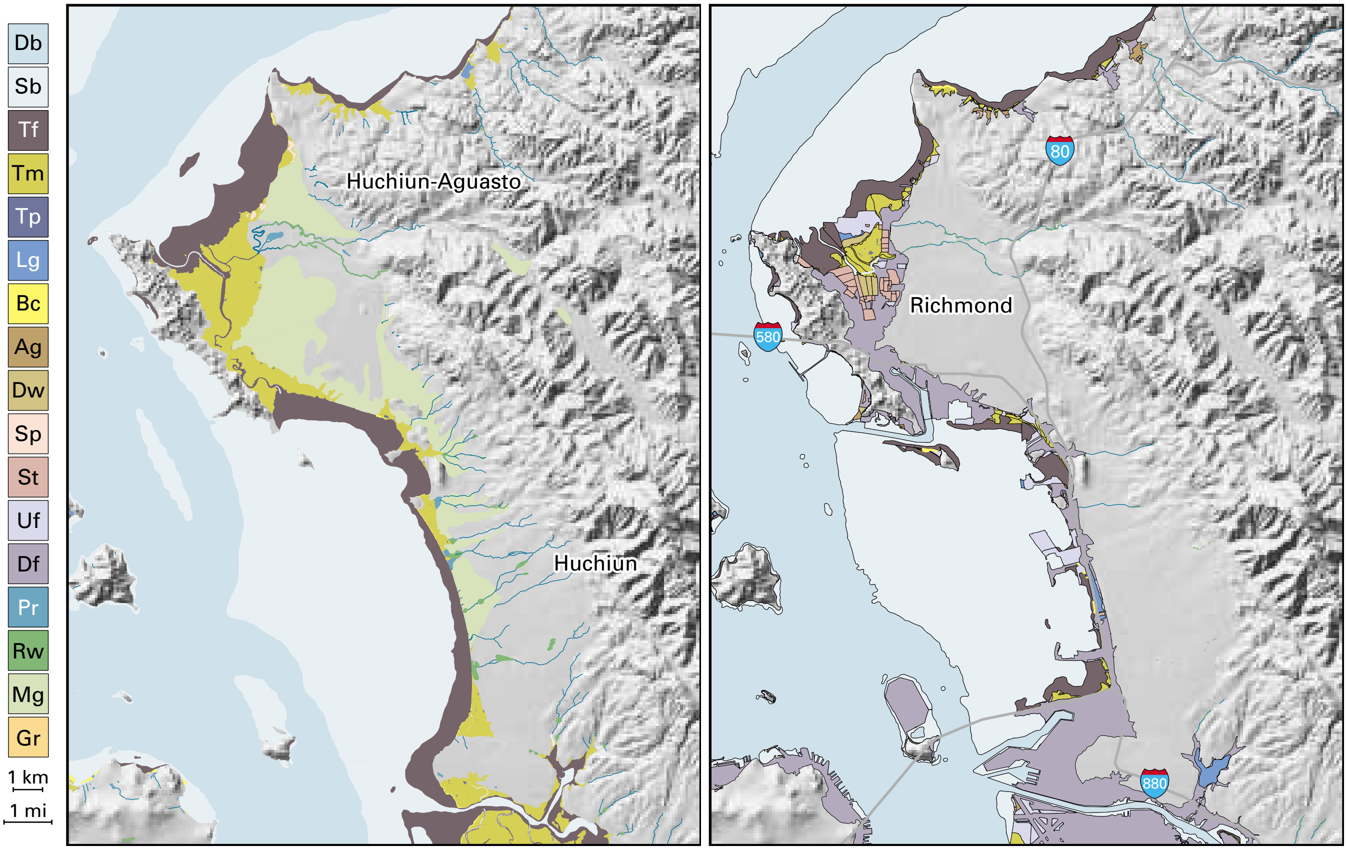
Unique Restoration Opportunities: This segment provides the opportunity to create additional nesting habitat for California least terns, to enhance degraded nesting habitat for Caspian terns, and to restore tidal wetlands in several areas. Conditions at some sites are potentially amenable to eelgrass restoration, and there is an existing eelgrass bed near Bay Farm Island that could be enhanced. Lake Merritt provides a unique opportunity to educate the public about wildlife habitat needs.

Recommendations:

- Enhance and expand tidal and diked habitats at all potential areas throughout the segment, for example, on Alameda Island, on Bay Farm Island, and in the vicinity of the Oakland Airport.
- Protect and enhance the eelgrass bed near Bay Farm Island.
- Enhance and protect suitable habitat (e.g., barren or sparsely vegetated areas protected from predators) for snowy plover and least tern at Alameda Naval Air Station, Oakland Airport, Bay Farm Island, and other locations.
- Restore beach dune and marsh in the sanctuary on the southern end of Alameda Island.
- Increase habitat in and around San Leandro Bay for harbor seals and develop extensive and connected segments of tidal marsh for small mammals.
- Restore pockets of low-lying sand beaches in sheltered sites to support reintroduced colonies of California sea-blite.
- Enhance Lake Merritt by improving tidal action and restoring tidal marsh along the lakeshore and the channel that connects the Lake to the Oakland Inner Harbor.
- Enhance riparian corridors along streams throughout the segment and reconnect tributary streams to the Bay.

Unique Restoration Benefits: Implementing the recommendations for this segment would restore and enhance habitat for many populations of key fish, amphibian, reptile, insect, mammal, and bird species. Expanding habitat for California least terns at the former Alameda Naval Air Station airfield could double the species' breeding population size, and expanding tidal wetlands at Alameda Point would provide additional habitat for wintering waterfowl and nesting shorebirds. Restoring low-lying sand beaches would provide suitable conditions for California sea-blite. Improving tidal habitats at Lake Merritt would help restore some of the area's estuarine functions, including natural water filtration and the restoration of local anadromous fish populations.

Possible Constraints: Large urban population, extensive fill along the shoreline, railroad tracks and spurs, major highways, exotic predators (e.g., rats and red fox), smooth cordgrass, and on-site contaminants.



Past

Present

Segment area: 6,723 acres

Segment L — Berkeley Area

Subregion: Central Bay

Location: Eastern edge of San Francisco Bay between the Oakland Outer Harbor and Point San Pablo.

Major or Unique Features: Historically, this segment was characterized by a narrow shoreline band of small tidal marshes, sand dunes, beaches, and extensive tidal flats. The adjacent uplands supported extensive areas of moist grassland and were dissected by numerous small streams that originated in the hills to the east. Some of these streams were bordered by riparian corridors and provided spawning and rearing habitat for steelhead. Some had lagoons at their mouths, and others terminated in willow groves.

Today, this segment is highly developed with cities, industrial areas, ports, and transportation corridors. Landfills, hotels, and other developments exist at many sites that once were tidal flat or marsh. Several relatively small isolated tidal flats, adjoining marshes, and other features continue to provide important habitat functions. Examples of good habitat in this segment are the tidal marsh and mudflats at the Emeryville Crescent and the small marshes and extensive mudflats north of Point Isabel. Shallow subtidal areas support eelgrass beds.

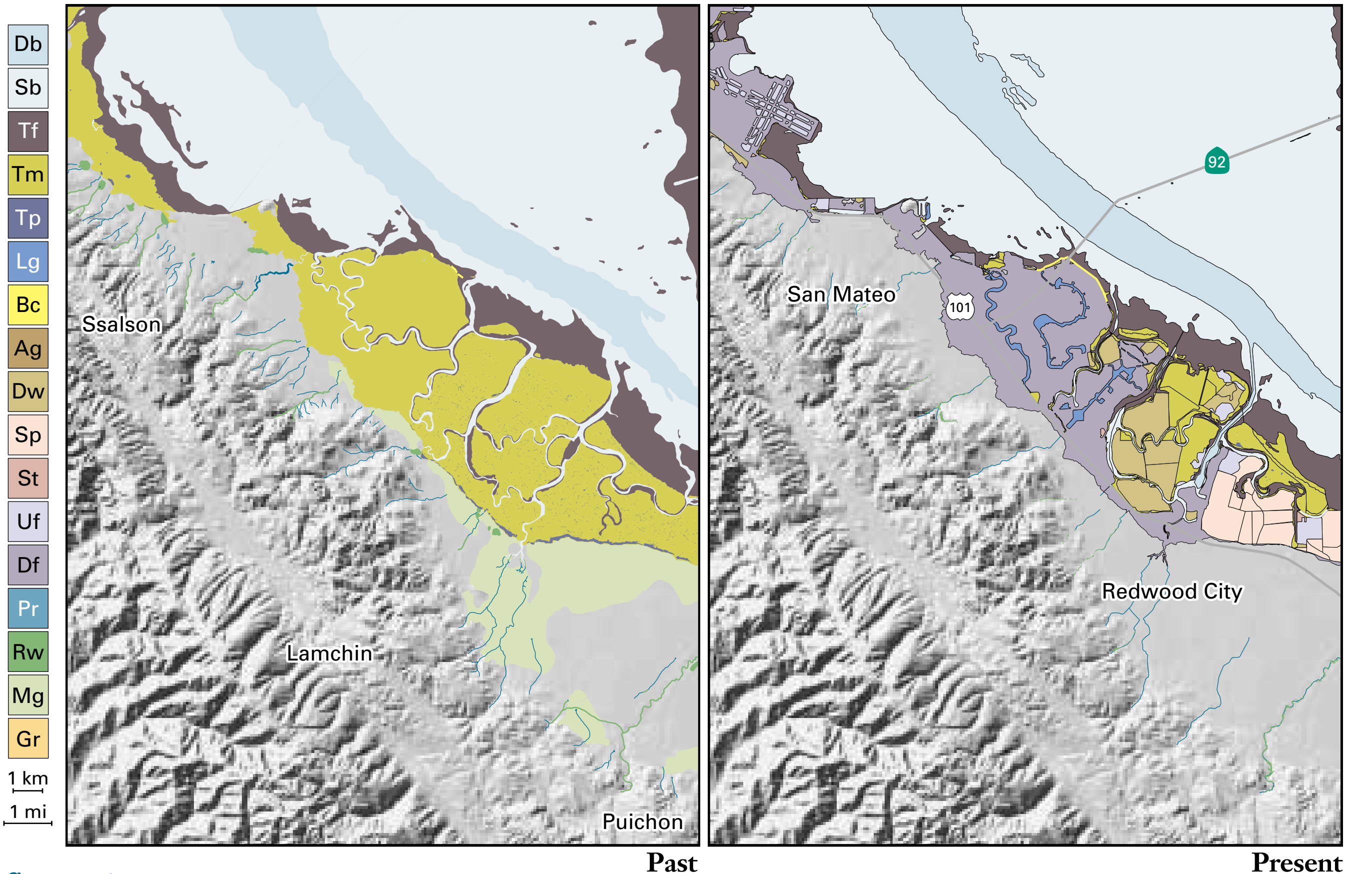
Unique Restoration Opportunities: There are several opportunities to restore and enhance tidal habitats in this segment. Examples include Hoffman Marsh, Emeryville Crescent, and the mouth of Codornices Creek. There also are opportunities to protect and restore other habitats such as eelgrass beds, moist grassland/seasonal wetlands at the Richmond Field Station and at Berkeley Meadows, and several roosting sites.

Recommendations:

- Restore, enhance, and protect a diversity of habitats, including tidal marsh, shorebird roosting sites, and seasonal wetlands.
- Restore and enhance the tidal marsh between the Hoffman Marsh and the Richmond Marina by removing fills that fragment the area.
- Restore riparian vegetation along Codornices Creek. Also enhance wetland/upland transitions in this area.
- Protect gull, tern, and egret nesting habitat at Brooks Island, Red Rock, and Castro Rocks.

Unique Restoration Benefits: Protecting the existing remnant wetlands in the area would provide habitat for a wide array of wildlife and fish species. Restoring beach habitat could improve conditions for sensitive plant species. Protecting islands would assure suitable sites for colonial nesting birds. Protecting and enhancing eelgrass beds would benefit several fish species.

Possible Constraints: Large urban population seeking access to the shoreline, extensive shoreline development, highways, and on-site contaminants.



Segment area: 9,247 acres

Segment M — San Mateo Area

Subregion: South Bay

Location: Western edge of San Francisco Bay between Coyote Point and Steinberger Slough.

Major or Unique Features: Most of this segment was once tidal marsh, and the marshes in this relatively flat area of the baylands included a transition of varying width into the coastal hills. Many of the tidal marshes had oyster shell ridges or beaches along their foreshores. Tidal flats and moist grassland were limited, as they are today.

Today, most of the former wetlands are developed urban/industrial areas (Foster City, Redwood City, and San Mateo). The wetlands that remain are fragmented narrow marshes, mostly along sloughs. Bird Island and the adjacent strip marshes along the levees are the most significant tidal wetlands in the segment. Small areas of diked marsh and seasonal wetlands persist in some of the developed areas (Area H and Redwood Shores Ecological Reserve in Redwood City, and Sun Cloud Park in Foster City). This segment was recently the invasion front of smooth cordgrass, which has since spread southward.

Unique Restoration Opportunities: This segment offers opportunities to protect and enhance the remaining tidal marshes and to enhance diked wetlands. There are potential reintroduction sites around sheltered shell beaches for California sea-blite and associated rare high marsh plant species.

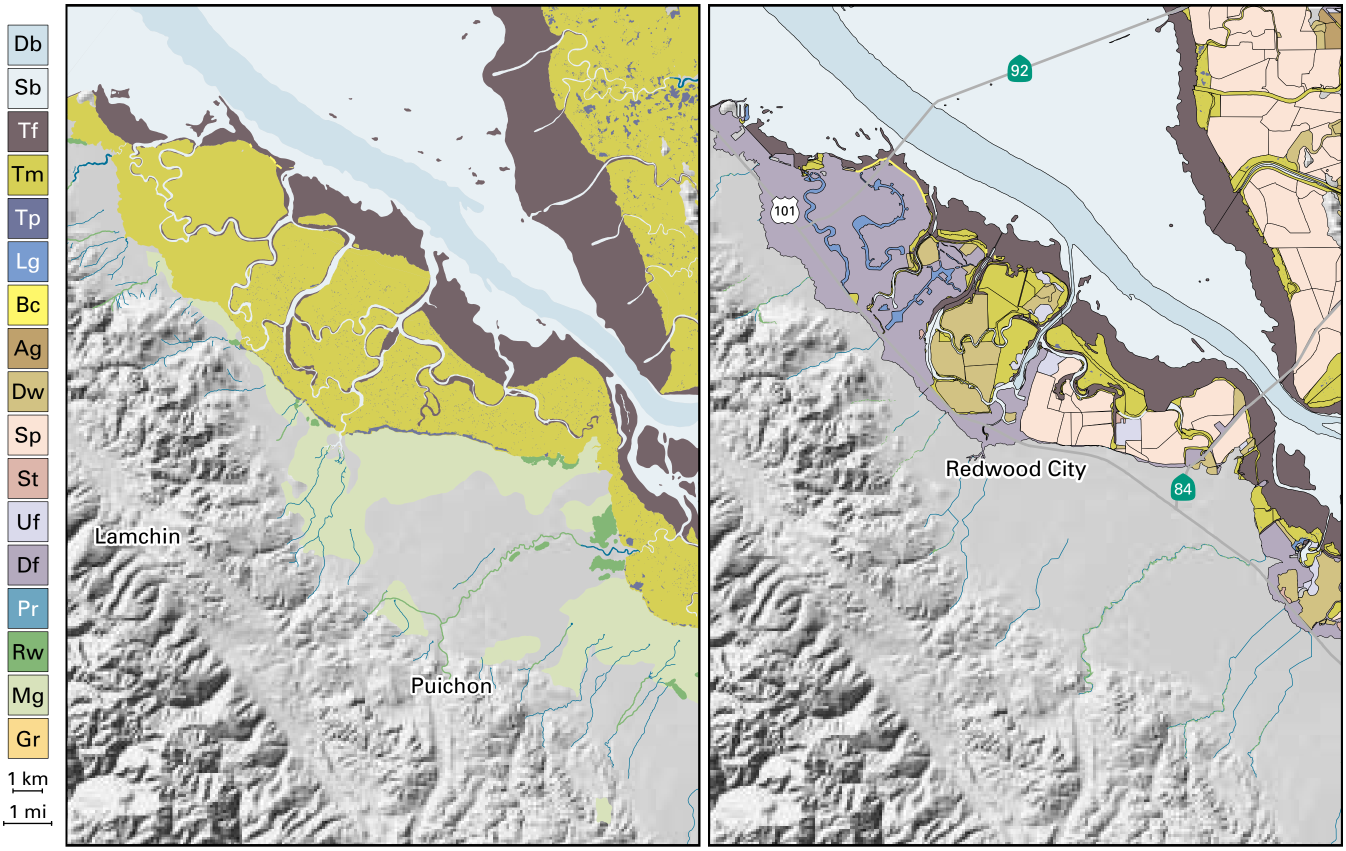
Recommendations:

- Maintain and enhance tidal marsh where possible.
- Protect and enhance diked marsh and seasonal wetland areas for shorebirds and waterfowl.
- Protect and improve oyster shell ridges near Foster City and on the Redwood Shores Peninsula.
- Improve the Foster City and Redwood Shores canal systems for fish and wildlife.
- Enhance seasonal wetlands at the Redwood Shores Ecological Reserve.
- Restore tidal marsh in the dredged material disposal lagoons at Coyote Point Marina.

Unique Restoration Benefits: Restoring oyster shell ridges would enhance habitat for some unique and rare plants and would provide roost sites for shorebirds. Providing an enlarged tidal marsh corridor would facilitate the dispersal of California clapper rails northward from population centers in Segment N to the south.

Possible Constraints: Large urban interface with heavy public access, numerous predator corridors and limited opportunity for predator management, smooth cordgrass, major transportation corridors, and flood control considerations.

Herb Lingl



Past

Present

Segment area: 11,540 acres

Segment N — Redwood City Area

Subregion: South Bay

Location: Western edge of San Francisco Bay between Steinberger Slough and the Dumbarton Bridge.

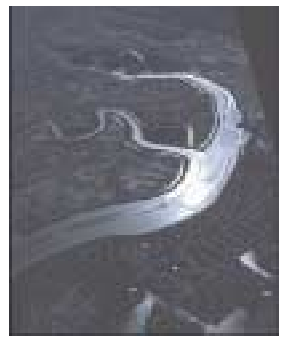
Major or Unique Features: Historically, this area was mostly tidal marsh with moist grassland habitat on the adjacent lands to the west. Large, well-developed channels and associated slough systems and numerous tidal marsh ponds characterized the tidal marshes in this segment. Outboard of the marshes were oyster shell beaches, large expanses of tidal flats, and oyster beds.

Today, this area is highly developed and many of the historical tidal marshes have been converted to salt ponds and urban uses. Greco Island is the largest contiguous tidal marsh on the western side of the Bay and is relatively protected from human disturbance; it is one of the main population centers of California clapper rail in South Bay. Currently, there is a large gap in tidal wetland between Greco Island and the Palo Alto tidal marshes in Segment O to the south. The large isolated channels in the Corkscrew Slough area provide haul-out areas for harbor seals, and the Bay's extensive tidal flats continue to provide excellent foraging habitat for shorebirds. Nearly all of the moist grassland areas have been urbanized. Until recently, uplands on outer Bair Island supported a large egret and heron rookery.

Unique Restoration Opportunities: This area has high potential for tidal marsh restoration and enhancement of seasonal wetlands and salt ponds for shorebirds and waterfowl. This segment contains Bair Island, the largest former tidal wetland currently available for restoration. Large-scale tidal marsh restoration would maintain and enhance extensive areas of channels and associated subtidal habitat and mudflats. The Redwood City crystallizers and associated salt ponds offer the opportunity to maintain and enhance shorebird and waterfowl habitat in close proximity to the large tidal flats that are so important for foraging shorebirds. Creating salt pan habitat would provide nesting habitat for the snowy plover.

Recommendations:

- Restore large areas of tidal marsh, providing a continuous band along the bayfront for the entire length of the segment.
- Restore most of Bair Island to tidal marsh and enhance oyster shell ridges in the intertidal zone.
- Restore tidal marsh along Westpoint Slough and Redwood Creek, but modify the salt crystallizers adjacent to Redwood Creek as salt pan habitat managed for shorebirds and waterfowl.
- Retain a complex of salt ponds near Ravenswood Slough, while assuring a wide band of tidal marsh around Ravenswood Point to the Dumbarton Bridge.
- Reintroduce rare and uncommon high marsh plant species at sheltered shell ridges.
- Restore dredged material disposal sites on outer Bair Island and at Deepwater Slough as marsh/upland ecotones, including seasonal ponds for plants and shorebirds.
- Restore egret and heron nesting habitat on Bair Island by removing red fox.



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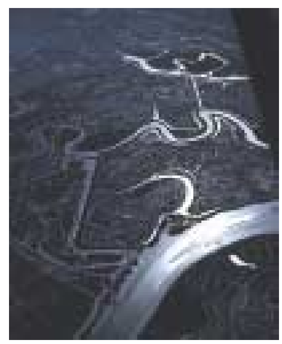

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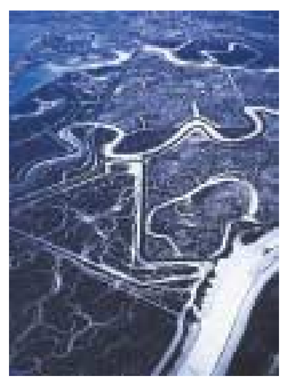
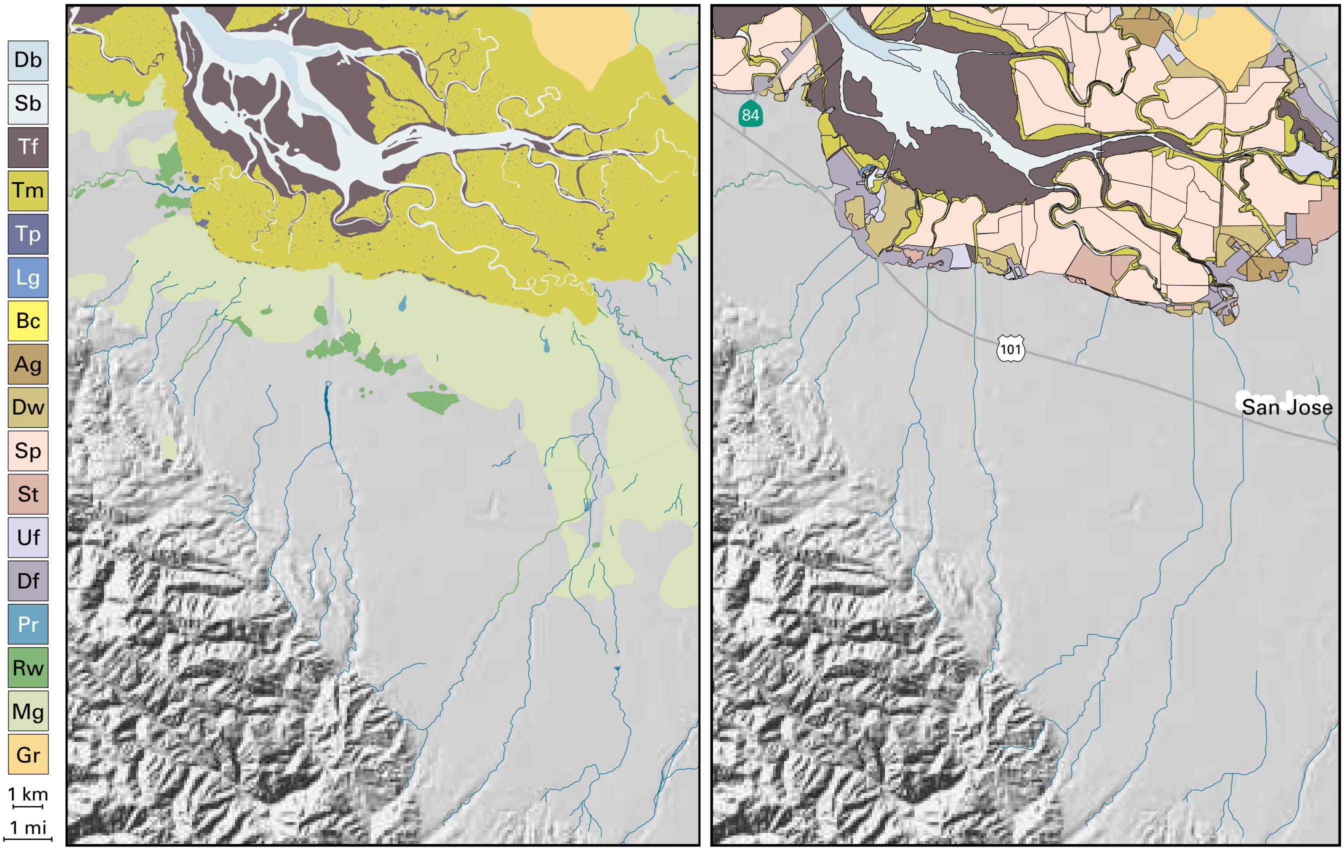
Unique Restoration Benefits: Implementing the recommendations would provide a large tidal salt marsh core area that would maintain and enhance the associated channel system. This would benefit harbor seals and several fish species. The tidal salt marsh restoration would directly benefit the salt marsh harvest mouse. It also would increase habitat for a major source population of the California clapper rail. Enhancing the salt ponds would benefit shorebirds and waterfowl and would provide an opportunity to improve snowy plover nesting habitat.



Herb Lingl

Possible Constraints: Smooth cordgrass, Pacific Gas and Electric Company transmission lines and other utility corridors, flood protection for urbanized areas and associated infrastructure, and ongoing salt production precludes restoring tidal marsh along Westport and Ravenswood sloughs.



Past

Present

Segment area:
12,526 acres

Segment O — Mountain View Area

Subregion: South Bay

Location: Western edge of San Francisco Bay between Dumbarton Bridge and Alviso Slough.

Major or Unique Features: Historically, this segment contained large expanses of tidal flats. Adjacent to these flats were tidal salt marshes that intergraded into moist grasslands in the adjacent uplands. These marshes supported extensive channel systems and an abundance of tidal pans. Many of the marshes had backshore pans along the marsh/upland transition edge. Much of the moist grassland habitat supported seasonal ponding in the rainy season. Streams that drained the coastal hills were bordered with riparian vegetation. Many of the streams did not reach the Bay, and there were willow groves and some ponds where the streams terminated near the baylands. Limited zones of brackish marsh were present along the tidal reaches of San Francisquito Creek and the Guadalupe River, both of which supported steelhead runs.

Today, most of the segment is salt ponds, sewage treatment ponds, or urban development, except for a few tidal marshes in the Palo Alto area. These tidal marshes are limited in extent, but they are the most productive and densely

populated marshlands in the Bay Area for California clapper rails. These marshes are essentially "islands" isolated from other tidal marshes by salt ponds and human development. The mudflats along the Bay margin in this segment provide important feeding and resting habitat for shorebirds. The salt ponds in this area provide post-breeding habitat for least terns and foraging and roosting habitat for shorebirds and waterfowl. Some salt ponds also provide nesting habitat for snowy plovers, other resident shorebird species, and terns.

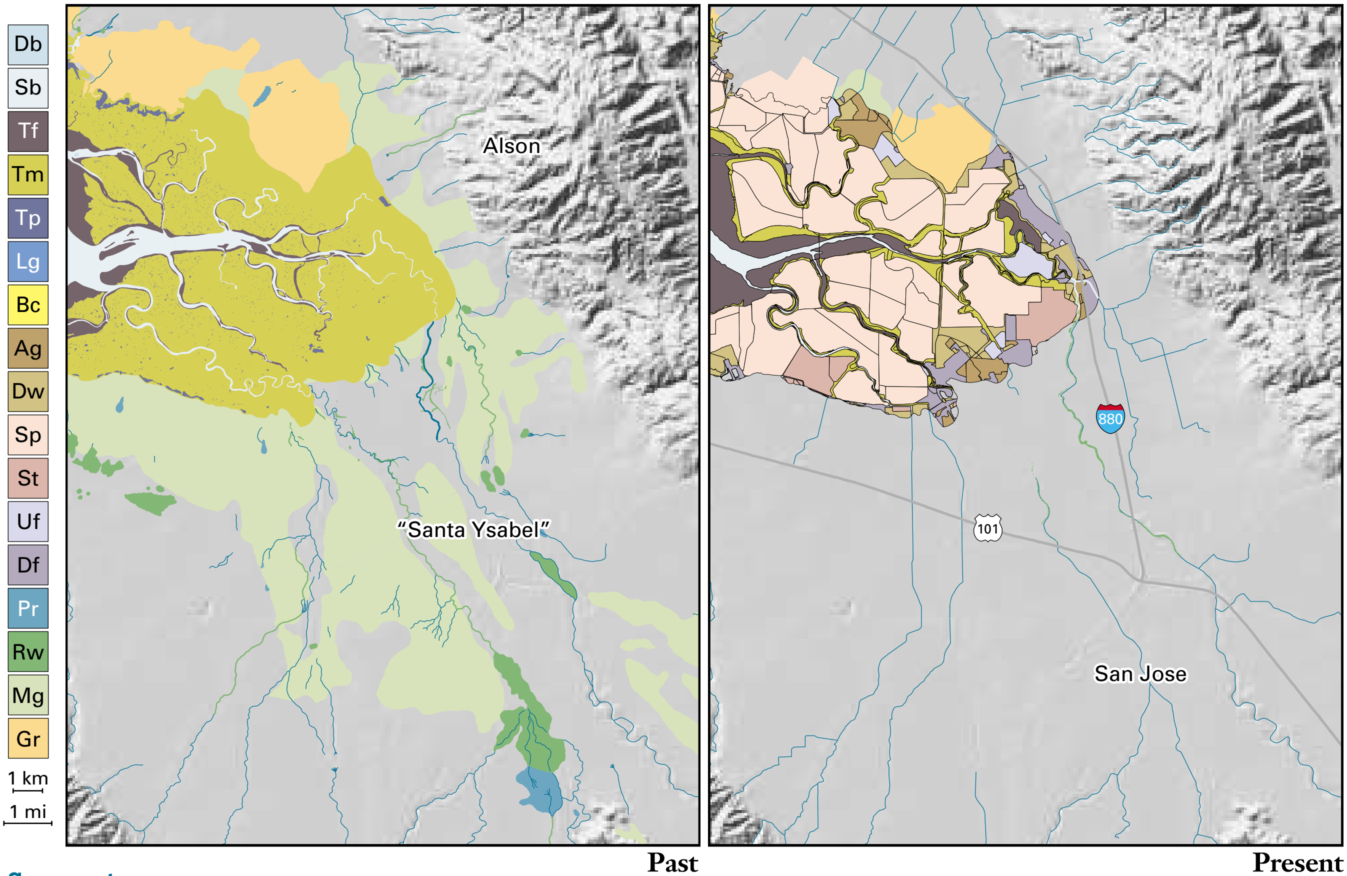
Unique Restoration Opportunities: In this segment, there is an opportunity to enlarge existing marshes and to provide dispersal corridors (where none now exist) linking the eastern and western parts of South Bay for tidal marsh-dependent species. There is the potential for managing salt ponds for the benefit of large numbers of shorebird species which forage on nearby mudflats. Retaining and modifying salt ponds would also benefit nesting snowy plovers, post breeding least terns, and waterfowl. Enhancing tributary streams, such as San Francisquito Creek and the Guadalupe River, could benefit riparian-dependent species and could help restore steelhead runs.

Recommendations:

- Restore large areas of tidal marsh and provide a continuous corridor of tidal marsh along the bayshore.
- Provide more and wider buffers to tidal marshes, and improve management to reduce human intrusion and predators.
- Modify and manage two or three complexes of salt ponds, including the pond adjacent to the Dumbarton Bridge, for shorebirds, waterfowl, and post-breeding least terns.
- Enhance the seasonal wetlands and burrowing owl habitat in the Sunnyvale baylands.
- Reestablish native vegetation and otherwise enhance the riparian corridor along San Francisquito Creek, Guadalupe River, and other tributary streams.

Unique Restoration Benefits: Maintaining salt ponds would provide high tide foraging and roosting habitat for shorebirds. This also would provide post-breeding foraging habitat for least terns, and nesting habitat for the snowy plover and other resident shorebirds and terns. Linking the eastern and western portions of South Bay would facilitate dispersal of California clapper rails (and other tidal marsh species) while minimizing predation and decreasing this species' vulnerability to local extinction. Riparian restoration and enhancement of tributary streams would improve stream and riparian habitat and benefit anadromous fishes, amphibians, small mammals, and birds.

Possible Constraints: Pacific Gas and Electric Company transmission lines and other utility corridors, flood protection considerations, historical land subsidence, freshwater outflow from wastewater treatment facilities, operation and maintenance of salt ponds in absence of salt production, and smooth cordgrass.



Segment area: 11,220 acres

Segment P — Coyote Creek Area

Subregion: South Bay

Location: Southern end of San Francisco Bay between Alviso Slough and Albrae Slough.

Major or Unique Features: Historically, most of this segment was tidal marsh. There were numerous sloughs and ponds throughout the marshes, but there was very little adjacent tidal flat habitat. Salinity was strongly influenced by high seasonal freshwater flows through Coyote Creek, one of the major tributaries to the subregion. On the northern edge of the segment was the only large area of vernal pools in South Bay. Moist grasslands bordered much of the eastern side of the segment.

Today, much of this segment is developed. Active salt ponds dominate the landscape, along with large landfills and a sewage treatment facility. Some narrow strips of tidal marsh occur outboard of the salt pond levees, and year-round sewage treatment plant discharges cause many of these to be brackish. This segment is the southern limit of the non-native smooth cordgrass invasion in the East Bay. Although the Warms Springs vernal pool area still exists, nearly all of the moist grassland in this segment has been developed for light industry or housing.

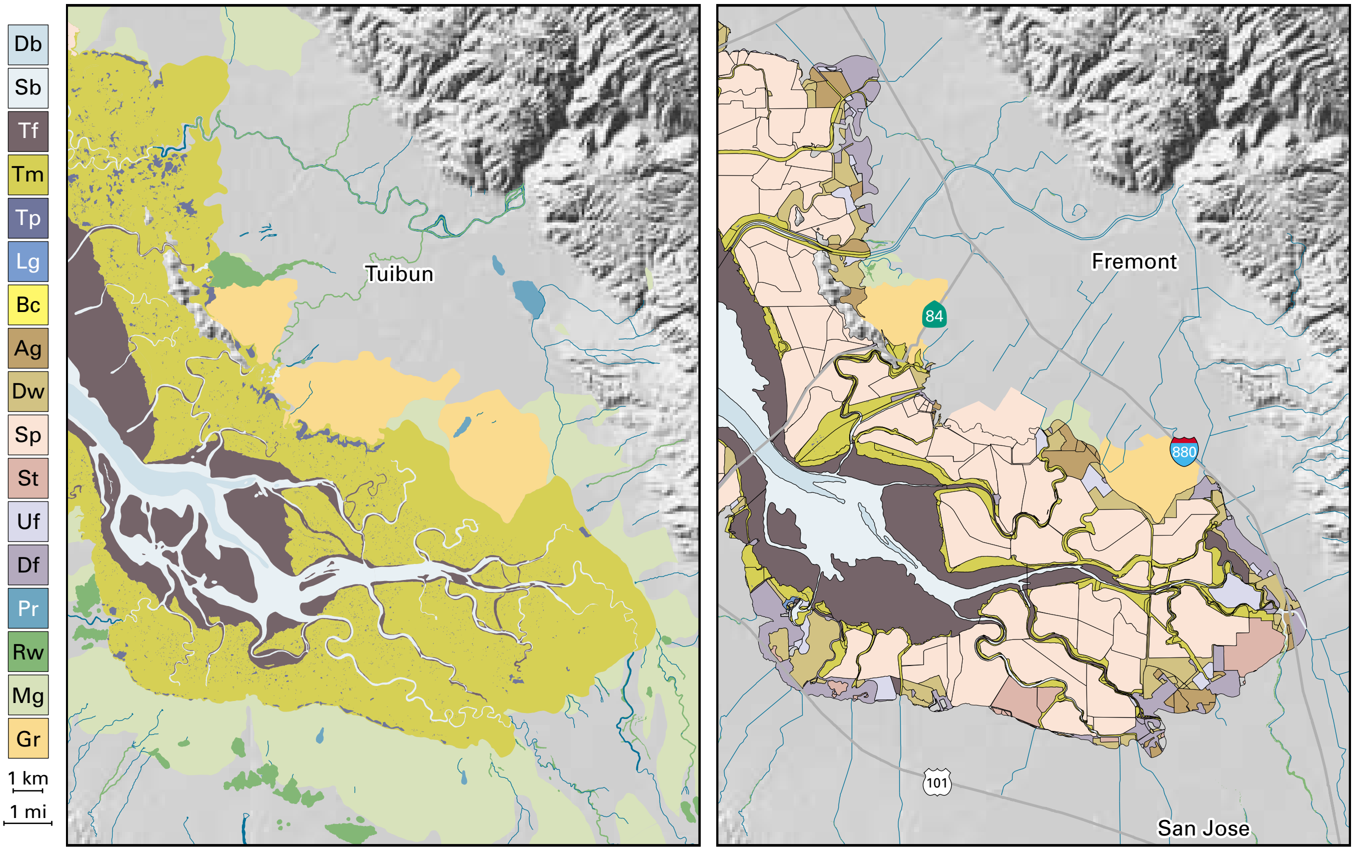
Unique Restoration Opportunities: This area provides excellent opportunities to develop large patches of tidal salt marsh along a major salinity gradient. This is one of few South Bay segments where it is possible to restore tidal brackish marsh. It is the only segment in South Bay where there is the potential to restore a large area of vernal pools near the baylands. It also is the only area where a wide transitional ecotone can be re-created between restored tidal marsh and a complex of vernal pools.

Recommendations:

- Restore tidal marsh throughout most of the segment, providing a continuous corridor of tidal marsh along the bayshore. The type of tidal marsh created (salt or brackish) will be dependent on the amount and proximity to local freshwater outflows. Restoration should emphasize reestablishing a natural transition between tidal marsh and adjacent wetlands and upland habitats, as well as transitions between salt and brackish tidal marsh.
- Modify and manage a large complex of salt ponds for shorebirds and waterfowl.
- Restore or enhance vernal pools in the adjacent undeveloped uplands.
- Reestablish native riparian vegetation and otherwise improve the riparian corridor along Coyote Creek.
- Manage discharges from the San Jose treatment plant to limit adverse environmental impacts, especially to tidal salt marsh habitat. Consider using recycled water to augment flows in Coyote Creek or for other habitat enhancements.

Unique Restoration Benefits: Implementing the recommendations would increase rare plant species populations by enhancing the tidal marsh/moist grassland transition zone and vernal pools in the Warm Springs area. This would benefit the only remaining populations of California tiger salamander and tadpole shrimp near the baylands. Restoring tidal marsh along the bayshore would provide dispersal corridors (where none now exist) for California clapper rail and salt marsh harvest mouse, allowing these species to move between neighboring segments while minimizing predation and decreasing vulnerability to local extinction. Enhancing in-stream conditions in Coyote Creek could benefit steelhead populations. Freshwater discharges from the San Jose treatment facility should be managed to minimize large-scale conversion of saline/ brackish tidal marsh while maintaining the large heron and egret rookery in Artesian Slough.

Possible Constraints: Pacific Gas and Electric Company transmission lines and other utility corridors, flood protection considerations, historical land subsidence, freshwater outflow from wastewater treatment facilities, operation and maintenance of salt ponds in absence of salt production, and smooth cordgrass.



Past

Present

Segment area:
11,196 acres

Segment Q — Mowry Slough Area

Subregion: South Bay

Location: Eastern edge of San Francisco Bay between Albrae Slough and Highway 84 (Dumbarton Bridge).

Major and Unique Features: Nearly all the wetlands within this segment were historically tidal salt marsh. These marshes supported extensive channel systems and numerous tidal marsh pans, including backshore pans along the marsh/upland ecotone. The mudflats outboard of the tidal marshes in the segment were moderate in size, with channel and shallow bay habitat more abundant than today. Extensive areas of poorly drained moist grasslands that supported vernal pools occurred in the adjacent uplands. Few streams entered the Bay in this area; consequently, riparian habitat was limited. Alameda Creek may have variously entered the Bay north of Coyote Hills, or south, in the vicinity of present-day Plummer Creek.

Today, the majority of the area is composed of diked salt ponds. However, this segment does contain the largest acreage of natural tidal marsh that exists in South Bay. These marshes at Dumbarton Point and the mouth of Mowry Slough

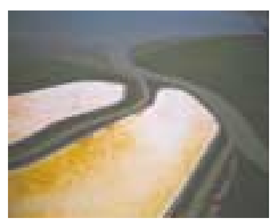
are centers for populations of California clapper rail and salt marsh harvest mouse. They currently support as much as one-third of the entire population of clapper rails remaining in South Bay. Mowry Slough provides an isolated haul-out area for harbor seals. The mudflats in this segment are important foraging areas for shorebirds.

Unique Restoration Opportunities: This segment provides the opportunity to restore and enlarge the Dumbarton/Mowry marsh complex of tidal wetlands, potentially expanding available habitat for a core population of the California clapper rail. There is the potential for modifying and managing salt ponds for the benefit of large numbers of shorebird species that forage on nearby mudflats. There are opportunities to restore historic tidal marsh/upland transitional habitat and associated vernal pool habitat at the upper ends of Newark, Plummer, Mowry, and Albrae sloughs. Another unique opportunity is the use of freshwater discharge from the San Jose wastewater treatment facility in Segment P to dilute bittern in the salt ponds.

Recommendations:

- Enlarge the Dumbarton, Mowry, and Calaveras Point tidal marshes, and provide a corridor of tidal marsh along the bayshore.
- Modify and manage for shorebirds and waterfowl a complex of salt ponds adjacent to and including the crystallizer complex between Mowry Slough and Newark Slough.
- Protect and enhance the tidal marsh/upland transition at the upper end of Mowry Slough and in the area of the Pintail duck club. Similar habitat can be protected and restored at the upper ends of Newark, Plummer, and Albrae sloughs.
- Protect the area of harbor seal haul-out along lower Mowry Slough.
- Consider, among other possible alternatives, using treated wastewater from the San Jose wastewater treatment plant to dispose of bittern.

Unique Restoration Benefits: Dumbarton and Mowry marshes contain a large source population of California clapper rail. This species would colonize any restored tidal marsh in this segment (California clapper rails have colonized several small diked wetlands that were recently restored to tidal action in the upper reaches of Newark Slough). One of the contributing factors to the health of clapper rail populations in this segment is that the marshes are large and have not been fragmented by levees. This makes them relatively resistant to dispersal of mammalian predators due to the absence of main travel corridors. Modifying and managing a system of salt ponds would increase snowy plover nesting habitat.



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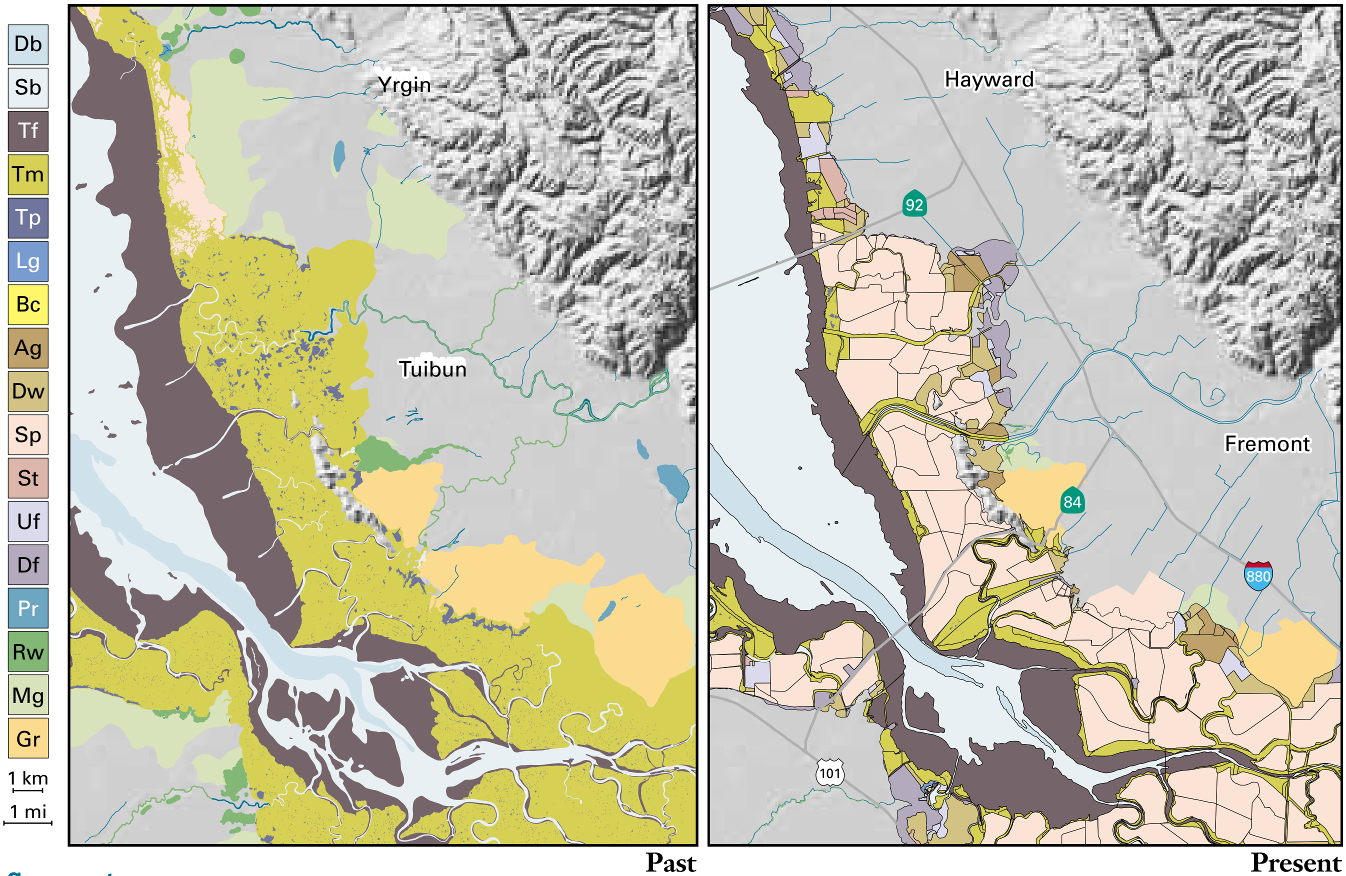
Possible Constraints: Union Pacific railroad tracks; Pacific Gas and Electric Company transmission lines, Hetch Hetchy Aqueduct, and other utility corridors; flood control considerations; operation and maintenance of salt ponds in absence of salt production; and current use of levees and salt pans by nesting snowy plovers.



Segment area:
4,703 acres

Segment R — Coyote Hills Area

Subregion: South Bay

Location: Eastern edge of San Francisco Bay between Highway 84 and Alameda Flood Control Channel.

Major or Unique Features: This area is dominated by Coyote Hills. Historically, the majority of the segment was tidal marsh. The marshes were expansive with well-developed channels and abundant tidal marsh pans. The marshes encircled Coyote Hills except to the east where moist grassland bounded the upper margin of the marsh. These grasslands were characterized by springs and seeps, willow groves, seasonal ponds, and a permanent freshwater pond at the foot of the eastern slope of the hills. Alameda Creek may have variously entered the Bay south of Coyote Hills, in the vicinity of present-day Plummer Creek, or just north of this segment. Outboard of the marshes were extensive tidal flats that continued north through Segments S and T.

Currently, most of the former tidal marsh is salt ponds. Coyote Hills and the large Alameda Creek Flood Control Channel are unique features. The diked baylands east of Coyote Hills support the largest remaining willow groves in the baylands ecosystem, seasonal and diked wetlands, and a permanent freshwater pond. The realignment of Alameda Creek through the northern portion of this segment has dramatically altered the hydrology of the area. Inactive salt ponds, salt pond beaches, and levees currently provide important snowy plover nesting habitat. Most of the snowy plover nesting in the South Bay subregion occurs in this segment and in Segments S and T to the north. The mudflats in this segment are very important foraging areas for shorebirds. This segment supports the largest population of non-native smooth cordgrass.

Unique Restoration Opportunities: This segment provides an opportunity to restore a corridor of tidal marsh along the bayshore. This corridor would connect the Dumbarton Marsh with the existing marsh to the north, along the Alameda Flood Control Channel. There also are opportunities to manage salt ponds for water birds adjacent to the restored marshes. This segment has excellent possibilities for restoring a natural marsh/upland ecotone on the western edge of Coyote Hills. On the eastern side of Coyote Hills, there are seasonal wetlands and willow grove habitat that could be restored or enhanced.

Recommendations:

- Maintain and manage a complex of salt ponds for shorebirds and waterfowl in the southern part of the segment and restore the remaining area to tidal marsh. Restoration should emphasize natural transition of tidal marsh/uplands at Coyote Hills and a continuous corridor of tidal marsh around Dumbarton Point.
- On the eastern side of Coyote Hills, enhance and expand muted tidal areas with improved water management.
- Protect and enhance existing willow groves and seasonal wetlands.
- Consider reintroducing coyotes into Coyote Hills to restore natural predator/prey relationships and to control the introduced red fox.
- Consider removing the flood control levees in the lower reaches of the Alameda Creek Flood Control Channel as part of restoration planning for this area.
- Control smooth cordgrass before restoring large diked areas to tidal marsh.

Unique Restoration Benefits: Restoring tidal wetland along the bayshore west of Coyote Hills would provide a dispersal corridor for California clapper rails between Dumbarton and Ideal marshes and the marshes north of the Alameda Creek Flood Control Channel. Restoring the tidal marsh/upland transition would provide high tide refugia for tidal species and increase habitat for rare plants. Maintaining and managing a system of salt ponds would provide snowy plover nesting habitat and roosting and foraging habitat for shorebirds and waterfowl. Controlling smooth cordgrass would minimize the spread of this species to neighboring, newly restored marshes.

Possible Constraints: Smooth cordgrass, flood protection considerations, predator corridor along Alameda Flood Control Channel, operation and maintenance of salt ponds in absence of salt production, and current use of levees and salt pans by nesting snowy plovers.

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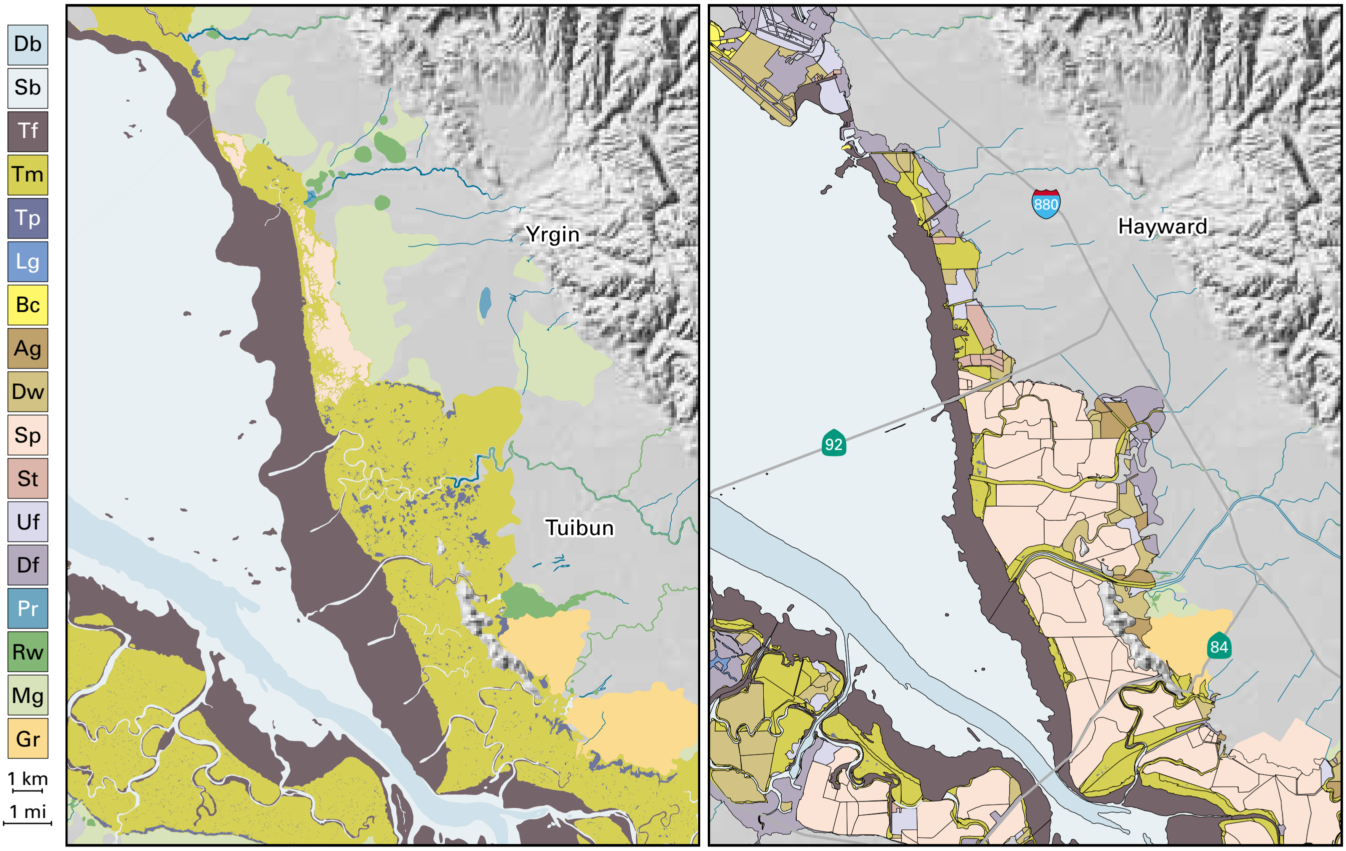


Past Present

Segment area:
9,933 acres

Segment S — Baumberg Area

Subregion: South Bay

Location: Eastern edge of San Francisco Bay between Alameda Flood Control Channel and Highway 92.

Major or Unique Features: Most of this segment was historically tidal marsh. These tidal marshes were very broad, with well-developed channels and abundant and large tidal marsh pans, including some backshore pans in the Baumberg area. Outboard of the tidal marsh were large areas of tidal flat. At the upland boundary of the marshes were grasslands, a limited amount of which was moist grassland capable of supporting seasonal ponding; the majority of this habitat was associated with the backshore pans near Baumberg. Alameda Creek, a major tributary to South Bay, entered the Bay in this segment. Due to its size, the Creek provided a significant zone of brackish tidal marsh. The Creek also supported well-developed riparian habitat and a run of steelhead. Turk Island, a northern extension of Coyote Hills, is in the southern portion of the segment.

Today, almost all of the tidal marsh has been converted to salt ponds. The largest extant tidal marsh is Whale's Tail Marsh, which was diked for salt production but abandoned in the 1920s. The other tidal marsh in the segment is just north of the Alameda Creek Flood Control Channel. This area was a salt pond restored with dredged material from the construction of the flood control

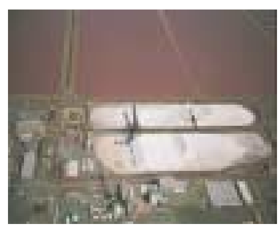
channel. Inadvertently, the restoration created a tidal marsh/upland transition by placing fill material above the intertidal zone on the eastern end of the site. Most of the snowy plover nesting in the South Bay Subregion occurs in this segment and in Segment T to the north and in Segment R to the south. The salt ponds in this area are important foraging and roosting habitat for shorebirds that use the nearby tidal flats.

Unique Restoration Opportunities: There are opportunities to restore tidal marsh to provide a dispersal corridor for California clapper rails where none currently exists. It also is possible to restore backshore pan habitat as part of tidal restoration in the Baumberg Tract. Opportunities exist for modifying and managing salt pond complexes to provide shorebird foraging/roosting habitat.

Recommendations:

- Modify and manage for shorebirds and waterfowl two complexes of salt ponds — one in the Turk Island area and one in the Baumberg Tract area (including the southern Oliver Brothers ponds).
- Restore the remaining areas to tidal marsh, ensuring a continuous corridor of tidal marsh along the bayshore, and incorporate shallow pans in the marsh designs.
- Enhance the Alameda Flood Control ponds in the Turk Island area as either tidal or muted tidal marsh.
- Maintain and enhance the existing willow grove and managed diked wetlands on the eastern side of the active salt ponds in the Turk Island area.

Unique Restoration Benefits: Restoration of tidal marsh and associated backshore pans could benefit sensitive plant species and provide refugia for tidal marsh species and shorebirds. Modified salt ponds would provide nesting habitat for snowy plovers and other resident shorebirds and terns; they also would provide waterfowl habitat.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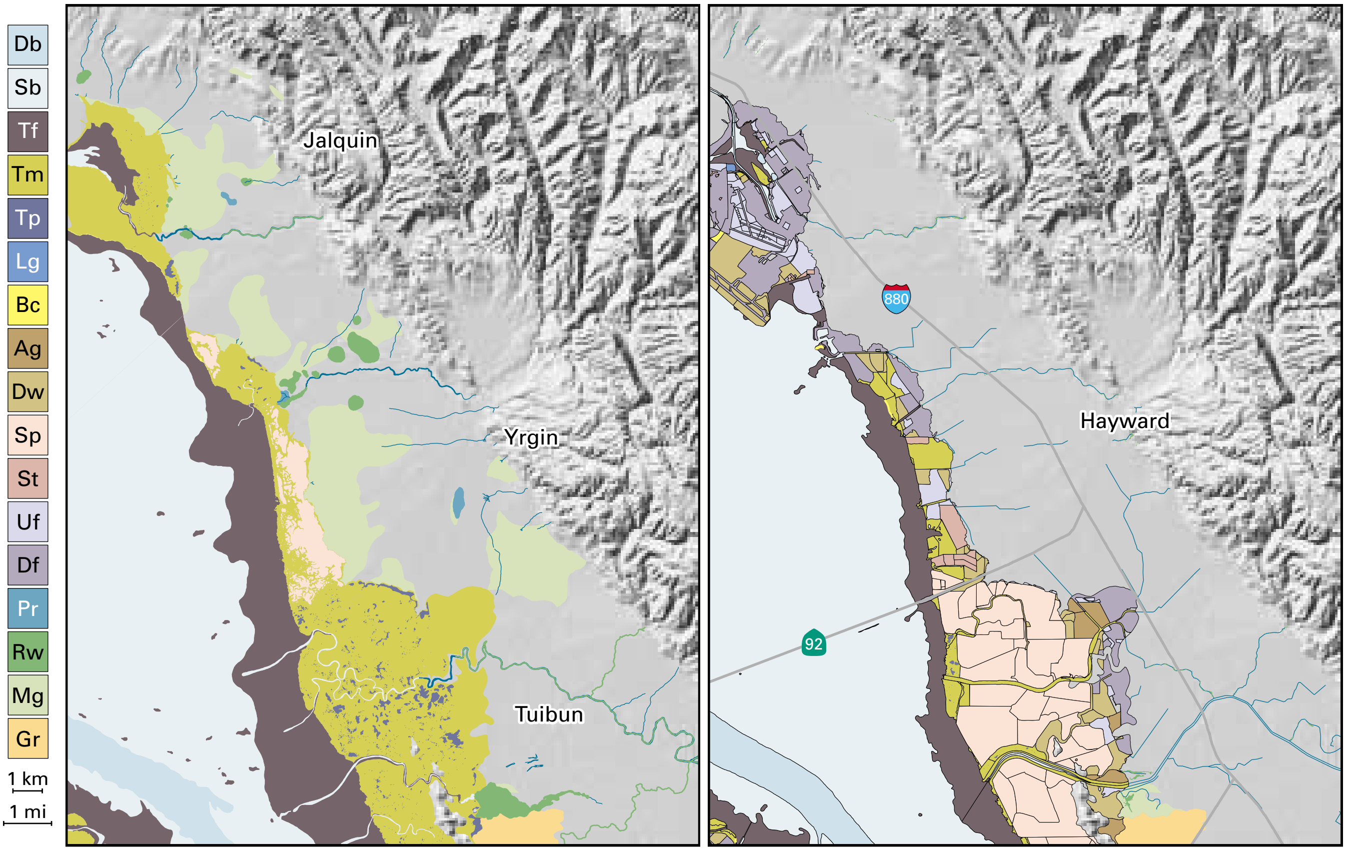
Possible Constraints: Smooth cordgrass, flood protection considerations, East Bay Dischargers Authority waste water pipeline, Pacific Gas and Electric Company transmission lines and other utility corridors, major predator access corridor on Old Alameda Creek, operation and maintenance of salt ponds in absence of salt production, and public access and recreation.



Past

Present

Segment area:
4,584 acres

Segment T — Hayward Area

Subregion: South Bay

Location: Eastern edge of San Francisco Bay between Highway 92 and San Leandro Marina.

Major or Unique Features: This segment historically supported several unique features, including a large salt pond (Crystal Salt Pond), sandy berms, and barrier beaches. Along the foreshore of the Bay, there was a narrow but continuous band of mudflat. At the upland edge and in the adjacent lands, there were large areas of freshwater seeps and seasonal wetlands in the extensive moist grasslands. Several willow groves existed adjacent to Sulfur and San Lorenzo creeks.

Today, this segment's major features are the muted tidal marshes at Roberts Landing, Oro Loma Marsh (with its remaining natural connection to the adjacent uplands), Cogswell Marsh, Hayward Treatment Marsh, and Hayward Area Recreation District Marsh. Other features include the inactive Oliver Brothers Salt Ponds, stretches of sandy beach, and landfills. Cogswell Marsh supports a growing population of California clapper rail, but is dominated by smooth cordgrass. The Hayward Treatment Marsh provides nesting habitat for herons and egrets and for resident shorebirds and terns. This segment is the southern limit for California sea-blite on the Bay's eastern edge.

Unique Restoration Opportunities: This segment provides an opportunity to restore natural salt ponds or backshore pans, sandy berms, and barrier beaches. It also is an area where it may be possible to have natural transitions from tidal marshes into the adjacent uplands, particularly in the Roberts Landing area.

Recommendations:

- Restore sandy berms and barrier beaches along the shoreline.
- Restore natural salt pond or backshore pans in the diked marshes adjacent to the West Winton Avenue landfill area and in the old oxidation pond to the south.
- Establish or maintain a complex of managed salt ponds to the north of Highway 92, including shallow pans.
- Protect the wetlands adjacent to the Hayward Area Recreation District Marsh and enhance tidal influence to the entire marsh system.
- Control smooth cordgrass.
- Reintroduce California sea-blite and associated flora in suitably restored habitat.

Unique Restoration Benefits: Restoring sandy berms and barrier beaches would provide high tide roosting habitat for shorebirds and would facilitate the reintroduction of California sea-blite and other associated high marsh plant species. Restoring natural salt ponds or backshore pans and improving the existing salt ponds would provide more nesting habitat for snowy plover and other resident shorebirds, and would enhance foraging and roosting habitat for migratory shorebirds and waterfowl.

Possible Constraints: East Bay Dischargers Authority pipeline, extensive stands of smooth cordgrass, Pacific Gas and Electric Company transmission lines and other utility corridors, Southern Pacific railroad tracks, and flood control levees for adjacent areas.

CHAPTER 6

Restoring and Enhancing Habitats: Things to Consider

Near the end of the process to develop habitat goals, the RMG decided that the final Project report should present more than just recommendations of habitat acreage and distribution — it should provide guidance to the project planners, agency personnel, and landowners that will implement the Goals recommendations. Thus, this chapter contains specific and general recommendations on a variety of technical and public policy issues.

This chapter is divided into three sections. The first section reviews several Bay Area habitat restoration and enhancement projects and some lessons that have been learned from them. The second section describes features of good habitat and presents recommendations on habitat design and management. The third section contains additional information and recommendations on a number of issues relevant to improving Bay Area habitats.

Habitat Restoration and Enhancement — Lessons Learned

At one of the Project's public workshops, several people voiced concerns about recommendations in the draft Goals report. Some stated that restoring large areas of tidal marsh would amount to little more than a big experiment. One person said that there have been no successful tidal marsh restoration projects in the Bay.

Project participants recognize that the science of habitat restoration is young (see Chapter 7). However, many wetland projects have been undertaken around the Bay during the past several decades and they have taught managers and scientists many important lessons. This section reviews some of these projects and describes some of what has been learned. Sharing this kind of information among the larger community will be important for successful regional habitat restoration and enhancement.

Wetland restoration and enhancement efforts of various kinds have been underway in the Bay Area since the late 1960s, and activities to enhance waterfowl habitat on managed wetlands have an even longer history. During this time, most wetland projects have been implemented as compensatory mitigation for development projects that destroyed or degraded wetlands. Even with several decades of experience, however, wetland restoration and enhancement remains controversial, and reviews of wetland creation projects have often been critical (Kentula et al. 1992, Race 1995). One of the most common shortcomings of tidal marsh restoration projects has been the inability to re-create all of the functions of a natural marsh (Zedler and Langis 1991).

Among the most detailed analyses of tidal marsh restoration in California are those from the Southern California coast (Zedler 1996). Some of the failures of Southern California tidal marsh restoration are due to specific restoration site conditions, predominately low-nutrient sandy substrates and low sedimentation rates, which are not typical of the San Francisco Estuary. Other factors, however, such as excess freshwater discharge and exotic plant invasions affect marsh restoration in this region as well. Generalizations about results or feasibility of tidal marsh restoration should be interpreted cautiously in appropriate regional contexts.

Several factors compromised the success of early wetland projects. One of the major factors was poor project design. Early projects that were developed to meet mitigation requirements tended to focus on specific habitat attributes and often incorporated unrealistic design, siting, and size constraints; far too often, this guaranteed failure, particularly for riparian restoration. Another factor was the requirement to undertake mitigation on the same site as the development impact, and to create the same type of wetland habitat. This often resulted in mitigation projects being sited in disturbed or marginally suitable locations. Also, a lack of clear or realistic objectives frequently made it difficult to determine whether a wetland project was a success or failure (BCDC 1988, Gahagan and Bryant 1994).

Over the years, restoration science has progressed substantially as scientists have learned from their early mistakes and have developed a better understanding of how natural wetlands function. Many articles and publications have been produced, particularly for tidal marsh restoration, and these provide a good basis for planning and implementing projects that have a high likelihood of success (Josselyn and Bucholtz 1984, PERL 1990, Zedler 1996). There has been substantial headway in restoring wetlands other than tidal marsh — particularly seasonal wetlands, vernal pools, riparian forest — and in developing planning protocols that can provide a high certainty of success. In all cases, most successes stem from selecting suitable sites and relying on natural processes for wetland evolution and long-term management.

Tidal Marsh

Mussels make a channel bed.

Josh Collins

A large number of sites have been restored to tidal influence within the Estuary, both purposefully and thorough natural processes. The most celebrated are the large mitigation projects, many of which have been accompanied by controversy and scrutiny. These projects include the Faber Tract in Palo Alto, Pond 3 in Hayward, Cogswell Marsh on the Hayward Shoreline, Muzzi Marsh in Corte Madera, and the Sonoma Baylands Project. All of these projects were highly designed and many incorporated the use of dredged material in their construction. Although they have had difficulty in meeting specific restoration objectives, as they develop and mature, they provide valuable wildlife habitat and a basis for the design of future projects. The older projects, such as Faber, Cogswell, and Muzzi marshes have developed many characteristics of adjacent natural marshes and support populations of endangered species. Muzzi Marsh has evolved for some 20 years and during this time the channel morphology, vegetative cover, and animal use have changed considerably (Josselyn, pers. comm.). In effect, these projects are part of an ongoing adaptive management program that will guide future bayland restoration.


Josh Collins

Brackish marsh goes to seed.

These projects demonstrate that dredged material can be useful in restoring subsided sites. This material may be particularly beneficial in re-creating habitat components, such as beach ridges and marsh/upland transition zones, on sites where they do not naturally occur and are unlikely to develop on their own. However, in most instances, one must be careful to allow natural sedimentation to establish final marsh plain elevations. Placement of fill material to elevations that are too high may inhibit channel formation and tidal circulation, and may produce less diverse habitats.

Another lesson learned from these projects is that sites must have unrestricted tidal connections to assure a full tidal range and timely development of target habitat components. Also, experiments in planting non-native marsh plants must be avoided (subsequent information in this chapter describes some of the problems caused by non-native invasive plant species).

Less well-known examples, but probably more important in guiding future restoration of tidal wetlands, are the large areas of the Bay where restoration has been left largely to natural processes. These include Outer Bair Island in Redwood City, Toy Marsh in Novato, White Slough in Vallejo, Whale's Tail Marsh in Hayward, Hoffman Marsh in Richmond, Petaluma River Marsh, and Pond 2A in the Napa Marsh. With the exception of Hoffman Marsh, which was a mudflat until the late 1940s (Haltiner, pers. comm.), these are previously diked areas where the levees have been breached purposely or through neglect. All of these sites, many highly subsided, have evolved over the course of many decades into productive marshes with characteristics similar to natural reference marshes.

These examples indicate that, in many parts of the Bay, the Bay water carries enough sediment to sustain the evolution of appropriate marsh elevations, even on highly subsided sites. Some sites, such as Pond 2A and Bair Island, have shown that remnant tidal channels may provide a template for channel formation. At Whale's Tail Marsh, well-developed marsh vegetation has formed in former salt crystallizers (Patrick and DeLaune 1990), and pans that are characteristic of large undisturbed and historic marshes have formed in the marsh plain. Natural re-vegetation occurs rapidly once appropriate conditions exist, and planting of dominant marsh species is generally not needed or effective in accelerating establishment of tidal marsh vegetation. Also, sites such as Toy Marsh have demonstrated that tidal scour can open small channels and that full tidal exchange develops with time. This also has been demonstrated at the Mini site in Napa County (Wilcox, pers. comm.).

Restored tidal marshes evolve over time, and sites that are initially lagoons or mudflats provide important habitat for fish and wildlife. For example, Sonoma Baylands and Upper Tubbs Island currently are microtidal lagoons, but they receive high use by dabbling and diving waterfowl, particularly in late fall and early winter, and by shorebirds. Monitoring at Sonoma Baylands indicates that the lagoons provide habitat for important fish species including juvenile Chinook salmon (USACE 1997; Heib, pers. comm.).

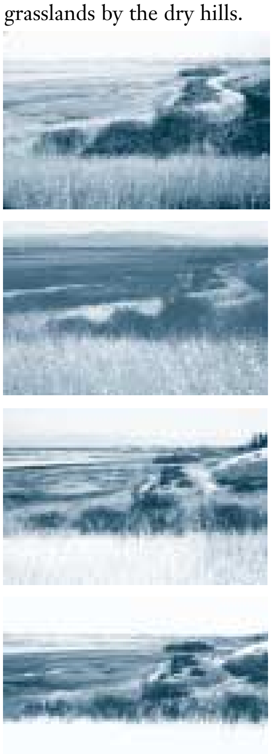
Some tidal marsh restoration projects have developed much faster than anticipated. Two recent examples are the Petaluma River Marsh Restoration Project and Pond 2A. The subsided 45-acre Petaluma River project, initiated in 1994, developed high mudflat, pioneer low marsh plant colonies on mudflats, and abundant peripheral low marsh vegetation in less than three years (Siegel 1998). The breaching of the 550-acre Pond 2A (an inactive salt pond) in 1995 resulted in greater than 80 percent brackish tidal marsh vegetation cover by 1998 (Wycoff, pers. comm.). Prior to these two projects, many scientists believed that native cordgrass was inherently slow to colonize restored sites.

The Petaluma River Marsh Restoration Project also demonstrated that grading unneeded levees to about the marsh plain elevation facilitates rapid establishment of high tidal marsh vegetation. This minimizes habitat for non-native invasive plants and access for predators, while providing high-tide refuge for small mammals.

Additional information has been drawn from observations of the way tidal marsh features develop, or fail to develop, over time. For example, if a large site is to be restored in phases, restoration should proceed from upstream to downstream. Also, the initial channels should be designed large enough to assure full tidal excursion to the site's upstream portion; otherwise, the upstream location may never receive sufficient tidal flows and suspended sediment for natural marsh restoration. An oversized channel is better than an undersized channel, since the channel dimensions will tend to naturally decrease faster than they can increase.

Seasonal Wetlands

Groundwater wets the grasslands by the dry hills.



Josh Collins

The science of seasonal wetland restoration and enhancement is not well developed. However, restoration ecologists have evolved techniques for restoring or enhancing some of these kinds of wetlands. Projects in the Central Valley and in the Santa Rosa area indicate that the most successful seasonal wetland projects are those that are sited in areas with suitable soils and that rely on natural hydrology (CH_2MHill 1995; Stromberg, pers. comm.). Although their design has been controversial, several projects in the Santa Rosa area mimic natural vernal pools in many respects and have maintained themselves for as long as ten years (Patterson, pers. comm.; Wilcox, pers. comm.). These results are promising for restoration and enhancement of seasonal wetlands adjacent to the baylands.

In most of the diked baylands, seasonal ponds have been the products of farming or of passive neglect. An example of this sort of passive management is at Cullinan Ranch, a 1600-acre derelict farm north of Highway 37 in Napa County. When this site was producing oat-hay, it required extensive pumping to maintain dry conditions. When farming ceased, the site rapidly developed features of fresh and brackish seasonal marsh — with plants such as cattail, spikerush, brass-buttons, and fat hen — and deep ponds and mudflats. The site now attracts and supports nesting and feeding waterfowl and shorebirds (Takekawa, pers. comm.).

More recently, bayland restoration project designs have begun to incorporate shallow pond features that are maintained by infrequent tidal flooding or by rainfall. The designs for the Hayward Area Recreation District Marsh and the Baumberg Tract project included managing inactive salt ponds to enhance shorebird habitats during fall and winter and snowy plover breeding habitat during spring and summer (Woodward-Clyde 1998, RMI 1999). The Oro Loma Marsh Restoration Project design included habitat similar to backmarsh ponds, which provide fluctuating shallow water for shorebirds and waterfowl, particularly in late summer through early winter (Levine-Fricke 1993). The Martin Luther King, Jr. Shoreline Wetland Restoration Project design included seasonal ponds adjacent to a newly restored tidal marsh (Levine-Fricke 1996). Future plans for upland dredge disposal sites at Petaluma and San Leandro will include enhancing seasonal ponding for shorebirds and waterfowl.

Many of these projects have only recently been completed or are still in the planning and implementation phases, so it is too early to evaluate their effectiveness. However, monitoring at Oro Loma indicates high use by the target species (Didonato, pers. comm.).

In planning and constructing seasonal wetlands, it is imperative to consider seasonal water availability, site hydrology, site substrate permeability, and site topography. Inadequate assessment of these factors will decrease the chances of creating high quality habitat.

Freshwater Marshes

The creation of freshwater marshes in the baylands has been limited primarily to projects using treated wastewater, stormwater, or flood flows. The Hayward Treatment Marsh and Mountain View Sanitation District Marsh are examples of marshes created with wastewater. The Coyote Hills Demonstration Urban Treatment Marsh receives stormwater flows. The Ygnacio Pond and Hanna Ranch in Novato are examples of marshes designed as integral features of flood control projects. In addition, there are several small freshwater marsh enhancement projects in Napa Marsh that rely on seasonal rainfall.

All of these freshwater marshes support permanent emergent vegetation and open water habitat. The North Bay marshes provide habitat for breeding waterfowl and other water birds. The Hayward Treatment Marsh supports large numbers of wintering waterfowl, an egret rookery, and nesting habitat for resident shorebirds and terns (Taylor, pers. comm.). Additionally, the small wastewater ponds at the Redwood City Wastewater Plant at Redwood Shores receive substantial use for their size, and probably contribute to the heron and egret rookery there (Baye, pers. comm.).

These freshwater marshes indicate that it is possible to use various sources of freshwater to create valuable wildlife habitat in and adjacent to the baylands and to provide other wetland functions. In using these kinds of water sources, however, it is critical to consider the seasonal nature of the water supplies and its effect on habitat functions. It also is important to assess potential contaminant effects.

Riparian Forest

Riparian forest restoration and creation has been underway in the Bay Area for many years, with limited success. Of all the wetland types, riparian forest may be the most difficult to restore because it must exist in proximity to a stream or on a flood plain. Success in restoring riparian habitats depends on imitating natural habitat (Baird 1989). Projects that ignore natural processes or that attempt to establish riparian vegetation at unsuitable sites are almost guaranteed to fail.

In rural parts of the Bay Area, streams are subject to rapidly changing conditions of erosion or sedimentation. Most are eroding along their banks and cutting down below their historical floodplains. As a result, their riparian forests

Some creeks have backyards.

NASA 1996/95

are being lost. Restoring them will require managing watersheds to reduce runoff and erosion.

Most of the region's urban streams have been channelized. This has severely limited their potential for restoration. Flood control levees may support some riparian trees, but only to the extent that this does not compromise the integrity of levees or other structures.

Objectives for flood control and riparian restoration have been met successfully on the lower reaches of Coyote Creek and Wildcat Creek (Riley 1998), and Novato Creek (Prunuske Chatham 1998). Plans are being developed to restore riparian functions along the lower Napa River in the context of flood management.

It is possible to design projects that provide flood control benefits and significant riparian functions. This requires careful planning by an interdisciplinary team of engineers, fluvial geomorphologists, and biologists. It also should involve extensive public input early in the process.

Many of the Bay Area's flood control districts are responsible for maintaining projects that were designed and constructed many decades ago, when there was much less appreciation for naturally functioning riparian systems. Today, several districts have efforts underway to repair some of the damage done by these projects, and these likely will continue for years to come. Perhaps the main lesson learned from recent experiences on local streams is that planning for flood control and riparian forest restoration must recognize the constraints and possibilities posed by activities throughout the watershed.

Site Assessment

One of the important lessons learned from past restoration and enhancement projects is the significance of complete site information. Each potential project site must be rigorously evaluated to determine its suitability for the proposed project. The major factors to assess include the site's historical and current conditions and its water and sediment supplies. To help ensure a successful project, the site should be assessed within a framework of well defined, quantifiable, ecological goals and objectives.

Site Conditions

A complete site assessment should consider a site's environmental history as well as its current conditions. It should assess current and historical land use, natural and unnatural disturbances (such as contaminant storage or leakage), levee failure and flooding, and sediment disposal. Evaluating site hydrology is particularly important and should include assessing water control structures such as tide gates, siphons, ditches, pumps, wells, storm drains or other outfalls, flood bypass channels, and remnant tidal marsh channels. For tidal marsh restoration, it is imperative to consider the site's historical drainage patterns, including the location of remnant channels and their confluences with adjacent tidal marsh channels, streams, or bays. Groundwater discharge should be considered for any site located at the base of a hill or downslope of a shallow aquifer.

A site evaluation should also consider existing and future uses of neighboring lands. If there are other potential restoration sites nearby, the planner should determine their possible physical and hydrological interactions with the proposed project. The project should be designed in the context of the future landscape.

Flood recedes and leaves debris.

Elise Brewster

Project planners should use site assessment information when designing and locating habitat components. For example, seasonal ponds in diked wetlands might be located adjacent to ditches to facilitate managing water levels, and levees might be breached where they cross historical tidal marsh channels in order to reestablish these features.

Water and Sediment Supplies

Site assessment must include an evaluation of water and sediment supplies that originate off site. As explained in Chapter 2, water and suspended sediment are key in controlling the initial formation and natural development of wetland habitats. In the context of restoration design and management, it should be kept in mind that tidal marsh depends on adequate sediment supply, whereas managed marsh, seasonal ponds, and tidal channels depend on adequate water supplies. Bayland restoration or enhancement projects must function within the limits and opportunities established by these natural controls.

The consideration of these controlling factors will involve determining site surface elevations relative to the tides, and the expected changes in tidal elevation due to sea level rise or ground subsidence. It also will entail evaluating the quantity and quality of water and suspended sediment supplies. Past professional experience, predictive models, and the study of reference sites are useful in estimating probable sediment deposition rates and other physical changes that the site will undergo as it evolves.

Habitat Design and Management

Implementing the Goals recommendations will require designing, constructing, and managing many kinds of habitats in and adjacent to the baylands. This section describes, for many of the habitats of the baylands ecosystem, the attributes of high quality habitat. It also presents recommendations on habitat design and management. The habitats are organized according to the Project's habitat typology.

Bay Habitats

Eelgrass

Eelgrass beds are the only Bay habitat for which Project participants made design and management recommendations. The distribution of eelgrass beds in the Bay is quite limited, and it is difficult to control the factors that determine where this habitat will thrive. Reducing turbidity is one of the most important factors that will allow an increase in eelgrass acreage.

High quality eelgrass beds are:

- Free of chemicals that are toxic to desired organisms.
- Geographically stable over the long term.
- Located in non-erosive environments.
- Rooted in a substrate of medium to fine sediment.

The design and management of eelgrass restoration projects should:

- Recognize that the local wave energy environment will determine sustainability.

Management Objectives and Project Design

When undertaking a project to restore or enhance a particular site, it is important to establish specific management objectives and to determine if the site can be designed and managed to meet these objectives.

Often, a primary management objective is to provide support for one or more particular species. In these cases, the project planner should identify the species for which habitat is to be provided and assess the species' habitat requirements. The planner should then carefully consider whether the selected site can support the desired habitat features.

It is much better to determine early on that a site is not suitable for a particular kind of habitat than to discover this several years after project construction.

- Minimize anthropogenic turbidity in order to increase transplanting success.
- Enhance beds by revegetating areas within bed margins.
- Restore beds only where key water quality features (e.g., low turbidity, well-oxygenated sediments) indicate a high likelihood of success.
- Schedule planting when water is warmer.

Bayland Habitats

Tidal Baylands

Project participants made design and management recommendations for three tidal bayland habitats: tidal flat, tidal marsh, and muted tidal marsh.

Tidal Flat

Resource managers have little control over the factors that determine the distribution of tidal flats in the baylands — this habitat occurs at the water's edge wherever there is suitable topography, sediment supply, and currents. They do, however, have some control over the way that tidal flat is managed. This section highlights the characteristics of high quality tidal flat and identifies several management considerations.

High quality tidal flat has:

- An absence of vascular vegetation, except for eelgrass.
- Diverse and abundant infauna and epifauna attractive to shorebirds at low tide and macroinvertebrates and fishes at high tide.
- No, or few, non-native invasive species.
- A range of particle sizes from sandy to clay.
- Salinities that are not subject to rapid fluctuation.
- Well-oxygenated sediments and low contaminant concentrations.
- A wide area with little shoreline disturbance.

Tide drains straight off flats.

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The design and management of tidal flat restoration projects should:

- Maximize distance from adjacent upland edge.
- Ensure sediments free from chemical conditions toxic to desired organisms.
- Ensure absence of pilings, powerlines, and other artificial structures.

- Locate flats between subtidal and tidal marsh habitats.
- Minimize human disturbance.
- Regularly assess the level of human access.
- Ensure presence of immediately adjacent, protected roosting areas.

Tidal Marsh

There is great potential for large-scale tidal marsh restoration in the Bay, although much needs to be learned about restoring marshes that have a full complement of natural components. Restoring tidal marsh will directly affect the processes that form and maintain deep and shallow bays and channels, and tidal flats. As noted in Chapter 2 and in the next section of this chapter, large-scale tidal marsh restoration will affect tidal prism, sediment deposition and scour, and possibly salinity gradients.

There is significant natural geographic variation in tidal marshes throughout the Estuary, and tidal marsh restoration designs should vary according to local conditions. Depending on management objectives, a design may emphasize different amounts of natural restoration and habitat components. The components to consider are large and small tidal channels, natural and artificial levees, pans, and the vegetated plain. All of these components will evolve in some form on their own in the suitable setting, but they can also be created or nurtured through restoration design. The relative abundance of these components can also be controlled, at least through the early phase of marsh maturation.

Although large patches of tidal marsh should be restored at many sites around the Bay, not all marsh restoration projects need be large. Small patches (i.e., a few acres) of tidal marsh can be ecologically important and may provide especially valuable habitat to certain plants and animals. Even small wetlands may be very important in maintaining populations of wetland-associated animals (Gibbs 1993). Regardless of their size, tidal marshes should be designed and managed to provide a gradual transition zone from the marsh plain to the adjacent uplands.

Tidal wetlands take time to develop; when a site is restored, the initial set of habitat components will evolve for many years. After establishment, a tidal marsh with adequate sediment supply typically evolves in the following way: (1) the drainage network becomes less complex, (2) remaining channels become deeper and narrower, (3) salinity gradients across the marsh plain become more variable and steeper, (4) the amount of marsh plain that is not directly serviced by any channel increases, (5) surface drainage decreases, and (6) the amount of pans increases. Even at restoration sites where there is rapid sedimentation (e.g., Pond 2A in North Bay and the Petaluma River Marsh), it may take many years, even decades, before the marshes exhibit a full array of habitat features. Thus, tidal marsh restoration designs should take into account the probable changes that will occur over a long time period. They also should consider the eventual set of habitat components that is likely to exist when the site matures.

High quality tidal marsh has:

- A well-developed system of tidal channels.
- A natural transition to adjacent uplands.
- Wide upland buffers to minimize human disturbance.
- Connections with other large patches of tidal marsh that enable marsh-dependent birds and small mammals to move safely between them.

Channels wind around pans.

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A pan holds water past low tide.

- Pans in the marsh plain and along the marsh/upland transition.
- Other wetland types and mudflats nearby.
- A dominance of appropriate species of native plants and animals.
- A minimum of uplands or structures intruding into or fragmenting the marsh to discourage predator access.

The design and management of tidal marsh restoration projects should:
- Assess the salinity regime (including artificial freshwater flows) and tidal range in the area where restoration is planned; there should be congruence between the physical parameters of the area (salinity, tidal range) and the expected habitat structure.
- Provide unrestricted tidal exchange, except where muted conditions are necessary or desired (see Muted Tidal Marsh discussion). Where full tidal exchange is not possible, encourage maximum tidal amplitude.
- Rely as much as possible on natural sedimentation processes. Natural sedimentation is preferable if adequate sediment supply is available for timely restoration of desired habitat.
- Utilize remnant natural channels (if present) as the template for channel formation. Fill borrow ditches when possible to keep them from capturing tidal circulation.
- Provide topographic variation to mimic natural conditions within the marsh. Provide small supratidal islands, at or slightly above MHHW, by leaving remnant levees or placing fill at appropriate elevations.
- Grade unneeded levees to marsh elevations (at or slightly above MHHW) when restoring diked baylands. Levee remnants will continue to reduce erosion and to provide high-tide roosting habitat, while discouraging predator access and invasion by weedy species.
- Design levees, where required as part of the restoration, to mimic naturally occurring transition zones (the slope should be as flat as possible).

Restoring Natural Salt Ponds

Historically, there was a large area of natural salt ponds and tidal salt marshes in the baylands near Hayward. It would be beneficial to re-create some naturalistic, unmanaged facsimiles of these ponds at appropriate locations within restored tidal marsh complexes. This could be achieved quickly by constructing very low berms (less than one foot above MHHW) across shallow basin floors near MHW elevation. Natural processes also could lead to the formation of salt ponds, but this likely would take many decades.

Natural salt ponds would provide conditions of near-marine salinity within a large marsh/pond complex, and this would help conserve viable populations of *Ruppia maritima* and unique pond fauna (Barnby et al. 1985). They also would encourage diverse macroalgae beds and provide unique feeding habitat for water birds. Based on historical and current conditions, it seems that natural salt ponds could be constructed near the landward edge of restored tidal marsh on the Bay shoreline in Alameda County.

- Provide for ongoing control of undesirable species including non-native invasive plants, undesirable predators, and mosquitoes. In the case of smooth cordgrass, undertake control as part of pre-construction.
- Rely in most instances on natural colonization by plants; however, there are some rare plant species that need to be reintroduced.
- Provide broad corridors (300 feet or wider) to connect neighboring marshes, except when the marshes are very small.
- Wherever possible, restore tidal marshes on sites that are contiguous with uplands and alluvial soils, seeps, and streams to facilitate establishment of natural transitions.
- Provide a buffer at least 300 feet wide between the upper edge of the marsh/upland transition and neighboring areas of developed use.

Muted Tidal Marsh

A muted tidal regime is required where a tidal marsh is desired, but where tidal flow must be limited to prevent site inundation. Muted marshes can provide many habitat functions for fish and wildlife that are similar to those provided by fully tidal marshes, and they should be considered where a fully tidal marsh would be unacceptable. Also, in some instances (e.g., the Cargill mitigation site near Whale's Tail Marsh), it may be preferable to create a muted tidal marsh as a first step in restoring full tidal action. This would enable sedimentation and would provide foraging habitat for shorebirds, but it would prevent the site from being completely inundated.

Restricting tidal flows can encourage specific tidal habitat features in subsided areas. It can enable the development of salt marsh habitat that mimics conditions of higher, fully tidal marshes. It also can help maintain tidal flats and open water habitat on sites that normally would become vegetated, a benefit for fish. Restricting tidal flows also can desynchronize tidal inundation, providing tidal flats that are available for shorebird foraging and roosting during high tides.

High quality muted tidal marsh has:

- Open water areas that are subject to restricted tidal influence and which provide important habitat for diving ducks, terns, and pelicans.
- Areas maintained as tidal flat with desynchronized tidal flooding to provide important high tide foraging and roosting habitats.

The design and management of muted tidal marsh should:

- Assess site constraints. A muted tidal regime should generally be considered for tidal marsh restoration only when full tidal action cannot be achieved due to flood control considerations or when it would not meet wildlife or habitat objectives.
- Consider elevating roads, rail lines, or transmission towers, especially when these structures are scheduled for upgrading. This would facilitate the eventual restoration of full tidal action to a site.
- Monitor hydrology and sedimentation to assure that there are desired conditions for healthy marsh vegetation.
- Consider developing muted tidal ponds or lagoons on subsided lands for waterfowl management. Such conditions would provide shallow water fish habitat without entrapment concerns.

A Note on Managing Habitats

Some habitats of the baylands ecosystem maintain themselves largely through natural processes, although they may require some management (e.g., control of non-native invasive plants) in order to provide maximum habitat functions. These are loosely referred to as "self-maintaining" habitats and include eelgrass bed, tidal flat, tidal marsh, some muted tidal marsh, riparian forest, and willow grove. Other habitats require more active and ongoing management in order to provide desired attributes or functions. These are referred to as "managed" habitats and include diked wetland, agricultural bayland, and salt pond.

The Goals recommend increasing the acreage of self-maintaining habitats. This will not eliminate the need for managed habitats (in some areas management will need to be very intensive), but overall it will help reduce it. The need for habitat management should be assessed as an integral part of any restoration or enhancement project; when management is necessary, it should be carefully planned and fully budgeted (see page 170 for more information regarding the costs of habitat restoration).

Within the diked baylands, managing lands specifically for wildlife — as at state wildlife areas, federal wildlife refuges, or duck clubs–usually results in the best wildlife habitat. However, management for other land uses, such as farming or salt production, also may provide valuable habitat.

Diked Baylands

Project participants made design and management recommendations for three of the four diked bayland habitats: diked wetland, agricultural bayland, and salt pond. They made no recommendations for treatment/storage ponds, as these are already subject to stringent management review. All of these habitats are managed to some degree for specific objectives, and past and present management actions influence their ability to support certain species of plants, fish, and wildlife. For example, the current farming practices of groundwater management, mowing, disking, or grazing strongly influence the conditions of agricultural baylands for various wildlife species. Converting any of these habitats to a different type of managed habitat will require careful planning and extensive long-term site management.

The habitat Goals call for restoring large areas of agricultural baylands to tidal marsh and managing the remaining areas primarily as diked wetlands, especially seasonal wetlands. They also call for managing some salt ponds in a manner that will make them more valuable for fish and wildlife. These changes should not be effected simply by discontinuing management practices; without adequate habitat design and ongoing management, the sites will not achieve their desired habitat functions.

In designing and managing diked bayland habitats, one should:

- Determine the site's elevation relative to a known tidal datum. If the site is subsided, can water be removed without pumping? Should the site be contoured to increase topographic variation?
- Determine if the quantity and quality (especially salinity) of available water are adequate.
- Determine if there are analogs or reference sites upon which to base the intended design and management. Assess the hydrology of the reference site and try to replicate it.
- Assess whether the site hydrology is appropriate to develop and maintain desired habitat functions without intensive management.

- Consider operation and maintenance issues such as water control structures, protection of adjacent properties from flooding, need for fish screens, and requirements for vegetation and invasive species control.
- Consult with the local mosquito abatement district to determine requirements for mosquito control.
- Assess the intensity of management that will be required to maintain the desired habitat; try to minimize the need for active management. (Management is costly and may be difficult to sustain in the long term.)
- Minimize the number and extent of levees. If levees are required for flood protection or water management, they should be wide enough to support maintenance equipment and should be designed and managed to discourage predator use.
- Consider removing or modifying overhead powerlines, berms, or boardwalks to reduce predation by raptors and small mammalian predators.
- Establish a 300-foot buffer of grasses or other native upland vegetation around periphery; if this is infeasible, maintain a buffer at least 100 feet wide.
- Manage to minimize disturbance from adjacent areas by humans and their pets.
- Inspect structures, water levels, and vegetation frequently to ensure the system is meeting its design criteria.
- Inspect for and control undesirable species (invasive plants, unwanted predators, and mosquitoes).


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Levees cut across the marsh.

Diked Wetland

As noted in Chapter 4, the term "diked wetland" includes two types of bayland habitats: managed marsh and diked marsh. Because diked marsh, by the Project's definition, is not actively managed for wildlife purposes, Project participants did not develop design and management recommendations for this habitat type. They did, however, develop many recommendations for managed marsh, and these are presented below in two groups. The first group pertains to marshes that are managed primarily, although not exclusively, for waterfowl, and it is referred to as "managed marsh." The second group pertains to areas that should be managed primarily, although not exclusively, to provide large, very shallow seasonal ponds for shorebirds; this group is referred to as "managed seasonal pond."

In diked habitats, waterfowl generally prefer areas where there is ponded water that is 12 – 18 inches deep, some emergent vegetation, presence of food plants or seeds in the soil, and presence of preferred invertebrates. Shorebirds prefer shallower water (generally less than four inches deep), unvegetated edge with fluctuating water levels, presence of bare areas and minimal emergent vegetation, and close proximity to tidal mudflats. Both shorebirds and waterfowl prefer seasonal wetlands that pond consistently from year to year and continuously throughout the winter season, and which have a presence of preferred invertebrate food items.

Managed Marsh — Most managed marshes are designed to provide optimal habitat for waterfowl, but in many instances it is possible to design and manage these marshes to provide benefits for a wider variety of organisms. For example,

Ken Burger

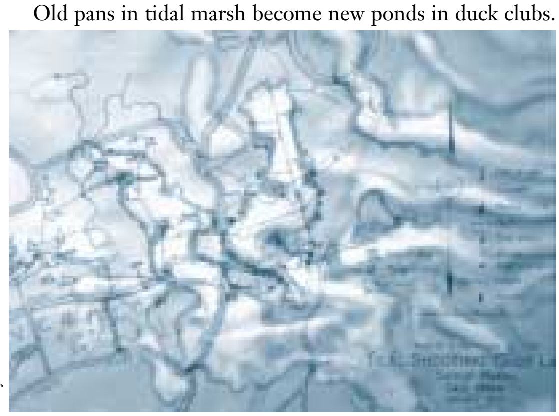
Some managed marshes serve as public parks.

marshes can be designed with deeper water for diving ducks and with shallower water for dabbling ducks and shorebirds.

In general, a high quality managed marsh has:

- Sufficient topographic variation to provide for a variety of water depths, wetland plant diversity, and high water refugia for small mammals.
- A diversity of habitat features to provide nesting, roosting, and foraging opportunities for a wide variety of species. These features include a mosaic of marsh vegetation, open water of varying depth, fluctuation zones with minimal vegetation (non-tidal mudflats), and areas of uplands within or adjacent to the wetland. Emergent vegetation provides cover for resting, nesting, and foraging habitat for a variety of marsh species including grebes, marsh wrens, waterfowl, egrets, and pond turtles. Open water ponds provide loafing and foraging areas primarily for waterfowl, but they are also used by foraging terns, grebes, and egrets. Water depth and duration are important in defining the kinds of wildlife that will utilize a marsh, and a variety of water depths helps to maximize species diversity. Providing deeper areas enables managers to maintain fish populations that diversify the prey base and aid in controlling mosquitoes.
- Provision for wetland habitat functions that are in short supply during certain seasons, years, and portions of the tidal cycle. These include non-tidal habitat for shorebirds and waterfowl during late summer and fall, foraging habitat for wintering waterfowl, drawdown conditions from late March through May to optimize shorebird foraging opportunities, and foraging and roosting habitat for shorebirds during high tide.
- Water level management to optimize wildlife utilization. The ability to vary water surface elevations aids in managing and controlling the types and amount of vegetative cover. This, in turn, determines habitat suitability for shorebirds and waterfowl. Shallow water areas (<4 inches) with exposed drawdown zones are extremely important to shorebirds, particularly in the spring.
- Well-maintained levees, preferably with some outboard marsh to help minimize erosion.
- A minimum impact on fish populations resulting from water diversions.
- An absence of contamination that adversely affects biota.

Old pans in tidal marsh become new ponds in duck clubs.



Tony Arnold

In addition to the general recommendations for diked baylands on pages 152 and 153, design and management of managed marsh habitat should:

- Consider whether site access will be adequate for management purposes in all seasons.
- Maximize a diversity of habitat functions in conjunction with the primary management objectives for a particular species or group of species.
- Provide and maintain water control structures (flood and drain capabilities) to manage the depth, duration, and timing of flooding. To operate most efficiently, the structures should be able to bring water on and off the site by gravity flow.
- Ensure the ability to prevent excessive soil salinity and the formation of acid sulfates in the soil of brackish or fresh water marshes. historical tidal marsh sediments are rich in sulfur, mostly as reduced sulfides bound to insoluble iron in the anaerobic conditions below the shallow root zone. When these soils are isolated from the tides, and permitted to dry, the abundant sulfides can be oxidized to sulfuric acid. If the soils are then wetted, the sulfuric acid can combine with organic acids from the oxidation of peat to acidify the surface sediments and overlying water. Such acidification greatly stresses the plant and animal communities of diked marshlands. Recovery from these conditions requires intensive management of surface hydrology, involving flushing of the acidified sediments.
- Emphasize the establishment of native plant species when feasible and consistent with management objectives.
- Install fish screens on water diversions where there is a potential to entrain endangered aquatic species.

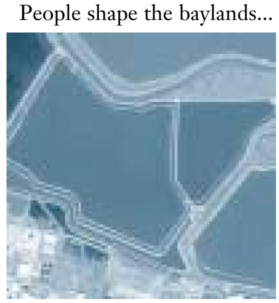
Managed Seasonal Pond — Much of the impetus for the Goals Project stemmed from disagreements among agency biologists regarding the ecological functions of shallow seasonal ponds. In the baylands, these ponds exist primarily in farm fields. Participants spent many hours discussing this kind of habitat and debating its functions for various key species. In the end, everyone recognized that these ponds and the surrounding lands are extremely valuable for many species. They also recognized that shallow seasonal pond habitat functions should be improved concurrent with tidal marsh restoration. Although the recommendations in this section pertain primarily to shallow seasonal ponds within the farmed baylands, they also may apply to the adjacent upslope areas.

The Goals call for enhancing seasonal ponds mostly to improve habitat for shorebirds and waterfowl. Although the general habitat needs of these two groups overlap, the needs of various species in each group differ considerably. Nevertheless, wherever possible, the design of managed seasonal ponds should consider the habitat needs of both groups.

High quality managed seasonal ponds have:

- Frequently or continuously inundated shallow ponds during waterfowl and shorebird migration and wintering periods (August through April) at depths suitable for waterfowl and shorebird foraging and roosting during high tides and storms. To achieve maximum value for shorebirds, inundation should be long enough to discourage dense ruderal cover, but short enough to prevent the establishment of emergent vegetation.

People shape the baylands...



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- Presence of ponds every year. Generally, seasonal wetlands that show the highest bird use are those that pond consistently from one year to the next, pond earliest, and remain ponded into late spring.
- Presence of well developed depressional topography, scattered shallow ponds that occur after heavy rains, and presence of short sparse vegetation with a significant component of native wetland vegetation.
- Location near tidal flats to minimize loss of energy by foraging shorebirds.
- No more than a minor component of tall, perennial wetlands vegetation, unless managed as a brood pond for waterfowl, where a fringe of dense, tall vegetation is desirable.
- Presence of unvegetated areas.
- Abundance of preferred plant and invertebrate food sources.
- Located within the baylands and on lands that are transitional with adjacent uplands.
- Few nearby obstructions and disturbances.

In addition to the general recommendations for diked baylands on pages 152 and 153, the design and management of managed seasonal pond habitat should:

- Select sites that do not have high ground water during the dry season to control the establishment of dense emergent vegetation.
- Retain or enhance depressional topography on the site.
- Use sites that are low enough to flood, but high enough to provide drainage using tidegates.
- Construct and maintain structurally sound levees at a 4:1 slope to maximize levee stability, minimize maintenance, and provide transitional wetland/upland habitat. Levee width and height should be based on impoundment size and expected depth. Place levees in areas that have limited exposure to wave action.
- For some areas within diked wetlands, design outboard levees that will episodically overtop with tidal flows to create high salinity and thereby minimize growth of woody, tall emergent vegetation. Alternatively, install adjustable water control structures to effect the same result.
- Manage for desired waterfowl and shorebird food sources through water manipulation to control moisture conditions and plant germination/seedling development.
- Provide a diversity of habitats by designing small impoundments within larger ones to allow for varied water depths, salinities, and other management practices.
- Control water depth unless the site has adequate topographic variation to maintain shallow areas with increasing water depth, and provide for gradual drawdown during the spring.
- Provide areas that consistently pond water when target species are present. For areas of seasonal ponding that are dependent solely on precipitation as a source of water, minimize drainage and encourage soil compaction to maximize ponding extent and duration. Ponding should occur as early in the season as possible. Flooding should be initiated in late summer or early fall for migrating shorebirds and waterfowl.

- Control vegetation to maintain large bare areas or areas of sparse low vegetation. Management techniques include grazing, mowing, disking, burning, and manipulating hydrology.
- Establish burning, mowing, and grazing regimes that favor native plant species.

The majority of diked bayland habitats that currently support seasonal ponds do not incorporate these design and management criteria. Improving seasonally ponded habitats will require changing land management practices.

Agricultural Bayland

As described in Chapter 5, Project participants recommended that agricultural baylands be restored to tidal marsh or be managed as diked wetlands to maximize wildlife habitat functions. However, they also agreed that farmers should continue to farm their lands for as long as they desire, and that landowner implementation of the Goals should be voluntary.

Agricultural baylands, especially portions that have seasonal ponds, provide habitat for several species of wildlife. Farmers that continue to produce crops in the baylands may be able to improve wildlife habitat by modifying their management practices. The kinds of actions they might consider include:

- Allowing ponding in field depressions for shorebirds and waterfowl.
- Creating small diked ponded areas adjacent to levees.
- Encouraging growth of vegetation along fence rows or field edges to provide habitat for small birds and mammals.
- Delaying spring harvest of oat-hay as late as possible to avoid nesting waterfowl.
- Fencing cattle from wetlands during wet periods.
- Increasing the practice of rotational grazing to encourage a more diverse grassland habitat.
- Avoiding farming in the more marginal areas.

Salt Pond

This section describes the habitat attributes of, and presents management recommendations for, salt ponds. It includes information for salt pond complexes that are actively producing commercial salt (active ponds) and for complexes that have been retired from active salt production (inactive ponds). The recommendations for active ponds apply primarily to South Bay ponds that currently are managed by the Cargill Salt Division. Those for the inactive ponds apply primarily to North Bay ponds that currently are managed by the California Department of Fish and Game. The recommendations for inactive ponds would apply to active ponds that are permanently removed from salt production.

High quality salt pond habitat has:

- A series of ponds with salinities varying from low to mid-salinity (<180 ppt), with few high-salinity ponds.
- Water depths that vary from shallow (<3 feet) to very shallow. For shorebirds, water depth should be less than 4 inches, with 2 inches ideal. Water deeper than three feet in lower salinity ponds provides habitat for diving ducks. Within a pond complex, water depth should be spatially variable to increase habitat diversity.

...and reshape the baylands.

NASA 1995/96

- Barren islands within the ponds and/or remote, undisturbed parts of dikes between ponds to provide roosting and nesting sites for shorebirds and terns.
- Proximity to tidal flats to minimize energy losses for shorebirds moving from tidal flats to peripheral foraging habitat.
- Limited nearby obstructions and disturbances.

The design and management of *active* salt ponds should:

- Include islets within ponds suitable for shorebird roosting and for nesting by least tern and snowy plover.
- Ensure that pond islands used by nesting birds are not inundated during the breeding season.
- Allow for drawdown of intake/low salinity ponds during April and early May to enhance shorebird foraging.
- Include sandy beaches on the levee edges along the leeward shore of ponds.

In addition to the general recommendations for diked baylands on pages 152 and 153, the design and management of *inactive* salt ponds should:

- Provide optimal habitat for shorebirds, waterfowl, other water birds, invertebrates, and plant species that typically occur in salt ponds. This is best achieved in a complex where the ponds are linked hydrologically.
- Provide a complex of ponds with various salinities (up to 180 ppt) and water depths.
- Include islets with little or no vegetation to provide roosting habitat for a variety of shorebirds and nesting habitat for terns, avocets, stilts, snowy plovers, and other birds.
- Ensure that each pond complex has access to tidal saltwater. Systems should have the capability to bring in low-salinity water to dilute the concentrated salt water before discharging it back to the Bay.
- Allow drawdown during early spring to optimize foraging habitat for migrating shorebirds.
- Construct nesting islands from levee remnants or by placing fill. Islands should be barren (dry mud is fine) and at least one foot above the maximum water surface elevation.
- Manage ponds so that islands will not eventually cover with salt marsh vegetation. This may require removing vegetation or drowning islands for three to six months during the non-nesting season.
- Manage ponds to provide appropriate conditions for nesting. Some species (e.g., Forster's tern) prefer to nest in low-salinity ponds, while others will nest in low-salinity and mid-salinity ponds. Prevent drainage or flooding of ponds when nests are present.
- Regularly inspect areas to ensure correct water levels are maintained for desired plant germination and growth.
- Provide deeper water depths in some ponds during the winter for diving ducks.
- Minimize maintenance requirements and move towards natural systems where possible. Designs should be tested to develop ponds that mimic historically occurring salt ponds or pans.

Adjacent Habitats

Project participants recommended protecting and improving many kinds of habitats adjacent to the baylands. However, riparian forest and willow grove are the only adjacent habitats for which they made design and management recommendations.

Elise Brewster

A riparian forest leans downstream.

Riparian Forest

Riparian forest habitat has been eliminated or extensively degraded on most of the Bay's small and large tributaries. It is in need of major restoration and repair.

High quality riparian forest habitat:

- Extends in a continuous corridor along a stream course.
- Extends laterally from the stream channel across an unimpeded floodplain.
- Forms a natural transitional ecotone with the adjacent uplands.
- Is free of domesticated animals and human disturbance.
- Supports a diversity of native understory and canopy plant species, and is free of invasive plants.

The design and management of riparian forest should:

- Incorporate setback levees into flood control planning to restore or maintain floodplain and riparian habitats.
- Allow natural stream processes to maintain channel form, provide flood flow passage, and maintain riparian vegetation.
- Control or remove non-native invasive species (giant reed, German ivy, eucalyptus, and Himalayan blackberry).
- Provide buffers at least 100 feet wide beyond the outer edge of the riparian vegetation.
- Minimize trails, grazing, and other disturbance within the riparian corridor.
- Utilize native plant species from the local area.
- Establish appropriate hydrological regime to ensure long-term persistence of native species.

Willow Grove

Willow groves, although never widely distributed, were abundant in South Bay and should be restored wherever possible. They should be incorporated into site designs associated with drainage ditches or flood detention basins.

High quality willow grove:

- Has hydrological conditions (including water quality) suitable to ensure long-term support of grove vegetation.
- Has a natural transitional ecotone with the adjacent uplands.
- Is free of domesticated animals and human disturbance.

Willows grow around a pond.

Josh Collins

The design and management of willow grove should:

- Establish appropriate hydrological regime to ensure long-term persistence of native species.
- Utilize native willow and other plant species from the local area.
- Provide buffers of at least 100 feet in width beyond the edge of the grove.

- Minimize trails, grazing, and other disturbance nearby.
- Control or remove non-native invasive species (giant reed, German ivy, eucalyptus, and Himalayan blackberry).

Other Important Considerations

This section describes several issues that arose during the development of the Goals. The issues range from very specific to very general; some are technical and others pertain more to policy. The RMG provided some guidance on each of the issues, but many will need to be discussed further and resolved in other forums. The intent of this section is to make the reader aware of these issues so that they can be factored into the earliest phases of restoration planning at the regional and local level.

Phasing

In this report, phasing refers to the timing of restoration and enhancement projects in and near the baylands. It is one of the key issues that led to the initiation of the Goals Project. At the heart of this issue is the recognition that tidal marshes and diked baylands cannot occupy the same places at the same time; increasing the acreage of one kind of habitat means decreasing the acreage of the other. In recent years, this issue arose primarily when tidal marsh was restored in agricultural baylands. In the future, it will arise in similar instances and also when tidal marsh is restored in salt ponds and in managed diked wetlands. Proper phasing will be necessary to ensure no overall loss of bayland ecological functions.

Phasing should occur within each subregion. Within a subregion, extensive restoration of tidal marsh should be undertaken, whenever possible, when there is significant progress in enhancing diked wetlands or salt ponds in the same subregion. Ideally, seasonal wetland enhancements would precede tidal marsh restoration. Alternatively, tidal marsh projects would include efforts to enhance diked habitats. In this way, there would be progress toward attaining all of the habitat goals, not just the goal of restoring tidal marsh. However, it will be difficult to attain this ideal unless habitat restoration and enhancement is undertaken on a large scale (i.e., thousands of acres) or within the context of a regional plan or subregional plans. Requiring each and every tidal marsh restoration project to enhance diked habitats as a condition of agency approval may defer endangered species recovery and overall improvement of the Estuary.

One of the more critical aspects of phasing will involve making decisions about habitats for threatened and endangered species — increasing habitat area for some species may reduce it for others. For example, restoring tidal marsh at a salt pond to benefit the California clapper rail and the salt marsh harvest mouse could reduce habitat for the least tern or snowy plover. Planning habitat restoration on a regional scale will minimize this kind of detrimental habitat trade-off. Fully implementing the Goals Project's recommendations should provide adequate habitat for all of the existing protected species.

Given the importance of phasing projects, it is appropriate for the resource and regulatory agencies to develop written agreements, perhaps phasing plans, for each subregion. This would help ensure that tidal marsh restoration occurs only with concomitant restoration and enhancement of other habitat types. It also would minimize short-term adverse impacts to protected species.

Contaminants

Contaminants such as lead, copper, mercury, petroleum, and pesticides may be found throughout the baylands and their concentrations vary greatly in water and in sediments. The design of wetland restoration and enhancement projects must, therefore, examine potential sources and loadings of contaminants to the project site and evaluate the potential problems that contaminants may pose to biota. The kinds of projects in which contaminants must receive especially careful consideration include those that use: (1) dredged material for restoring intertidal habitat and tidal marsh, (2) sewage sludge in diked wetlands, (3) wastewater to create or restore marshes, and (4) wastewater for streamflow augmentation.

Some segments of the baylands are generally more contaminated than others, based on past or current land use. The more contaminated areas include the highly industrialized parts of Central Bay, especially the western shoreline between San Francisco and the San Mateo Bridge, and along portions of some of the East Bay shoreline between Richmond and San Leandro. Wetland restoration projects planned in these areas, especially at sites with a history of industrial activity or use as formal or informal landfills, should include careful assessments for contaminants.

Use of Dredged Material for Wetlands Restoration

Much of San Francisco Bay is naturally very shallow and must be dredged to enable the safe passage of modern, deep-draft vessels in navigation channels, turning basins, and marinas. During the past four or five decades, an annual average of some six million cubic yards of sediment was dredged from the Bay.

Dredged material is disposed of in the ocean, at in-Bay sites, and at some upland sites, particularly landfills. In recent years, dredgers and the agencies that regulate the discharge of dredged material have given attention to expanding the beneficial uses of some of this material. There is much interest in using dredged material to restore tidal wetlands in portions of diked baylands. The Final EIS/EIR for the Long-Term Management Strategy for dredged material disposal proposes that about 40 percent of clean Bay Area dredged material be used for beneficial re-use in a variety of ways, including wetland habitat restoration (LTMS 1998).

Many areas of diked baylands have subsided substantially since they were isolated from tidal waters decades ago. This has been caused by soil decomposition, wind erosion, and compaction of organic matter. Groundwater pumping has contributed to subsidence of some diked areas, especially in South Bay. Restoring tidal marsh or creating shallow ponds for wildlife in subsided areas may require elevating the bottom substrate. Using dredged material is a way to accelerate this process, especially where the suspended sediment supply is limited. Dredged material also may be used to restore a full range of marsh, beach ridge, roosting island, and other habitat that may not develop through natural processes (see page 142).

In certain locations, and in order to meet specific project design objectives, the use of dredged material may be an appropriate adjunct to natural sediment deposition. Where dredged material is used to raise elevations of subsided baylands for tidal marsh restoration, care must be taken to avoid potentially negative effects such as overfilling, burying historic slough traces, and inhibiting proper slough channel formation. Also, the risk of adverse effects of

A dredger clears a creek crossing.

Elise Brewster

contaminants on water quality and biota must be addressed. It is particularly important to rely on natural sedimentation processes to the maximum extent possible when establishing the final substrate of the marsh plain.

The decision to use dredged material for wetland restoration or enhancement must be made on a project-specific basis. The LTMS Final EIS/EIR lists specific factors that should be evaluated for any wetland project that proposes to use dredged material.

Given the concerns regarding the use of dredged material in the Bay Area for habitat restoration, the RMG recommends that dredged material be used very selectively and only when it is of suitable quality. All restoration projects that have used or are proposing to use (e.g., Montezuma Wetlands, Hamilton Field) dredged material should be monitored intensively. This would provide a better understanding of the long-term effects of this material on marsh evolution and ecological functions.

Wastewater Re-use

Each day, more than 40 municipal wastewater treatment plants discharge some 600 million gallons of treated wastewater to the Bay. These flows affect the condition of the baylands and some offer potential for improving its habitats.

Most Bay Area municipal wastewater treatment plants discharge effluent to deepwater areas of the Bay, and these discharges do not significantly affect the plant composition of bayland habitats. However, discharges of treated wastewater to sloughs and shallow areas may affect bayland habitats by making them fresher. An example of this is in South Bay, where discharges from the City of San Jose's treatment facility into Artesian Slough have caused large areas of nearby tidal salt marsh to become brackish. This has degraded the habitat of several salt marsh dependent species, and the resource agencies and City staff have spent considerable effort trying to improve the situation.

Treatment facilities that discharge closer to the bayshore, rather than into sloughs, may have more options for avoiding marsh conversion. For example, the East Bay Regional Park District operates the Hayward Treatment Marsh by mixing wastewater from the Union Sanitary District wastewater treatment plant with Bay water before discharging it to the Bay. In doing this, it has avoided significant adverse impacts.

Although wastewater discharge may cause unwanted changes in the baylands if managed incorrectly, it also offers opportunities to create or improve habitats. Most treatment facilities have ponds in which water is stored before being discharged, and waterfowl and other water birds use some of these ponds. Also, some treatment plants use marshes to remove, or polish, pollutants from wastewater before discharging it to the Bay. The Hayward Treatment Marsh and the wetland at the Mountain View Sanitary District facility in Martinez are examples of the kinds of habitats that can be created using wastewater.

Although it may be feasible to create or improve habitats with treated wastewater, the effects of discharging wastewater to wetlands and other areas must be carefully considered beforehand. Flows should be free from potentially harmful contaminants and the receiving wetland or stream should be carefully monitored for long-term effects. Care is also needed to avoid inadvertently converting seasonal wetlands to perennial habitat, causing bioaccumulation of contaminants, or adversely affecting anadromous fishes by discharging water from one watershed into another.

As the population of the Bay Area grows, there will be increased interest in re-using wastewater for many purposes. Given its potential for both positive and adverse effects on the baylands, wastewater re-use should be addressed on a region-wide basis. Efforts underway by the U.S. Environmental Protection Agency, the San Francisco Bay Regional Water Quality Control Board, and others should continue.

Stormwater

During the wet season, large volumes of stormwater enter the baylands. Stormwater flows originate in urban areas and rural settings and, by the time they reach the baylands, they contain a variety of pollutants including suspended solids, trace elements, oil and grease, and pesticides. It is important to remove these pollutants from flows before they cause environmental harm.

Created wetlands can be effective at removing pollutants from stormwater. Perhaps the best local example is the 55-acre Coyote Hills Demonstration Urban Stormwater Treatment Marsh. Although treatment efficiency fluctuates between seasons, between storms, and even within the same storm, this marsh removes several kinds of pollutants from stormwater, including suspended solids, nutrients, and trace elements (Meiorin 1986). The marsh has vegetated and unvegetated areas, as well as islands constructed for nesting birds, and it provides habitat for wintering waterfowl, nesting egrets and terns, and resident shorebirds.

The use of created wetlands to treat stormwater runoff requires careful planning and design. It also requires monitoring of soils and biota to assess long-term effects.

Although wetlands are able to improve water quality, using them to treat highly polluted stormwater may involve some risks. Accordingly, urban stormwater should not be applied to natural wetlands until the risks are more clearly understood.

Salt Pond and Bittern Discharges

Disposing of concentrated waste products is a major management issue of salt ponds. In pond systems where salt is harvested commercially, the waste product is known as bittern, and it contains the magnesium-potassium salts that remain after sodium chloride has been harvested from Bay water. In inactive salt ponds, the waste product that forms when Bay water evaporates is referred to as hypersaline brine.

The San Francisco Bay Regional Water Quality Control Board regulates the disposal of bittern and hypersaline brines in Bay waters. It prohibits bittern disposal because this substance is acutely toxic to aquatic organisms if discharged in a concentrated form (toxicity is a result of high biological oxygen demand, hypersalinity, and specific ion toxicity). It prohibits the disposal of hypersaline brines because these liquids exceed background salinity requirements and, depending on their salinity, may be toxic.

Successfully restoring bittern and brine ponds to tidal marshes will require removal of bittern and brines. Disposal most likely will involve diluting these waste products before discharging them to the Bay. The Bay is one potential source of dilution water, and discharges from wastewater treatment facilities are another. At pond complexes that continue to produce salt, it may be possible to dilute bittern enough to allow its discharge to the Bay; without the need for bittern storage, existing bittern ponds possibly could be restored to tidal marsh.

Resolving this issue will require establishing criteria to determine how, and under what circumstances, these liquids can be discharged safely to the Bay. This should involve careful evaluation of a wide array of potential disposal alternatives for bittern and hypersaline brines. It also should involve the development of validated models to help predict the effects of salt pond restoration in the context of adjacent bayland habitats and restoration efforts. The current scientific investigations of the Napa-Sonoma Marsh Restoration Group, which is working to resolve this issue for the inactive salt ponds of North Bay, should be examined as a possible approach that could also be applied to South Bay.

Buffers

Project participants strongly agreed that existing and restored wetlands must be protected from factors that diminish wildlife habitat quality. It makes little sense to expend private or public funds to restore a site, only to have its biological functions compromised by residential and industrial activities, dogs and cats, unrestricted entry, and illegal dumping. One of the best ways to help ensure that the baylands provide maximum benefits for wildlife is to incorporate buffers into project design and management.

As used in this report, a buffer is a zone of transitional or upland vegetation that abuts a bayland or stream. Its purpose is to minimize the negative effects of adjacent land uses on the bayland or stream. The optimal dimensions of a buffer will vary from locale to locale as a function of local environmental constraints and the ecological objectives of restoration projects.

To develop recommendations for buffers, the RMG and the focus teams integrated the recommendations for many species and habitats. They recommended a minimum buffer width of 300 feet. Where existing land uses or other factors such as steep terrain preclude this, wetland buffers should be no narrower than 100 feet. For riparian habitats, the recommended minimum buffer width is 100 feet beyond the outside boundary of the riparian vegetation.

Most buffers should be fenced to prevent entry of humans, dogs, and livestock. However, there may be some instances where fencing may not be required. Buffers also should be free of human disturbance (e.g., tennis courts, swimming pools, trails) and non-native invasive vegetation.

Buffers should be considered an integral part of every wetland restoration or enhancement project. Funds for their acquisition, design, and long-term maintenance should be provided along with other project funding.

Public Access

In recent years, the public has become increasingly interested in gaining access to the Bay's shoreline for recreational enjoyment. In response to this demand, cities, counties, and several state agencies are facilitating recreational uses of the baylands. For example, the legislation that established the Bay Conservation and Development Commission mandates that agency to require maximum feasible public access as an integral part of shoreline development projects.

Agencies that encourage or require public access to the shoreline are fulfilling a part of their public trust responsibility as they enable people to use a public resource. They also are helping to ensure long-term Bay protection, as people who can use the Bay likely will seek to protect it. On the other hand, agencies that discourage public access because of concerns regarding impacts to wildlife are also fulfilling their public trust responsibilities. Balancing public access and natural resource protection clearly is one of the more difficult arenas of public policy.

Public access has been found to disturb many species of wildlife. Studies have shown that human disturbance can have significant adverse impacts on the feeding and breeding behavior of water birds (Anderson and Keith 1980, Burger 1981). For example, human disturbance may cause a decrease in the duration and intensity of foraging activities by migratory shorebirds, thereby resulting in decreased energy reserves necessary for successful migration and breeding. One study in the Bay Area showed that human activities on a trail reduced the number of birds in adjacent, suitable habitat (Josselyn et al. 1989). Increased human access to wetlands also provides access for foxes, dogs, cats, and other predators, which often follow the same trails used by the public. Due to these impacts, and given the small amount of natural bayland habitats that exist at this time, resource agencies responsible for protecting wildlife consider uncontrolled public access to many baylands incompatible with wildlife protection.

Recognizing the need for more research on this topic, the Bay Trail Project (a regional effort to establish a system of recreational trails around San Francisco Bay) is funding an investigation into the impacts of recreational trails on wildlife. Researchers at San Jose State University are conducting the study, which will assess the effects that trail users have on the immediate behavior of birds and on bird species abundance and diversity. The study will collect data on the effects of typical Bay Trail users — walkers, dog walkers, bicyclists, photographers, birdwatchers, and in-line skaters — on salt marsh and brackish marsh birds (Sokale and Trulio 1998). The results of this study may help project sponsors design trails with fewer adverse impacts to wildlife.

To balance the need for natural resource protection with the increased demand for public access, a thorough assessment of opportunities and constraints for public access should be conducted during the design phase of all restoration, enhancement, and recreational use projects in the baylands. Agencies responsible for authorizing, planning, or requiring public access should:

- Limit or prohibit public access in areas of high biological value during nesting seasons or other appropriate times of the year.
- Provide limited access for compatible wildlife-dependent activities, such as fishing, wildlife observation, or environmental education in areas of higher biological value that can support such activities.
- Provide interpretive signs along trails and focus access on a destination, such as a pier or overlook deck, to limit intrusion into wetlands.
- Minimize construction of extensively improved “loop” trails.
- Emphasize high-quality wildlife viewing experiences that minimally affect wildlife.

- Place heavy-use recreational trails whose primary purpose is not wildlife-dependent (e.g., hiking, biking trails) at inland locations or along the upland edge of buffers, as far as possible from wetlands.
- Actively enforce access restrictions.
- Where necessary, establish and enforce appropriate restrictions on dogs to protect wildlife.
- Provide animal-proof trash receptacles at trailheads and do not allow trash to accumulate.
- Prohibit feeding of wildlife or feral animals.
- Develop a program to educate the public about the many benefits of wetlands. This will foster public awareness of, and appreciation for, wetlands and will encourage voluntary compliance with wetland conservation efforts.

Many of these restrictions on public access are necessary because of the extensive losses of tidal marsh and transitional habitat along the Bay edge. But, as restoration and enhancement projects increase the amount and quality of these habitats, and as populations of marsh-dependent threatened and endangered species rebound, public access impacts to wildlife may become less significant.

Control of Non-native Invasive Plants

There are several species of non-native invasive plants in the baylands ecosystem. These species have the potential to alter the ecosystem by dramatically affecting habitat structure or seriously reducing populations of endemic plants and animals. Thus, their control is of special concern.

Among the several non-native invasive plant species that are causing problems in the Bay, smooth cordgrass perhaps gives the greatest cause for alarm. This is because its spread could effect large-scale impacts to the Bay ecosystem by converting valuable mudflats and small tidal channels to dense marsh of relatively low habitat value for many species. Another species, pepper grass, is displacing native plant species on levees and is spreading into brackish marshes. Giant reed threatens riparian habitats as it displaces native vegetation and reduces habitat quality. These successful, non-native invasive plants are able to out-compete native species that have similar habitat requirements. The regional distribution of introduced tidal marsh plants is reviewed in Grossinger et al. (1998).

There needs to be a major commitment to control the spread of smooth cordgrass before it becomes established throughout South Bay. Control should begin immediately; unless this is done, tidal marsh restoration will likely lead to the spread of this exotic plant species, and the resulting large stands of smooth cordgrass on tidal flats and in channels probably will undermine restoration objectives. Some suggest that planting native cordgrass may help slow the spread of smooth cordgrass into restored marshes; however, recent research indicates that the two species hybridize where they are in proximity, and thus, even planting efforts may be insufficient (Strong and Ayres 1998).

For any tidal marsh restoration project between the San Francisco-Oakland Bay Bridge and the Dumbarton Bridge, a systematic and coordinated program of smooth cordgrass control should be developed and implemented at least two years prior to restoring tidal action. Local colonization pressures by smooth cordgrass must be reduced to insignificant levels before extensive tidal restoration takes place. The goal is to prevent dispersal of smooth cordgrass into the restoration area. A plan should also be in place prior to restoring tidal action to monitor the restoration site for smooth cordgrass invasion and to control any infestations. There should be efforts to control other invasive plant species including dense-flowered cordgrass (currently limited to Richardson Bay, Corte Madera Creek, and Point Pinole), pepper grass, and giant reed.

Introduced Animal Species and Predator Control

Over a period of many years, a variety of introduced estuarine fish and invertebrates have become established in the Estuary; the Bay's history is filled with a litany of successful introductions. In recent years, scientists and managers have become increasingly concerned about introduced animal species and their effects in the Estuary. Many of the introduced species that have been studied are aquatic (Cohen and Carlton 1995), and some of these, such as the mitten crab and the Asian clam, have received considerable media attention.

Many of the introduced species were transported to the Bay in ship ballast water. It is probably not possible to control the species that have already been introduced, but efforts should be directed toward preventing the introduction of additional species. The most effective way to accomplish this is by prohibiting the discharge of untreated ship ballast water in the Bay.

Terrestrial animals are also of concern, especially those that are effective predators on native species. With many of the Bay Area's natural habitats disturbed or lost, predation by mammalian predators on several endangered species has become a crucial management issue.

The red fox is an introduced predator that threatens the survival of the endangered California clapper rail and severely reduces populations of other native ground nesting birds (Jurek 1992, Lewis et al. 1992). Red fox predation on the clapper rail is especially severe because the two species did not evolve together. Also, the rail's tidal salt marsh habitat is greatly reduced in area and is highly fragmented by levees that provide easy access for foxes. Cats are another especially effective mammalian predator on bayland wildlife, particularly on the California least tern. Cat control near tern colonies is critical for this species' survival in the Bay.

Urban development and its associated infrastructure contribute to predator problems. Developments in close proximity to marshes and other bayland habitats provide conditions suitable for terrestrial predators such as red fox, dogs, cats, rats, raccoons, and opossums. The presence of power poles, lighting fixtures, and unnatural landscaping in or near wetlands enhances habitat for avian predators, such as raptors and ravens which prey on snowy plovers, terns, and other bird species. Measures to minimize predator habitat should be an integral part of each restoration project.

Habitat restoration that increases tidal marsh area, reduces its fragmentation, and removes predator travel corridors will reduce the vulnerability of native species to predation by exotic predators. This could lessen the amount of active predator control needed to protect endangered, threatened, and other vulnerable species. However, it is expected that predator control will continue to be necessary to maintain wildlife species, given the proximity of urban areas to the baylands, the need to maintain existing flood control channels and levees (features that provide habitat for predators), and the difficulty in eliminating exotic predators.

One possible management technique that could augment existing predator control programs in South Bay is the reestablishment of coyote populations. Coyotes may help control red fox and other similar predators; however, this technique should be pursued very carefully in order to be certain that it would not adversely affect other wildlife species and people.

Mosquitoes

Mosquitoes are one of the many groups of animals that occur in the baylands ecosystem. Certain bayland mosquito species transmit diseases, the most important of which are those caused by encephalitis viruses. Although clinical cases of encephalitis have rarely been reported in recent years, the virus is still detected annually in wild birds, in sentinel chickens, and in mosquito populations. The primary goal of mosquito abatement efforts is to keep mosquito populations below threshold levels for disease transmission to humans, and to reduce nuisance problems that can impact recreational, economic, and agricultural activities and create public distress.

Mosquitoes rarely occur in significant numbers in tidal marshes that have full tidal action. But they can occur in large numbers in seasonally ponded wetlands with inadequate water control engineering or poor water management practices, and in densely vegetated tidal areas that hold water between tides.

The design of wetland restoration and enhancement projects should include input from the local mosquito abatement district in order to prevent or discourage the build-up of mosquito populations. Where mosquitoes are a potential problem, designs should incorporate features to help discourage and control mosquitoes. Appropriate designs include: (1) deep water, especially on the down-wind side, (2) open water with little or no vegetation, (3) long fetch for waves, (4) permanently flooded areas for mosquito predators, and (5) water control capacity. In addition, designs should incorporate a wide buffer between wetlands (especially seasonal ponds) and residential areas, and provide access points for mosquito surveillance and control.

Once a project is constructed, the site manager should maintain good communication with the mosquito abatement district regarding water levels, predator abundance, and observations of mosquito larvae or adults. The manager should also budget funds for mosquito control, especially for lands which do not contribute funds to the local mosquito abatement district, for projects with habitat types that are especially conducive to mosquitoes, and for projects near residential areas.

Freshwater Flows

Freshwater inputs to the Bay are critical to the healthy functioning of the baylands ecosystem. These flows influence salinity gradients, affect shallow bay habitats, contribute sediments to maintain the marsh plain, and provide energy to the aquatic ecosystem. Changes in the volume and timing of freshwater flows have dramatically affected the baylands in measurable ways since about the 1920s, when diversions from the Sacramento and San Joaquin rivers began to increase markedly. While the effects of diversions are Estuary-wide, the most obvious changes in the baylands have been upstream of Carquinez Strait.

The overall effect of altered seasonal flows from the Central Valley has been to increase salinity in Suisun Bay during spring and summer and to decrease it during the fall and winter. In dry years, relatively high salinities now occur yearlong (SFEP 1992). As noted in Chapter 2, this has caused the tidal marshes in the Suisun subregion to become more brackish. On a smaller scale, hydrological changes in local streams have altered the salinity gradients and salinity regimes where they flow into the Bay, and this has affected the plant communities and habitat functions of tidal marshes.

Some of the water that is diverted from the Bay's streams returns to it in the form of large inputs of year-round freshwater flows from municipal wastewater treatment plants. These flows are changing the tidal marsh habitat types and functions on a local scale.

To the extent possible, the volume and timing of freshwater flows to the Bay should reflect historical or natural conditions under which the bayland habitats and animals developed. Appropriately timed increased freshwater flows in tributaries as large as the Sacramento River and as small as the intermittent streams of South Bay would improve bayland habitat diversity and function.

Wetland Success Criteria

Establishing widely accepted project success criteria is one of the more controversial areas of habitat restoration. Over the years, criteria have evolved from simple measures of vegetation to sophisticated indicators of habitat structure and function. Frequently, restoration projects fail to meet many of their success criteria, but still provide valuable habitat. Conversely, projects that produce low value habitat sometimes are labeled "successful" because they met some inappropriate criteria. The San Francisco Bay Regional Water Quality Control Board, U.S. Army Corps of Engineers, and others have begun work to develop uniform guidelines for evaluating restoration success (DeWeese 1994, Pavlik 1996, Simenstad and Thom 1996, Breaux et al. 1997, Thom 1997, SFBRWQCB 1998).

Project participants offered the following observations and suggestions regarding the measuring of restoration project success:

- The time frame for determining project success needs to be carefully considered. Many types of restored habitats evolve slowly over a period of years, or even decades. A typical five-year monitoring period is not sufficient for evaluating most projects.
- Reference sites for a variety of tidal and diked habitats should be used to help measure project success. To reduce cumulative adverse impacts from repeated monitoring excursions, monitoring of these sites should be coordinated and controlled.
- The relative success of a project should be evaluated in light of natural, external variables, such as drought and flood cycles, regional invasion by non-native species or diseases, and sea level rise. Project design should also address other variables, such as natural subsidence and sediment supply and deposition.
- Success criteria should be uniform to the extent possible, but they also need to be flexible to accommodate changes in understanding.
- A project may not result in the exact type of habitat or condition initially designed for, but it may still be a "success" if it provides good habitat that improves the overall health of the Estuary.

Case Study: A Hypothetical Wetland Restoration Project — Where the Money Goes

The costs of wetland restoration projects vary considerably. It is instructive to see what the money is spent on in a typical project. The following is a case study for a hypothetical medium-sized project at a site with moderate constraints and management requirements. It includes many of the kinds of costs that real restoration projects incur.

Acquisition: *$5 million*. Purchase 500 acres of baylands, which are a mix of uplands, inactive salt ponds, and agricultural baylands. The site has moderate flood protection and infrastructure constraints. Flood protection requires only upgrading of existing perimeter levees. Some powerlines and a pipeline for recycled wastewater will require minimal modification to accommodate restoration.

Project Planning and Permitting: *$250,000 and 18 months*. Conduct site survey, hydrologic study, biological assessments, and historical site assessment. Prepare public access plan. Prepare restoration plan based upon studies and input from public and regulatory and resource agencies. Prepare environmental documents (California Environmental Quality Act/National Environmental Protection Act) and circulate for public and agency review; respond to concerns. Apply for and obtain authorizations: Section 404 of the Clean Water Act, State Waste Discharge Requirements/Section 401 Certification, BCDC permit, compliance with State and Federal Endangered Species Acts.

Project Construction: *$1.3 million and five months*. Dredge 150,000 cubic yards to clear tidal channels ($5 per cubic yard), construct 5,000 linear feet of new levee ($7 per foot), upgrade 8,000 linear feet of existing levee ($3.50 per foot), relocate access roads and construct 100-foot bridge ($200,000), protect existing power and sewer lines onsite ($75,000), install four 36-inch culverts with control gates ($36,000), construction administration and oversite ($100,000), contingencies 10% ($120,000).

Project Monitoring: *$125,000 and five years*. Includes monitoring hydrology, vegetation, and fish and wildlife at $25,000 per year.

Ongoing Operation and Maintenance: *$35,000 per year*. Maintain levees, water control structures, fences, gates, signs, and trails (including prorated replacement costs), $12,000 per year. Other costs associated with management, patrol, inspections, operation of water controls, predator control, and site administration, $23,000 per year. This cost does not include biological surveys or interpretive activities.

In this example, total project cost for the first five years is approximately $7 million. On a *per-acre basis*, the total cost is $14,000. Beyond the fifth year, annual project cost drops to $35,000, the cost for operation and maintenance. Ongoing monitoring costs would be additional.

This example demonstrates that wetland restoration can be an expensive proposition, both in the short-term and in the long-term.

Costs of Habitat Restoration

Restoring bayland habitats will cost millions of dollars. Private and public interests will bear these costs over many decades. There are several aspects of this issue that warrant review.

The cost of restoring wetlands varies widely, and it is influenced primarily by site characteristics, by the complexity of design and construction, and by the type of desired habitat. In recent years, there have been some tidal restoration projects that entailed little or no planning — they were effected by natural or artificial breaching of levees. Examples of these kinds of restorations are at White Slough near Vallejo and at Pond 2A in the Napa Marsh. Although these projects were essentially cost-free or inexpensive, they certainly do not represent the norm. Most restoration projects require substantial funding over a period of many years.

Land Value — A Perspective

Implementing the Goals will require significant land acquisitions. Beyond having adequate funding, one obstacle to acquiring lands for wetland restoration and enhancement is arriving at land valuations that meet the expectations of the buying agency and a willing landowner. In recent years, disagreements regarding land value have prevented some public agencies from acquiring private lands. Further, some landowners and members of the public have questioned the prices that agencies have paid for wetland parcels.

Much of this controversy centers around the work of the appraiser and the assumptions that he or she makes about the opportunities and constraints on property. Some people believe that properties with wetlands should be valued according to current use and fully recognizing regulatory constraints; this tends to minimize the property value. Others, usually landowners, believe that valuations should consider the wildlife benefits provided by the land, not just its commercial potential.

Recent valuations indicate considerable variation in land values from one part of the baylands to another. For example, in South Bay, land valuations for wetland parcels have ranged from $6,000 to $15,000 per acre during the last several years. In North Bay, most of the baylands have been valued much lower, typically in the range of $2,000 to $3,000 per acre. Suisun Marsh property values are similar to those in North Bay. This wide range in valuations has led some to believe that their land is worth more than an objective appraisal would indicate. A review of the appraisal process should help everyone understand this issue better and to appreciate its complexity.

The Appraisal Process

There are many distinct steps in the process of appraising property. The first steps are to identify the property to be appraised, and to determine the property rights that are involved, the use the client will make of the appraisal, a definition of market value, the effective date of the appraisal, and any underlying assumptions and limiting conditions that apply.

Next, the appraiser makes a plan to collect and analyze general information about the market and the government regulations and environmental forces that affect the value of the property. This provides the background against which the specific data are analyzed. Specific data include information about the subject property site and improvements (the land and buildings or other structures), and the comparable data on properties which have sold, rented or are listed for sale (comparable sales, comparable rentals, or comparable listings). The appraiser must consider the effect on use and value of the following factors: existing land use regulations, reasonably probable modifications of such land use regulations, economic demand, the physical adaptability of the real estate, neighborhood trends, and the highest and best use of the real estate.

An analysis of the highest and best use is an important step in the process of estimating the value of any property. The appraiser must first estimate the highest and best use of a property, regardless of whether the site is unimproved and vacant, or is improved and occupied. They identify that use which, in their opinion, would be the best development of the property in terms of its total economic worth. They do a second highest and best use analysis of the property as it is actually improved to identify what could be done to the existing improvements to make the property more valuable. Highest and best use is defined as: "the reasonably probable and legal use of vacant land or an improved property, which is physically possible, appropriately supported, financially feasible, and that results in the highest value. The four criteria the highest and best use must meet are legal permissibility, physical possibility, financial feasibility, and maximum profitability." (AIREA 1989). To determine the highest and best use, the appraiser needs to analyze:

- What are the possible physical uses of the site?
- What legal restrictions or limitations are being imposed as a result of zoning and/or deed restrictions?
- What uses would feasibly produce the highest present value for the site?
- What is the highest and best use from among the feasible uses?

Three Approaches to Value

In appraising real estate, there are three separate methods that are customarily utilized for the purposes of determining the economic value of any given property. The nature of the property determines which one or more of these methods is utilized and which receives the greatest emphasis in the reconciliation. While the appraiser generally bases his/her valuation of the land on sales of comparable

(continued on next page)

Land Value — A Perspective (continued)

lands, a general definition of the three approaches to value is as follows:

Cost Approach

The value concluded via the Cost Approach is comprised of two components: the value of the underlying land as if vacant and available for development, and the estimate of the reproduction replacement cost of the improvements. An aggregate amount reflecting the decrease in utility brought about by various forms of physical, functional, and economic depreciation is then subtracted to arrive at the calculated value. This method typically receives the greatest emphasis when valuing special purpose or newer properties for which relative construction costs can be determined. Because many of the lands appraised for public agencies, particularly land acquired for wetland preservation and restoration, are vacant lands, the Cost Approach is not utilized.

The Market or Sales Comparison Approach

This approach requires several distinct steps. It compares the property being appraised to other similar nearby properties that have recently sold or are currently listed for sale. When good data are available, the results obtained by this approach are the most satisfactory and also the easiest to understand. Since no two properties are exactly alike, the appraiser must make adjustments for significant differences between the comparable sales and the subject property. Keeping in mind that a sales comparison value estimate decreases in reliability if there are many differences between the subject property and any of the comparable sales, the four general categories of adjustments are as follows:

- Time adjustment, to reflect market differences between the date of the appraisal and the comparable's date of sale.
- Location adjustment, to reflect value differences between the location of the subject and the location of each comparable sale.
- Adjustments for differences in physical characteristics between the subject and the comparable sales, such as size, condition, special features, amenities, etc.
- Adjustments, if needed, for special conditions or special financing that might have influenced the selling price of the comparable.

In general, restoration projects incur costs for five different kind of activities. These activities include site acquisition, planning and permitting, construction, monitoring, and maintenance. The cost of each of these five activities varies considerably from project to project. Accordingly, the total long-term per-area cost for wetland restoration or enhancement varies substantially. The following four examples demonstrate the range of costs:

- **Pond 2A in Napa Marsh** — the total cost to restore an acre of wetland was only about $1,000. This inexpensive project restored tidal action to an inactive salt pond using explosives to blast a hole in a levee.
- **Baumberg Tract in Hayward** — the total cost per acre of restored wetland will be about $18,000. This project to restore seasonal and tidal wetlands requires constructing levees, installing water control structures, and relocating power lines.
- **Tolay Creek in North Bay** — the total cost per acre of restored or enhanced wetland was about $27,000. This tidal marsh restoration project required levee construction and repair, and extensive channel dredging.
- **Martin Luther King Jr. Shoreline Wetland** — the total cost per acre of restored wetland was about $56,000. This project to restore tidal marsh and to establish seasonal wetlands was highly engineered; it involved moving large volumes of soil, excavating channels, and creating low berms.

The main factors that account for the large range in the costs of these projects are land acquisition costs and design complexity. Although there are economies of scale associated with larger restoration projects, even very large projects may be relatively costly if they are in areas where land is expensive. Based on several recent examples of restoration projects, one may reasonably expect that a typical bayland project will cost somewhere between $5,000 and $50,000 per acre of restored wetland. Most projects probably will be in the range of $10,000 to $20,000 per acre of restored wetland.

An important aspect of restoration project funding is long-term maintenance. As anyone who has had to take care of land knows, maintenance costs can be substantial. Maintenance activities include tasks such as fixing water control structures, repairing eroded levees, removing trash, repairing fences, controlling predators, replacing signs, and paving and grading roads. It is important to recognize that long-term maintenance does not come cheaply, and its costs must be an integral part of any wetland restoration budget. Because much of the habitat

Land Value — A Perspective (continued)

Reconciliation Approach — The Final Value Estimate

In instances where the cost approach and the market approach produce substantially different valuations, the appraiser will reconcile these differences. In this reconciliation approach, the appraiser considers all of the available data and uses his or her knowledge, experience, and professional judgment to estimate a final value for the subject property.

Appraisal Report

The final step of the valuation process is the preparation of the appraisal report. Complete appraisal reports are usually in narrative format and contain, in addition to the estimated value, many details about how the appraiser arrived at the value as well as supporting maps, charts, and photographs.

Professional Ethics and Standards

The Appraisal Foundation, through its Appraisal Standards Board, has been mandated by Congress to develop a code of ethics, which is called the Uniform Standards of Professional Appraisal Practice. Appraisers follow this code or similar professional standards enforced by various independent appraisal organizations which also have their codes of ethics.

All states require that real estate appraisers who are licensed and/or certified comply with these standards. All of the various independent appraisal organizations also have their codes of ethics that are enforced by internal committees on professional standards.

Conclusion

The key to the appraisal process is recognizing that every piece of real estate is unique, and that the type of value to be estimated must be determined by the needs of the client. Tens of millions of acres of environmentally significant real estate worth perhaps billions of dollars need to be appraised for acquisition and protection in coming years. How this property will be valued, and values that may be estimated, will be based on fair market appraisals by independent appraisers. Government agencies, historically the most frequent purchasers, will undertake acquisitions from willing landowners. Also, these agencies typically have standards requiring appraisers to evaluate the real property rights acquired, based on a traditional market value definition, premised on a highest and best use determination, that permits an estimate of market value, arrived at using comparable sales.

The evaluation of lands in Suisun Marsh, around San Pablo Bay, and in South Bay will be pivotal to the ultimate implementation of the Goals recommendations. Many landowners consider the prices currently offered for their lands a pittance compared to the open space and habitat values that society seems to place on them. Resolving this issue immediately and fairly must be a high priority of the agencies.

changes envisioned in the Goals ultimately will occur on public lands, it is imperative that the managers of these lands receive the funding necessary to maintain habitat and to meet their responsibilities as good neighbors.

Restoring Wetlands Outside of the Baylands

Many valuable wetlands used to exist outside the baylands, particularly vernal pools and other seasonal features in moist grasslands and riparian vegetation adjacent to streams. Although agriculture, flood control, and other kinds of development have affected many of these wetlands, some are intact, and new wetlands have recently developed on altered landscapes. There are many sites that could be restored or enhanced and improving them could help replace some of the habitat functions that will be lost as diked areas within the baylands are restored to tidal marsh.

All wetlands and riparian corridors outside of the baylands should be fully protected to prevent their further degradation or total loss. In addition, there should be a detailed inventory of these resources, with attention focused on vernal pools and other seasonal wetlands, as many of these support unique plant and animal species. Projects to enhance and restore these valuable resources should be undertaken in tandem with projects in the baylands.

Baylands Science — History and Needs

Developing the Goals required a large body scientific information. The Goals Project itself was part of a rich history of scientific investigation about the San Francisco Estuary. The Project participants collectively represented hundreds of years of baylands field and laboratory experience. The institutions they represent have long histories of both bayland science and management. While it is certainly true that much is known about the estuary and the baylands, much remains to be learned.

The first half of this chapter presents an overview of past and present bayland studies, and provides some perspective on the breadth and depth of current scientific knowledge. The second half of this chapter presents the Project's recommendations for future studies and urges the implementation of a region-wide research and monitoring program.

History of Baylands Science

The history of science and management of the baylands begins with the native peoples that lived near the baylands for at least 30 centuries. Their survival depended upon a detailed understanding of the ecological structure and functions of the baylands (Milliken 1995). To the extent possible, the available fragments of this native knowledge have been incorporated into the Project through the historical view of the Bay Area EcoAtlas, which is based in part on Native American accounts of habitats and wildlife. It is well documented that the Native Americans used the tidal marshes for salt production and waterfowl hunting (Ver Planck 1958, Brown 1960). The emerging picture of native land management may provide some guidance for managing the baylands in the future.

Beginning in the mid-1700s with the earliest Spanish explorers, people began to record the physical features of the region's landscape on maps, and later to describe its physical and biological characteristics in journals and reports. The

Tules are turned into houses.

Elise Brewster

A Wealth of Baylands Knowledge

Over the last hundred years, there has been a rapid increase in the amount of scientific information about the baylands. In the 1980s, more than 350 technical reports and articles about the baylands were produced; nearly twice as many as were produced in the 10 previous decades. These figures do not include the numbers of environmental impact reports and monitoring reports.

Since the 1980s, the number of baylands researchers has increased, with the universities, colleges, and government agencies in the region contributing more to baylands science than ever before. The amount of scientific information about the baylands continues to grow. And yet, much of the more current information has not been published; it exists in the field notes and collective experience of the regional community of wetland scientists and managers.

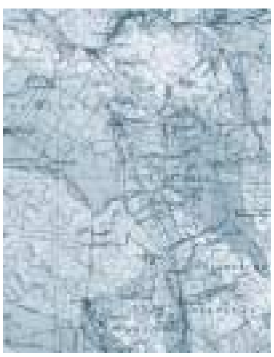
By bringing together these regional experts, the Goals Project was able to draw not only from many decades of published information, but also from the greater wealth of professional scientific experience.

following three sections trace the evolution of baylands knowledge through mapping, physical science, and ecological science.

Mapping

No map shows all.

Bancroft Library



USDA 1914

Whitney 1873

Various maps of the estuary and its immediate environs have been produced in the last two centuries. Juan Crespi drew the first published map in 1772, during the expedition of Pedro Fages. Other Spanish explorers produced no fewer than seven maps during the late 1700s. From 1827 to 1839, the English expedition led by Frederick Beechey made five separate maps of the estuary and some of its harbors. All of these maps include considerable detail of the bathymetry of the bays and straits, and features in the baylands, including lagoons, and local streams.

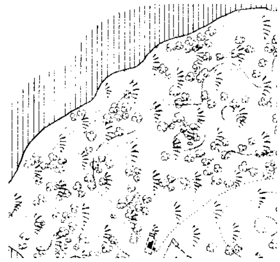
Early maps of the Spanish ranchos and Mexican land grants were sketched by the landowners to support their claims. These maps, which date between about 1830 and 1850, show appreciable detail of tidal marshlands and riparian forests. In 1841, Charles Wilkes created a detailed map of Suisun, the Delta, and the lower reaches of the Sacramento River for the U.S. Navy. The U.S. Hydrographic Office (Harlow 1950) revised this map in 1850.

The most detailed and well-documented maps of the baylands were produced by the U.S. Coast Survey in two sets, the T-sheets and H-sheets, beginning in 1852. Although these maps vary in quality among the surveyors, they remain some of the most detailed shoreline maps ever made (Grossinger and Collins 1999).

Other maps made during the late 1800s and early 1900s can be used to confirm the details of the T-sheets and H-sheets, and in some cases to add local information. Examples of these kinds of maps include historical county maps, local soil surveys by the Bureau of Soils of the U.S. Department of Agriculture, the first topographic maps produced by the U.S. Geological Survey, and the regional geomorphic maps produced by Josiah Whitney as the first State Geologist.

Since the beginning of this century, the number and kinds of maps of the Bay Area has increased. However, until the last few decades, most modern maps disregarded the baylands. The navigational charts produced by the Coast and Geodetic Survey, and later by the National Oceanographic and Atmospheric Administration, focused on the bathymetry of the bays and straits, and the foreshore between the baylands and the open bays. The second and third generations of topographic maps made by the U.S. Geological Survey tended to only show the levees and roads of the baylands and some of the largest tidal marsh channels.

It was the advent of computer-based cartography that greatly improved mapping of the baylands. During the last few decades, global positioning systems, which use satellites to determine the geographic coordinates of the ground surface, have been combined with digital imaging technologies (e.g., radar, infra-red, and other spectral themes) in geographic information systems to create electronic maps. Digital terrain models and high-resolution digital images from airplanes and satellites are fundamental elements among these technical mapping systems. The U.S. Geological Survey recently produced a new set of digital terrain models for the Bay Area, and the National Oceanographic and Atmospheric Administration and the National Atmospheric and Space Administration are developing high-resolution imagery of the baylands.


USCS 1860
Oaks dot a map...

A cooperative venture between the National Ocean Survey and National Geodetic Survey has produced a new array of global positioning system control stations in the North Bay and in Suisun (BCDC and NOAA 1998) to improve the spatial registration of baylands images. Bay Area maps are moving onto the Internet as interactive references to spatial data and their sources (e.g., the Regional Environmental Geographic Information System at the University of California, Berkeley; Bay Access at the U.S. Geological Survey in Menlo Park; and Comprehensive Monitoring Assessment Research Inventory at the Estuary Institute). The Bay Area has become a center for new information technologies, including state-of-the-science cartography.

Physical Science

The earliest known studies of the physical nature of the estuary dealt with the tides and currents. The early explorers recorded the strengths of the currents and the depths of the bays relative to tidal stage. There has been a nearly continuous record of the tides at Fort Point since 1868. Another permanent gage was later installed at the Alameda Naval Base. This gage provides a record that is more indicative of tidal patterns in the estuary.

The National Ocean Survey is responsible for measuring the tides. It periodically computes the tidal datums for permanent and temporary gages around the Estuary, and these computations are used to adjust the datums for sea level rise (Gill et al. 1998). The National Ocean Survey has conducted regional studies of the spatial variations in tidal datums (NOAA 1980 and 1983), and both the U.S. Army Corps of Engineers (USACE 1984) and the California State Lands Commission have analyzed the frequency of different tide heights. The California Department of Water Resources has tide gages in Suisun that are referenced to the National Ocean Survey tidal datums. Some cities have their own gages and use their own datums. Field studies have revealed natural, local variations in average tide height among tidal marsh channels that are ecologically significant (Collins and Evens 1992). Recent studies of tidal marsh geomorphology suggest that these spatial variations in tidal datums also have a significant effect on the natural maintenance of tidal marsh channels (Siegel 1993). The ongoing measurements of the tides and currents are an essential part of the basic information about the baylands.

...of oaks on a hillside.


NASA 1995/96

There are few early records about the physical nature of the baylands, except with regard to the tides. The earliest explorations provide some accounts of the sources of fresh water around the edges of the estuary, but these accounts mainly focus on plants and other wildlife. Some of the written records of extreme events, such as Brewer's observations of the great flood of 1862 (Farquhar 1966), or the descriptions by Crespi of natural salt ponds in the South Bay (Bolton 1930), help to visualize the historical, natural variability in weather and landscape.

There have been far fewer studies of the physical nature of the baylands than of their ecology. Gilbert's study of currents and sedimentation (Gilbert 1917) is the "nearest thing we have to a base line analysis of the physical characteristics of San Francisco Bay" (Hedgpeth 1979). This study marked the start of a continuing investigation into the hydro-dynamics of the estuary (Miller et al. 1928, Young 1929, Fischer 1976, Conomos et al. 1979, CDWR 1986, Ogden Beeman and Associates 1992, Cheng et al. 1993, McDonald and Cheng 1993) and sediment transport (Krone 1966, Buchanan and Schoelhammer 1995), which has lead to increasingly useful numerical models.

Until very recently (Schoelhammer 1998), the hydrologists who study the open bays and straits had not studied the baylands. Past analyses of sediment fate and transport within the estuary has disregarded the baylands (Krone 1979 and 1985). Hydrological studies of the baylands did not begin until the 1960s. Studies undertaken at this time focused on the form and function of small tidal marsh channels (Pestrong 1965, Holland 1976, Collins et al. 1987, Haltiner and Williams 1987a, b, Siegel 1993, Leopold et al. 1993) and local patterns of sedimentation (Pestrong 1972, Wells and Goman 1995). The most recent field studies in the Napa-Sonoma marshes (USACE 1998), and the estuarine hydro-dynamic modeling for South Bay have begun to elucidate the hydrological interactions between the bays, the baylands, and local watersheds.

Chronic subsidence of the baylands has been addressed from two perspectives. Subsidence due to groundwater extraction has been measured and mapped by the U.S. Geological Survey (Helley et al. 1979) for the Santa Clara Valley and adjoining baylands of South Bay; groundwater levels in this area are intensively monitored by local agencies. Local subsidence of diked baylands due to wind erosion and the oxidation of peaty soils has been studied in the Delta (Hastings 1998), with findings that apply to diked baylands elsewhere in the region. Bayland farmers and duck club members understand the influence of local subsidence on surface water management. Their practical experience in water management can be applied to the enhancement of diked baylands.

Until recently, water quality studies have focused almost exclusively on the open bays and local watersheds (Miller et al. 1928, Filice 1959, Luoma and Cain 1979, RMP 1998). Studies of the distribution and the ecological effects of contaminants are now being extended into the baylands (Lee et al. 1995, RMP 1998). The potential use of dredged sediments to nurture tidal marsh restoration (LTMS 1998) has also nurtured the study of intertidal sediment toxicity (Lee et al. 1995). Ongoing studies of the fate and transport of estuarine contaminants within the baylands will help to quantify their regional function as a water filter.

Ecological Science

The journals of naturalists that accompanied the earliest Spanish explorers are the oldest written ecological surveys of the Bay Area. The naturalists that traveled into the region more than 200 years ago with Gasper de Portola, Pedro Fages, Don Fernando Rivera, Juan Manuel de Ayala, and Juan Bautista de Anza (Bolton 1930) made notes about the plants and animals that they encountered near the estuary, and about the landscapes around them. These accounts of local settings collectively provide a rough sketch of the native landscapes of the region. They were followed in the late eighteenth and early nineteenth centuries by other explorers, most notably George Vancouver, who made maps and recorded the natural history (Vancouver 1798), and F.W. Beechey (Beechey 1941). Perhaps the first substantial biological survey of the estuary and its adjacent uplands was made in 1824 (Hedgpeth 1979) by scientists accompanying the Russian explorer, Otto von Kotzebue (Essig 1933).

These and other early accounts were later combined with anthropological studies of contemporary Native American culture in technical references about the historical ecology of the region (Cooper 1926, Skinner 1962). These records have since been compiled and augmented with more recent findings to create the current set of references (Mayfield 1978, Atwater 1979, Harvey et al. 1992). The historical view of the EcoAtlas that was developed for the Goals Project is one of the most detailed regional maps of native landscapes ever produced.

There was a long hiatus in regional ecological studies of the baylands between the early 1800s and the mid-1900s. Voyages of the U.S. Fisheries Commission steamer Albatross within the estuary beginning in 1912 yielded a variety of technical articles on the estuarine water and their biota, but almost nothing about the baylands (Hedgpeth 1979). Researchers at Stanford University and at the University of California, Berkeley made significant collections of the fauna and flora of some locations. However, these were not compiled into a regional view until a few decades ago. Reverend Edward Greene conducted botanical surveys through much of the region in the late 1800s, but his collections are not comprehensive for the baylands. The longest running ecological records for the region are the U.S. Fish and Wildlife Service's and the California Department of Fish and Game's mid-winter waterfowl surveys, and the California Department of Fish and Game's annual mid-water trawls. The waterfowl surveys began in 1955, and the trawls began in 1967. Of these studies, only the waterfowl surveys pertain directly to the baylands.

Environmental legislation enacted in the early 1970s created a need for scientific information about the baylands. A new industry of environmental science was built on the need to inform regulatory decisions. The sudden growth in ecological information about the baylands, and its variable quality, warranted a series of regional and subregional reviews during the late 1970s (CDFG 1977, Harvey et al. 1977, Atwater 1979, Jones and Stokes Associates et al. 1979, Josselyn 1983).

These reviews identified gaps in understanding that began to be addressed by a growing number of baylands scientists in government, academia, the private sector, and not-for-profit scientific institutions. Ecologists and hydrologists at the University of California, Davis; University of California, Berkeley; San Jose State University; Hayward State University; and San Francisco State University developed new lines of baylands research. The U.S. Fish and Wildlife Service, California Department of Fish and Game, Point Reyes Bird Observatory, and San Francisco Bay Bird Observatory began regular field surveys of baylands birds and other wildlife. Field data began to flow from baylands restoration projects.

Science for Baylands Restoration

A large amount of scientific information about the estuary has been developed during the past century. Although much is known about the baylands, there is much to learn. Throughout the course of the Goals Project, participants frequently noted a scarcity of data on many important bayland issues. They identified many research needs in their focus team recommendations and in their species profiles. At the five-day integration workshop, Project participants agreed that future efforts to restore the baylands ecosystem should be supported by an integrated program of research and monitoring. Such a program is needed to provide better information on habitats and their functions and on the effects of restoring and enhancing these habitats. It also is needed to track progress towards achieving the Goals.

Perspective on the Science of Wetlands Restoration

The science of wetland restoration is still in its infancy — active restoration has been underway for less than three decades. Achieving the ambitious vision presented by the Goals Project will require rapid advancements in the state of this science. We must learn from past and present efforts — gathering, interpreting, and sharing information so that each generation of restoration projects is more predictable and cost effective.

How does a new science typically develop? We can obtain some historical perspective by considering advances in other fields, such as space exploration, electronics equipment and data processing, and water resources engineering. In each of these cases, advancements stemmed from nationally recognized public mandates. Spurred by public sentiment, elected officials and government agencies provided support through legislation and resources. Public interest and government support resulted in integrated programs of fundamental research, extensive laboratory-scale experimentation, carefully monitored pilot projects, and large-scale project implementation. All phases of these efforts were monitored and evaluated, so that the designs could be refined and the success measured.

Similarly, the field of wetland restoration had its beginning when ecologists and the public, recognizing the value of wetlands, directed the government to halt their continued widespread destruction. In response to public pressure, elected officials passed laws restricting unnecessary wetlands destruction and requiring mitigation for permitted losses. The government also established funding to purchase and restore wetlands in some areas. Although the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, and the U.S. Fish and Wildlife Service are conducting some research on many aspects of wetlands ecology, much remains to be done to develop a coordinated program of research, experimentation, and monitoring. Most wetlands restoration projects continue to be monitored solely to verify compliance with permit requirements, and this limited monitoring information is typically not widely disseminated. Inadequate attention is typically given to evaluating these individual projects holistically to determine how they support overall ecosystem health, or to glean new knowledge from the effort.

Despite this disorganized beginning, the current state of the science of wetlands restoration is starting to resemble the early stages of advancement in other scientific fields — there are national and state mandates to protect and restore wetlands, most government agencies concerned about the baylands recognize that a comprehensive program is needed, and the public broadly supports the idea of protecting and restoring wetlands as a part of a larger movement to preserve the environment. It is now reasonable to envision that, given adequate funding and more integrated federal and state agency support, wetlands restoration might advance into a more mature science, with appropriate levels of research, monitoring, and implementation.

— By Jeff Haltiner, Hydrogeomorphic Advisory Team

Many endeavors, in addition to the Goals Project, have recognized the need for a regional program of baylands science. Such a program was called for in the National Oceanographic and Atmospheric Administration's proposed San Francisco Bay Estuarine Research Reserve System (NOAA 1992), in the Estuary Project's *Comprehensive Conservation and Management Plan* (SFEP 1993) and its *Regional Monitoring Strategy* (SFEP 1993), and in the CALFED Bay-Delta Program's Comprehensive Monitoring and Research Program (CALFED 1998a).

Suggested Program Objectives

A regional program of baylands science should focus on meeting the scientific needs of baylands managers. To do this, there must be a critical look at each existing and new restoration or enhancement project, and a series of questions must be asked: Is the project successful? How is "success" defined? Are there any negative effects of the project? What are the combined effects of this and other projects on regional conditions? Does the project bring us closer to the regional habitat goals? What should be done differently with the next project?

The breadth of these issues underscores the need for a comprehensive science program that includes the following objectives:

- **Increase understanding of baylands habitats and ecological functions.** The capability to restore or enhance the baylands is linked to an understanding of their function as ecological systems. Much of the ecological function of wetland systems results from complex interactions among physical and biological factors that are not well understood. Increased understanding of these complex systems will enable improvements in the planning, designing, and management of restoration and enhancement projects.
- **Build upon existing science and monitoring experience.** Although there is much to learn about baylands restoration and enhancement, past projects provide important lessons. The exchange of ideas among local and regional experts should be encouraged and facilitated.
- **Obtain useful information from each restoration and enhancement project and use projects to test new ideas.** Much can be learned about baylands restoration and monitoring through projects that are designed to help meet research needs. Controlled scientific experimentation should be supported as a way to rapidly improve the ability to create functional systems.
- **Monitor to measure progress towards the Goals.** The Goals provide a yardstick by which to measure progress towards a healthy and sustainable baylands ecosystem. This information can be used to prepare a "report card" to Congress, legislators, the public, and other stakeholders, and to inform the Estuary Project's continuing State of the Estuary updates.
- **Monitor some mitigation projects.** Wetlands restoration projects frequently occur because of requirements associated with dredge or fill permits, and they must be monitored to assure compliance with permit conditions. In some circumstances, it may be beneficial to include monitoring of these sites as part of a regional program.

- **Make information readily available to agencies and the public.** Policy makers and other planners can make better decisions based on up-to-date, accurate information on the health and status of restoration of the baylands.

To help meet these objectives, the Estuary Institute has begun to develop a program for baylands science, focusing on the baylands downstream of the Delta (Collins 1999). In a somewhat parallel fashion, CMARP has begun developing a plan to assess the ecological health of shallow water habitats in the Sacramento/ San Joaquin River watershed, including the Delta and Suisun Marsh (Collins, J. 1998). Coordination of these efforts is required for them to address the needs for baylands science throughout the estuary.

Suggested Program Framework and Elements

The wetland science program should be developed within a logical framework. This framework could possibly consist of a set of conceptual models about the baylands and their ecological functions. The conceptual models could help the regional experts generate hypotheses and identify critical gaps in understanding or information. A draft set of conceptual models has been developed (Collins 1999), but these are very preliminary and will need further review and revision.

Project participants and others have identified many of the needed elements of a baylands science program. The following sections briefly describe these elements and some priority topics that should be addressed. Additional and more detailed research and monitoring recommendations are in the focus team recommendations (Appendix C) and in the species and community profiles (Goals Project 1999).

Please note that the suggested program elements and topics presented here are incomplete and preliminary. Designing the bayland science program will require a thorough and systematic assessment of these and other elements and topics. During that assessment, it may be helpful to organize each program element according to a hierarchy similar to the one presented in the next section.

Research

Research is needed to expand scientific understanding of the baylands ecosystem. Agencies should establish priorities to help focus this research toward key topics of interest to bayland managers. Within this framework of priorities, researchers should be encouraged to explore new ideas and confirm new discoveries. This approach would link research to practical management needs.

An effort to prioritize research topics has already begun, as Project participants identified many questions relating to their particular interests. Others, too, have identified research topics (SFEP 1995, Collins, J. 1998 and 1999). In general, there seems to be a need to better understand the nature of the baylands as habitats for native and introduced fish and wildlife, and as transitional landscapes between the open bays and the local watersheds. These topics can be further separated into a larger number of more specific questions according to their physical or biological aspects and the scale to which they pertain. It should be recognized that research priorities will change.

On a regional scale (i.e., whole estuary), research should be conducted to answer the following types of questions:

Physical Sciences

- What are the effects of tidal marsh on the sediment budget and tidal prism?
- How does the form of tidal marsh channels vary with salinity?
- What is the availability of sediment for tidal marsh restoration?
- What is the appropriate scale to measure shoreline loss or gain?
- What factors affect the evolution of mudflats and tidal marsh features?

Biological Sciences

- What is the effect of tidal marsh on nutrient supplies to the bays?
- What is the tidal marsh fish community?
- What are the patterns of migration of waterfowl and shorebirds through the baylands?
- For which species of fish and wildlife is the baylands ecosystem fragmented?
- Where do birds go if their habitat is converted to another habitat type?

On a subregional scale (Suisun, North Bay, Central Bay, South Bay), research should be conducted to answer the following types of questions:

Physical Sciences

- How do the relative influences of watersheds and bays on sediment supply and contaminant loading vary with distance along the tributaries, such as Nurse Slough, Suisun Slough, Napa River, Petaluma River, or Coyote Creek?

Biological Sciences

- What controls the distribution and abundance of California clapper rail, salt marsh harvest mouse, and other resident species — what are the roles of dispersal, food, nesting resources, and salinity?
- Where do tidal marsh birds and tidal flat birds go at high tide?
- What support functions are provided by salt ponds, seasonal wetlands, and managed marsh?
- What is the long-term effect of waterfowl management practices on marsh soils and vegetation?

On a local scale (projects and wetland patches), research should be conducted to answer the following types of questions:

Physical Sciences

- What is the relationship between tidal marsh patch size or shape and natural channel maintenance?
- How do marshes act as chemical or sediment filters; what is the relationship between loading, distance from channel, and plant architecture?
- How does tidal marsh affect local watershed drainage, including flood frequency?
- How are mature, high tidal marsh conditions restored quickly, especially in subsided baylands?

Biological Sciences

- What causes plant zonation in a tidal marsh?
- What is the relationship between habitat patch size and production of waterfowl or shorebirds in managed and unmanaged diked marshes?
- How can non-native plant and animal species be monitored and controlled, and how can new introductions of invasive species be prevented?

Pilot Projects

Because most of the restoration efforts over the past 30 years have been mitigation projects, they have been designed and monitored primarily to meet permit requirements. Consequently, these efforts have focused little on expanding restoration science or our technical understanding of the baylands ecosystem. Pilot projects are needed now to answer the high priority questions about baylands restoration. Depending on the kind of information needed, pilot projects typically may range in size from a few hundred square feet to many hundreds of acres, or even larger. Pilot projects looking at natural habitat controls or large-scale tidal marsh design issues should be very large, from 500 to 1,500 acres.

Project participants suggested that pilot projects should be undertaken on many topics that fit into the general outline of needed research. Topics that should be addressed through one or more pilot projects include:

- Optimal design, configuration, and management of salt ponds to support shorebirds and waterfowl in the absence of commercial salt production.
- Effective and affordable methods for controlling non-native invasive plants, such as smooth cordgrass.
- The effect of smooth cordgrass on habitat function.
- Techniques for incorporating naturalistic high marsh pans and other features as integral components of large-scale tidal marsh restoration projects.
- Methods for restoring tidal marsh in the deeply subsided areas in South Bay.
- Options for using organic, rather than strictly mineral, sediment for restoring tidal marsh elevations.
- Possible non-traditional water management methods to provide good waterfowl habitat.

Monitoring

Monitoring is a repeated set of systematic observations designed to measure change over time. It is essential for determining the success of restoration projects, the effects of management decisions and practices, and progress toward the Goals. Monitoring is required by regulatory agencies for mitigation projects and for most restoration projects. However, the existing approach to monitoring is piecemeal and should be improved to enable comparisons of projects and to measure regional conditions.

One of the first steps in improving the approach to monitoring should be an assessment of existing baylands monitoring efforts. This assessment should lead to the development of standard monitoring methods that would enable short-term and long-term project comparisons. These methods should include practical monitoring parameters and protocols that would provide useful information at a reasonable cost.

The performance of wetland projects must be evaluated relative to the natural variability of the baylands. This requires establishing a network of reference sites that can be used to monitor background variation in populations of key species of fish and wildlife and their habitats. Although there are no sites within the baylands ecosystem that have remained pristine, there are less-disturbed sites or portions of sites which still provide a useful basis for comparison. The proposed San Francisco Bay Estuarine Research Reserve of the National Oceanographic and Atmospheric Administration can help provide a large part of the needed network of reference sites (Vasey 1995).


Jack Feminella

A biologist learns the ropes.

In addition to monitoring done for individual research projects, pilot projects, and restoration projects, information is also needed on a broader scale. The distribution, abundance, and health of populations of key fish, wildlife, and plant species should be monitored on an ongoing basis. The status of endangered species may be of greatest concern, but this should not reduce the need for comprehensive and routine monitoring of other fish and wildlife populations.

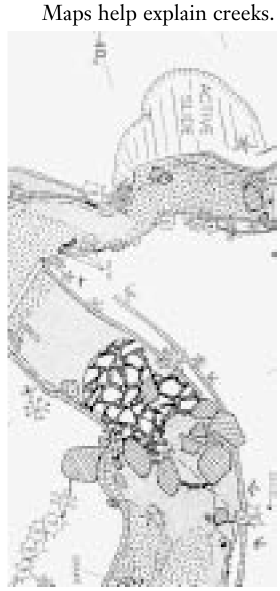
The program will need to provide quality control and assurance for monitoring data and their interpretation. The methods of data collection must be repeatable, and the data must be defensible and address the monitoring issues or objectives with adequate accuracy and precision. There should be protocols for data storage and transfer that maintain the integrity of the data and minimize their misuse.

Monitoring results must be made available to those who can use them to improve the next generation of restoration projects. Also, the information derived from projects should be used to adjust the regional Goals according to new understanding. In this way, new projects will continue to make progress towards the overarching goal of restoring the physical, chemical, and biological health of the estuary.

Mapping

Mapping is an important tool for effectively relaying many kinds of information obtained through research and monitoring. Paper or "hardcopy" maps are useful to display simple concepts. A computerized geographic information system (GIS) is an extremely powerful form of mapping that can be used to create and update maps of any combinations of landscape features at any scale. Data, reports, other maps and images can be electronically "linked" to maps in a GIS, creating a visual, geographic index to information. New technologies are being developed that enable an on-line GIS, so that maps and related information can be accessed over the Internet.

Maps help explain creeks.


Laurel Collins

There will also be a need to track changes in the distribution, quantity, and quality of key bayland habitats. This will require careful mapping of changes in the baylands landscape. The EcoAtlas could be a useful tool for tracking and visualizing such changes.

Project participants identified many mapping needs, including:

- Current distribution and abundance of the key habitats. Resolution of the maps may need to increase for habitats of some key species of plants and some animals that occupy small habitat patches. Ideally, the regional maps of key habitats would indicate the variation in habitat quality between habitat patches, relative to the desired support functions for the key plant communities and fish and wildlife species. These would need to be updated periodically.

- Topography and tidal elevations of the diked baylands. This information is needed to estimate the amount of tidal prism and sediment that might be required to achieve the tidal marsh restoration called for by the Goals.
- Distribution and abundance of many key species of fish and wildlife, particularly threatened and endangered species.
- Rocky intertidal habitats and significant feeding and roosting areas for rocky intertidal shorebirds.
- Salinity and moisture gradients within habitats.

Information Management Systems

Information about the baylands is distributed among many documents and libraries. For example, there are scientific journals, environmental impact reports and statements, and monitoring reports for compensatory mitigation projects. Many studies have never been reported. Very few organizations subscribe to more than a few of the dozens of scientific journals that are likely to contain information relating to the baylands. Most of the existing reports for baylands restoration projects are located in government agencies, universities and other research institutions, private companies, or non-profit environmental organizations. Very few reports are widely distributed. A large body of valuable information also exists in the form of casual observations of local conditions by landowners, scientists, and other resource managers.

There are several ways, from simple to quite sophisticated, that information about the baylands could be made more accessible. The first, and simplest, approach would be to create a comprehensive bibliography of research and monitoring information. It would be possible, for example, to create an on-line bibliography that is updated frequently. Portions of the initial contents of such a bibliography already exist in various offices and could be readily assembled.

A more advanced approach would involve creating and maintaining a dedicated web site to enable anyone with Internet capability to access information about the baylands. Information could be accessed through a set of written menus and a map of the baylands. The kinds of information that could be available are almost unlimited; they include pictures, movies, graphs, maps, reports, tabular data, and commentary. Information could be accessed for a particular baylands site, subregion, or for the entire baylands ecosystem. There could be an on-line GIS for making custom maps and viewing the distribution of data. It is possible to create an on-line information system that enables people to correspond, even to send email with attached files, through an interactive map of the baylands.

"Perhaps there will always be more information about the baylands than can be made available to any one person or organization. ...The challenge is to provide as much useful information to as many people as possible."
— J. Collins, SFEI

The most beneficial information system will meet the variable technical capabilities of its users. This means that there should be access to information through CD-ROM and other portable electronic media, and there should be paper products like conventional maps and reports, as well as interactive maps on-line. The EcoAtlas includes many of these features and has the potential to become a comprehensive information management system for the Bay Area.

Conclusion

There has been considerable scientific information compiled about the estuary and the baylands in the past decades. In recent years, the volume of information has grown exponentially. Increased information promotes a better understanding of this complex environment and will help improve habitat restoration design and management. However, access to the information needs to be improved, and even with all of the information that is available, there is still a need for more.

The RMG warned that there is a significant ecological risk in undertaking region-wide bayland restoration efforts without an adequate program of science support. This chapter has identified many aspects of the science program that is needed. Appropriate steps should be taken immediately to establish a regional science program to support the management of the baylands ecosystem. The first tasks should be selection of reference sites to monitor background conditions, development of uniform data collection and interpretation protocols, and creation of a system for managing information. The initial emphasis should be placed on making existing and new information more available for those who can use it to improve restoration planning, design, and management decisions.

"A program of wetlands science should accompany any region-wide restoration effort. However, science should not be pursued in lieu of restoration, and it should not be extravagantly funded. Both efforts must be undertaken concurrently."
— P. Baye, RMG

Local scientists and other experts should develop the baylands science program. This should involve regional experts in population biology, community and ecosystem ecology, hydrology and geomorphology, toxicology, and information technologies. The Estuary Institute should coordinate the effort as part of the Regional Monitoring Strategy that was recommended by the *Comprehensive Conservation and Management Plan* (SFEP 1993). The agencies and programs that should participate in developing this program include:

- CALFED Bay-Delta Program
- California Coastal Conservancy
- California Department of Fish and Game
- California Department of Water Resources
- California Environmental Protection Agency
- California Resources Agency
- California Water Resources Control Board
- National Atmospheric and Space Administration
- National Geographic Survey
- National Marine Fisheries Service
- National Oceanographic and Atmospheric Administration
- National Ocean Survey
- San Francisco Bay Conservation and Development Commission
- San Francisco Bay Regional Water Quality Control Board
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- U.S. Geological Survey

Developing and implementing an adequate bayland science program will require considerable resources. The agencies and other entities that develop the program will need to consider both short-term and long-term costs and should take steps to ensure adequate funding.

Next Steps

Sponsors of the Goals Project anticipate that several agencies and other entities will immediately begin to implement the recommendations in this report. This chapter identifies some of these groups and describes how each one will likely use the Goals. It also highlights some of the incentives that are available to private landowners that are considering restoring or enhancing bayland habitats. And it describes an effort that will begin in spring 1999 — the development of a regional wetland strategy.

Regional Planning Efforts

There are several agencies and other groups that have begun, or soon will begin, to undertake specific, large-scale wetlands planning efforts in the Bay Area. These include CALFED, California Coastal Conservancy, San Francisco Bay Conservation and Development Commission, San Francisco Bay Joint Venture, San Francisco Bay Regional Water Quality Control Board, and U.S. Fish and Wildlife Service. Although the purpose, geographic scope, and products of these planning efforts vary considerably, the Goals recommendations should help all of them develop or fund useful habitat restoration and enhancement projects.

CALFED

The CALFED Bay-Delta Program is a collaboration among state and federal agencies and the state's leading urban, agricultural, and environmental interests. These groups are seeking to address and resolve the environmental and water management problems associated with the Bay-Delta system and ultimately to develop a long-term comprehensive plan for restoring ecological health and improving water management. The primary issues for which specific actions will be developed are ecosystem restoration, water supply reliability, water quality, and levee system integrity. Although the geographic scope of the CALFED problem area includes the Delta, Suisun Bay, and Suisun Marsh, the scope of its solution area reaches well beyond. It includes the Central Valley watershed, parts of Southern California, San Pablo Bay, San Francisco Bay, and near-shore portions of the Pacific Ocean (CALFED 1998b).

Within CALFED, the program to address ecosystem health is known as the Ecosystem Restoration Program. Its goals are to improve and increase aquatic and terrestrial habitats, and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species. The Ecosystem Restoration Program Plan (ERPP) establishes a framework for implementing long-term, ecosystem restoration efforts over several decades.

Since 1995, CALFED has been a major source of funding for environmental projects in the solution area, including some limited parts of the Bay. For the near future, projects funded through the ERPP likely will emphasize improving aquatic resources. When CALFED staff consider proposals for ecosystem restoration, the Goals should help them decide where, and for what kinds of projects, to expend funds in the Bay Area, particularly in the Suisun and North Bay subregions.

California Coastal Conservancy — San Francisco Bay Area Conservancy Program

The California Coastal Conservancy administers many programs to improve natural resources along the California coastline. In 1997, under legislative mandate, it established the San Francisco Bay Area Conservancy Program. This program is the Conservancy's primary effort to identify and adopt long-term goals for resource protection and outdoor recreation in the nine-county Bay Area. It involves governmental agencies, nonprofit land trusts, and other interested parties. The goals developed in this program will guide the Conservancy's priorities for undertaking projects and awarding grants. Although the program's scope includes all lands within the immediate Bay watershed, the Conservancy will base its resource and recreational goals for the baylands on the Goals Project's habitat recommendations.

San Francisco Bay Conservation and Development Commission — Bay Plan Update

The San Francisco Bay Conservation and Development Commission was established by the McAteer-Petris Act of 1965. It implements a comprehensive plan, referred to as the *San Francisco Bay Plan*, for the conservation of San Francisco Bay waters and regulation of shoreline development. The Commission updates the Bay Plan periodically, and the last update was in 1988.

In 1999, the Commission will begin a five-year process to update the Bay Plan. Its staff will use information developed by the Goals Project to assist in revising sections on Fish and Wildlife, Marshes and Mudflats, and Salt Ponds and Managed Wetlands. In addition, they will use Goals Project products in developing Bay Plan policies to minimize conflicts between bayshore public access and sensitive wildlife populations. They also may refer to Goals Project materials as they complete the North Bay Wetlands and Agricultural Protection Program. This program is designed to provide local governments with the tools and information they need to protect, enhance, and restore North Bay wetlands, and to protect agriculture and allow compatible uses to continue.

The Commission uses the EcoAtlas maps developed for the Goals Project as base maps for the San Francisco Bay Plan. These maps also provide the Commission's planning and regulatory staff with site information about the location and extent of various wetlands and transitional habitats along the Bay edge, a great aid in land use planning.

San Francisco Bay Joint Venture

The San Francisco Bay Joint Venture was initiated in 1996. It is a public-private partnership that seeks to promote the acquisition, restoration, and enhancement of Bay Area wetlands and associated habitats. It is one of 15 joint ventures that operate under the auspices of the *North American Waterfowl Management Plan*, which was signed by the United States, Canada, and Mexico. It includes partners from public agencies, environmental organizations, hunting and fishing groups, the business community, local government, and landowners.

Joint Venture partners currently are preparing an implementation strategy that is scheduled for release in spring 1999. The strategy will guide the Joint Venture as it undertakes specific wetland projects, and it will include habitat goals that are derived from the Goals Project recommendations.

San Francisco Bay Regional Water Quality Control Board — Basin Plan Triennial Review

The San Francisco Bay Regional Water Quality Control Board is the State agency responsible for regulating surface water and groundwater quality in the nine-county San Francisco Bay Area. The *Water Quality Control Plan for the San Francisco Bay Basin* (Basin Plan) is the Regional Board's master policy document. It describes the legal, technical, and programmatic bases of water quality regulation and defines programs to preserve and enhance water quality and protect the beneficial uses of the waters of the State. The Basin Plan identifies the protection, preservation, and restoration of the baylands' tidal marsh system as essential for maintaining the ecological integrity, and hence water quality, of San Francisco Bay.

In order to keep current with technological, hydrological, political, and physical changes within the region, the Regional Board reviews and revises its Basin Plan about every three years. Board staff have begun the preliminary stages of revising the Plan and expect to complete the process in 2000. The Regional Board will consider the Goals Project's recommended habitat changes and other technical information as they update the Basin Plan's wetlands protection strategy.

U.S. Fish and Wildlife Service

Endangered Species Recovery Plans

The U.S. Fish and Wildlife Service is preparing two endangered species recovery plans that will affect the restoration and enhancement of bayland habitats. These plans are the *Recovery Plan for Tidal Marsh Ecosystems of Central and Northern California* and the *Recovery Plan for Western Snowy Plover, Pacific Coast Population*. The tidal marsh plan will revise and expand the existing recovery plan that was prepared several years ago for the California clapper rail and salt marsh harvest mouse; it will include recovery actions for these species and for several others. The western snowy plover recovery plan will include recovery actions for this species along the U.S. Pacific Coast, including the San Francisco Bay recovery unit. Each of these recovery plans will identify actions necessary to achieve self-sustaining, wild populations of listed species so they will no longer require protection under the Federal Endangered Species Act. These recovery plans are scheduled to be available for public review in 1999. Also, the Fish and Wildlife Service has begun to revise the recovery plan for the California least tern, which was originally completed in 1980.

Many members of the Goals Project have participated, or are currently participating, on recovery teams. As a result, recovery plans likely will reflect the concepts and general recommendations in this report. However, it is important to note that the recovery plans are aimed at restoring a limited number of species, while the Goals seek to describe the habitat conditions necessary for a much larger and more diverse group of organisms. Accordingly, while recommendations in these recovery plan actions may be consistent with the general intent of the Goals Project to protect, enhance, and restore the estuary's ecosystem, specific recommendations may differ. For federally listed species, specific recovery plan recommendations will take precedence over general recommendations in this report.

San Francisco Bay National Wildlife Refuge Complex Comprehensive Conservation Plan

Soon after 2000, the U.S. Fish and Wildlife Service is scheduled to begin preparing a Comprehensive Conservation Plan (CCP) for the San Francisco Bay National Wildlife Refuge Complex. Through a process of public involvement and consultation with wildlife biologists and wetland scientists, the CCP will identify wildlife management objectives, amounts and types of wetlands to be restored, and specific restoration projects to accomplish these objectives. The CCP will provide site-specific analysis and will incorporate funding realities and engineering considerations that are beyond the scope of the Goals Project. As a result, the configuration, location, and types of wetlands to be restored on Refuge lands in North Bay and South Bay may differ from the site-specific recommendations presented in this report.

Use of the Goals by Non-governmental Organizations

There are many non-governmental organizations in the Bay Area that actively seek to protect or improve wetlands and other valuable areas. Some of these organizations also undertake environmental restoration and enhancement projects. The organizations that likely will help implement some of the Goals recommendations, or that will have an interest in ensuring that the recommendations are implemented carefully, include the eight Bay Area Audubon Society chapters, Bay Area Open Space Council, California Waterfowl Association, Citizens Committee to Complete the Refuge, Ducks Unlimited, Nature Conservancy, Save San Francisco Bay Association, Sierra Club, The Bay Institute, Trust for Public Lands, Urban Creeks Council, and many smaller groups with more local focus.

Landowner Incentives

Private lands around the estuary provide valuable habitat for fish and wildlife. This report recommends enhancing habitats on many of these lands. For other lands, it recommends restoring habitat, mostly to tidal marsh. Project participants recognized that the majority of lands around the estuary are privately held, and agreed that habitat changes should occur only with landowner consent. Therefore, attaining the Project's long-term vision will require cooperation of private landowners, resource agencies, and other interests.

There are many incentives available to landowners who are interested in improving wetlands and other habitats. These incentives include conservation easements, land purchase and lease-back programs, funding for maintaining infrastructure, such as levees and water control structures, and funding to pay for reduced crop production. **Table 8.1** presents some of the voluntary landowner incentive programs that may be used to improve wetlands on private lands. Information about each program is available from the respective agency or organization.

Some landowners have indicated they would be more interested in improving wetland habitats if the regulatory procedures were less complex and more streamlined. They also want to be offered fair market value for lands that are desired for tidal marsh restoration or that are managed primarily for wildlife.

There are many ways that the public and private sectors will need to collaborate to improve habitats in the coming years. One of the first steps could be for landowners to assess their short-term and long-term interests and to identify the kinds of restoration actions that are acceptable on their lands. For areas that

TABLE 8.1 Voluntary Landowner Incentive Programs for Wetlands

Program	Agency/Organization
Acquisition Program	U.S. Fish and Wildlife Service
California Waterfowl Habitat Program	California Department of Fish and Game and California Waterfowl Association
Conservation Reserve Program	Natural Resources Conservation Service
Environmental Quality Incentives Program	Natural Resources Conservation Service
Partners for Wildlife	U.S. Fish and Wildlife Service
Permanent Wetland Easement Program	California Department of Fish and Game and Wildlife Conservation Board
Resource Enhancement and Agricultural Programs	State Coastal Conservancy
Wetland Reserve Program	Natural Resources Conservation Service and U.S. Fish and Wildlife Service
Wildlife Conservation Board Program	Wildlife Conservation Board
Valley/Bay CARE	Ducks Unlimited

they do not want restored, landowners could identify acceptable enhancement actions. Agencies should work closely with landowners to identify the financial and regulatory tools that may facilitate these improvements.

Regional Wetland Strategy — A Framework for Coordination

The Goals establish a very flexible vision for restoring bayland habitats. Because they are not a blueprint of specific projects, implementing the Goals recommendations will require close coordination among landowners, agencies, and others. Restoration and enhancement projects will need to be tracked so everyone will know who is doing what, and as projects are monitored and as research is undertaken, the results will need to be made readily available. Without some kind of framework to ensure better coordination among restoration entities, appropriate research and monitoring, and improved agency policies and procedures, effectively restoring bayland habitats will be extremely difficult.

Poor coordination of restoration efforts could result in many kinds of problems. For example, planning for a particular tidal marsh project might not take into account the need for concomitant enhancement of nearby seasonal wetland habitat. Or, several tidal marsh projects might be undertaken concurrently in a segment of the Bay where there is insufficient suspended sediment. Or, two groups of scientists might unknowingly and unnecessarily duplicate research or monitoring work.

From the outset of the Goals Project, and in keeping with the Estuary Project's *Comprehensive Conservation and Management Plan*, the RMG envisioned that the agencies and the public would develop a framework for implementing the Goals. This framework would be developed after completing the Goals, as part of a regional wetland plan.

In spring 1998, at the request of the Estuary Project's Implementation Committee, staff of the U.S Environmental Protection Agency and the San Francisco Bay Regional Water Quality Control Board began a dialogue with the public and with other resource and regulatory agencies to determine the most appropriate way to develop a regional wetland plan. They discussed this issue with several landowners, with the San Francisco Estuary Project's Wetlands Subcommittee, and with the Bay Area Wetlands Planning Group. (The California Resources Agency initiated the Bay Area Wetlands Planning Group in 1994. Its members include the state and federal resource and regulatory agencies that are involved in wetland issues in the Bay Area. Its purpose is to improve regional wetlands planning and regulation.)

Most everyone agreed it would be beneficial to develop a wetland plan and expressed interest in participating, provided the process were limited in scope. Several people stated that, rather than trying to resolve each of the many wetland issues described in the CCMP, it would be preferable (and much quicker) to identify the most critical issues pertinent to implementing the Goals, and then to establish a brief framework or strategy for addressing them. Such a strategy would build upon and complement ongoing wetland planning efforts and could be completed relatively quickly and cheaply.

Based on these discussions, the California Resources Agency, which the *Comprehensive Conservation and Management Plan* designates as the lead agency for developing a regional wetland plan, agreed that the Bay Area Wetlands Planning Group should take the lead in developing the plan as a regional wetland strategy. This past winter, group members drafted a general scope for this effort. The tasks in the draft scope include forming a stakeholder committee, holding technical workshops, preparing a draft strategy, seeking public comments on the draft strategy, and preparing a final strategy. The stakeholder committee will include landowners, business interests, environmental groups, and local governments. Initial stakeholder meetings are scheduled to begin in spring 1999, and the process to develop the wetland strategy is expected to take six to twelve months.

At this time, it is difficult to predict exactly what the wetland strategy will include. At a minimum, it should (1) contain a plan (or plans) for implementing the Goals in each of the four subregions; (2) identify restoration projects (including pilot projects) and their short-term and long-term costs; (3) establish a wetland monitoring framework; and (4) include written agreements among the parties that will be funding, regulating, or undertaking projects.

Updating the Goals

The Goals are long-term recommendations that will take decades to implement. In preparing them, Project participants developed a detailed view of the estuary's historical and existing habitat conditions and a better understanding of the habitat needs of the baylands ecosystem key species. In the future, as additional ecological planning work is done, as wetland projects are undertaken, and as scientific information on restoration techniques and species needs improves, the Goals will need to be reviewed and possibly revised periodically. This should be done by the Resource Managers Group or its successor on a regular basis, perhaps every five years or so, and the regional wetland strategy should establish the procedures for doing this.

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EcoAtlas

The Bay Area EcoAtlas

Visit the EcoAtlas at the SFEI website: www.sfei.org

The San Francisco Estuary Institute manages the Bay Area EcoAtlas as a growing assemblage of maps, images, scientific data, and information sources about the ecology of the bays, wetlands, and watersheds of the San Francisco Bay Area.

The EcoAtlas began in 1995 as a computerized Geographic Information System (GIS) to support the multi-agency Bay Area Wetlands Ecosystem Goals Project. Hundreds of volunteers worked with the regional community of environmental scientists to develop detailed views of past and present ecological conditions along the broad zone of transition between the open bays and local watersheds of the San Francisco Estuary, downstream of the Delta. The EcoAtlas includes maps of Bay Area watersheds and key sets of regional data about stream fishes, introduced species, and contaminants. Efforts will continue in the future to expand the EcoAtlas with the new information needed to understand and protect the natural resources of the Bay Area.

The hallmarks of the EcoAtlas are authenticity and accountability. The contents of the EcoAtlas reflect ongoing discussions among many interest groups. Federal and state agencies involved with resource management help prioritize the possible contents. Local agencies and non-governmental organizations assist with EcoAtlas design concepts and formats. The EcoAtlas staff at SFEI always consult with the sources of outside information to understand the limits of its applicability. All the contents are supported by detailed records of their development. SFEI works with many partners in and out of government to maintain the integrity of the EcoAtlas.

Current development of the EcoAtlas is focused on making it widely available to the private sector and the public. Earlier versions of the EcoAtlas were distributed to a test group of Bay Area resource managers. These tests showed the need for the EcoAtlas to be available in many formats, including paper maps and reports, overheads, photographic slides, and digital files suitable for graphics production or inclusion in a GIS. On-line access with interactive maps and information exchange services is also being planned. SFEI is focused on developing the EcoAtlas as a readily accessible source of authoritative information about the ecology of the Bay Area.

For more information on the EcoAtlas, or to request maps, please contact SFEI:

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Past and Present Acreage for the San Francisco Bay, the Baylands, and Adjacent Habitats

TABLE 1 Past and Present Habitat Acreage for the Project Area

Habitat Type	Historical (ca. 1800) acres	Modern (ca. 1998) acres	% Change +/-
Bays			
Deep Bay/Channel	99,529	82,410	-17%
Shallow Bay/Channel	174,442	171,818	-2%
Total	273,971	254,228	-7%
Baylands			
Tidal Flat	50,469	29,212	-42%
Tidal Marsh	189,931	40,191	-79%
Lagoon	84	3,620	4209%
Salt Pond	1,594	34,455	2062%
Diked Wetland	-	64,518	
Agricultural Bayland	-	34,620	
Storage or Treatment Pond	-	3,671	
Undeveloped Bay Fill	12	7,598	63217%
Developed Bay Fill	-	42,563	
Other Baylands	254	1,951	668%
Total	242,344	262,397	8%
Adjacent Habitats			
Moist Grassland	60,487	7,474	-88%
Grassland/Vernal Pool Complex	24,070	15,038	-38%
Riparian Forest/Willow Grove	4,800	774	-84%
Total	89,357	23,286	-74%

TABLE 2 Past and Present Habitat Acreage for the Suisun Subregion

Habitat Type	Historical (ca. 1800) acres	Modern (ca. 1998) acres	% Change +/-
Bays			
Deep Bay/Channel	16,746	11,584	-31%
Shallow Bay/Channel	24,095	22,428	-7%
Total	40,841	34,012	-17%
Baylands			
Tidal Flat	2,405	1,124	-53%
Tidal Marsh	65,358	13,562	-79%
Lagoon	2	6	200%
Salt Pond	-	0	
Diked Wetland	-	49,873	
Agricultural Bayland	-	5,544	
Storage or Treatment Pond	-	720	
Undeveloped Bay Fill	-	762	
Developed Bay Fill	-	2,453	
Other Baylands	2	570	28380%
Total	67,767	74,614	10%
Adjacent Habitats			
Moist Grassland	6,529	936	-86%
Grassland/Vernal Pool Complex	14,178	9,153	-35%
Riparian Forest/Willow Grove	700	75	-89%
Total	21,407	10,164	-53%

TABLE 3 Past and Present Habitat Acreage for the North Bay Subregion

Habitat Type	Historical (ca. 1800) acres	Modern (ca. 1998) acres	% Change +/-
Bays			
Deep Bay/Channel	20,139	10,362	-49%
Shallow Bay/Channel	55,120	53804	-2%
Total	75,259	64,166	-15%
Baylands			
Tidal Flat	13,351	9,118	-32%
Tidal Marsh	55,076	16,347	-70%
Lagoon	37	2,353	6259%
Salt Pond	270	7,143	2545%
Diked Wetland	-	7,622	
Agricultural Bayland	-	27,732	
Storage or Treatment Pond	-	1,266	
Undeveloped Bay Fill	-	1,648	
Developed Bay Fill	-	6,211	
Other Baylands	24	565	2254%
Total	68,758	80,003	16%
Adjacent Habitats			
Moist Grassland	15,416	5,841	-62%
Grassland/Vernal Pool Complex	3,502	3,263	-7%
Riparian Forest/Willow Grove	1,000	315	-69%
Total	19,918	9,419	-53%

TABLE 4 Past and Present Habitat Acreage for the Central Bay Subregion

Habitat Type	Historical (ca. 1800) acres	Modern (ca. 1998) acres	% Change +/-
Bays			
Deep Bay/Channel	55,609	53,614	-4%
Shallow Bay/Channel	57,272	53,774	-6%
Total	112,881	107,388	-5%
Baylands			
Tidal Flat	13,532	4,014	-70%
Tidal Marsh	13,461	947	-93%
Lagoon	45	658	1363%
Salt Pond	-	-	
Diked Wetland	-	1,314	
Agricultural Bayland	-	34	
Storage or Treatment Pond	-	57	
Undeveloped Bay Fill	-	3,420	
Developed Bay Fill	-	21,970	
Other Baylands	215	380	77%
Total	27,253	32,794	20%
Adjacent Habitats			
Moist Grassland	5,466	-	
Grassland/Vernal Pool Complex	-	-	
Riparian Forest/Willow Grove	800	87	-89%
Total	6,266	87	-99%

TABLE 5 Past and Present Habitat Acreage for the South Bay Subregion

Habitat Type	Historical (ca. 1800) acres	Modern (ca. 1998) acres	% Change +/-
Bays			
Deep Bay/Channel	7,035	6,851	-3%
Shallow Bay/Channel	37,955	41,812	10%
Total	44,990	48,663	8%
Baylands			
Tidal Flat	21,181	14,955	-29%
Tidal Marsh	56,037	9,335	-83%
Lagoon	-	598	
Salt Pond	1,316	27,313	1975%
Diked Wetland	-	5,709	
Agricultural Bayland	-	1,309	
Storage or Treatment Pond	-	1,628	
Undeveloped Bay Fill	12	1,768	14637%
Developed Bay Fill	-	11,930	
Other Baylands	13	347	2570%
Total	78,559	74,893	-5%
Adjacent Habitats			
Moist Grassland	33,077	696	-98%
Grassland/Vernal Pool Complex	6,391	2,622	-59%
Riparian Forest/Willow Grove	2,300	297	-87%
Total	41,768	3,615	-91%

Compilation of Focus Teams and Hydrogeomorphic Advisory Team Recommendations

Notice

The following is a compilation of the recommendations produced by each of the focus teams and the HAT. You will note that some of the terminology used in these reports differs from that used in the Goals Report. For example, some teams discuss regions and subregions that are defined differently, and some use different names for habitats. This is because the terminology used within the Project has evolved over time, and some has been developed specifically to facilitate presentation of the Goals.

In order to preserve the original intent of the focus team authors, no changes, other than minor formatting changes, have been made in the teams' reports. We believe the intent of their recommendations is made clear by the information contained in the reports.

Plants Focus Team

Recommendations

The Plants Focus Team submits these recommendations regarding marsh restoration in the San Francisco baylands. Included is an introductory section on estuarine plant community objectives. Each recommendation includes descriptive background information and supporting rationale. For additional information regarding the plant communities of the baylands ecosystem, please refer to the community narratives that will be compiled in the Goals Project's Species and Community Profiles Report.

1. Overall estuarine plant community objectives. From the perspective of plant community conservation, the Plants Focus Team recommends the following objectives as the highest priorities for conservation of plant associations and rare plants in the San Francisco Estuary:

(1) protection of existing tidal marshes against further artificial losses and degradation;
(2) extensive restoration of *whole* tidal marsh systems (not just pocket marsh indentations within a matrix of levees that separate them from the historic Bay margin) and restoration of *associated ecotonal estuarine-margin plant communities* (e.g., freshwater riparian wetlands, vernal pool and swale grasslands, alluvial seasonal wetlands).

Tidal restoration of diked historic baylands (former marsh and mudflat) typically displaces non-tidal salt marsh, brackish marsh, freshwater seasonal wetland plant communities, and salt pans. While most diked wetland plant associations are less diverse and contain more exotic species than tidal marshes, some contain important populations of regionally rare plants which have been eliminated from their original communities in the ecosystem (e.g., subsaline vernal pools, alluvial terraces). The weedy character of much diked wetland vegetation is merely a contingent feature of past degradation from adverse land management practices (discing, ditching, filling), not an essential feature. Diked wetlands should therefore not be presumed to support entirely ruderal floras or degraded non-tidal salt marsh. They should be carefully assessed individually for regionally important plant associations before they are converted to tidal marsh, and some should be conserved and enhanced if they support scarce plant associations that cannot feasibly be replaced.

Tidal marsh restoration typically involves either passive sedimentation or engineered placement of dredged material to develop new marsh substrate in subsided diked baylands. These measures produce youthful marsh systems with little soil development, relatively little microtopographic differentiation, and usually support relatively low native plant species diversity. Well-developed and complex microtopography and marsh soils are often necessary for viable populations of rare tidal marsh plant species. Restoration designs should therefore be adapted to include structural features which will facilitate development of mature marsh features, while avoiding compromising natural marsh succession (e.g., gently sloping upland transition zones with suitable soils). This is particularly important along the upper marsh profile, where ponds, streams, alluvial deposits, and upland soils form complexes of ecotonal plant communities that naturally supported a high diversity of native plant species, which have declined significantly since most of the tidal marshes were diked.

The Plants Focus Team has chosen to use plant communities rather than species as the ecological units for conservation planning of the Estuary. This is partly because more is understood about the ecology of the habitat in which rare species occurred than about the species themselves, particularly for species which are now regionally extinct or reduced to minimal remnants of their original populations. It is also partly because many rare species are united by similar and related habitat requirements, often associated with the high marsh zone. For the plant communities considered, it would be arbitrary and unrealistic to prescribe specific acreage of plant associations as habitat goals at this regional level of planning. This is because plant associations and populations are highly dynamic in density, distribution, and area. Moreover, many rare plant populations, particularly rare annuals, are likely to exhibit fluxes of local extinctions and colonizations, often in concert with disturbances or environmental fluctuations. Instead, the Plants Focus Team is prescribing conservation priorities for the Bay ecosystem's plants which would apply to opportunities to acquire, manage or restore diked baylands and adjacent lands as they become available.

2. Natural geographic variation in marsh structure and composition should be incorporated into marsh restoration designs and objectives. In planning marsh restoration in the San Francisco Estuary, priority should be given to regenerating the full range of wetland types, local wetland habitats, and microenvironments within marsh systems. Much of the historic diversity of estuarine marsh was geographically embedded, reflecting local and subregional variations in substrate texture, wave energy, tidal energy, upland soils, upland drainages, etc. Some natural elements of the historic Estuary are either extinguished or drastically reduced or altered, such as sandy backbarrier marshes, lagoon-fringe marshes, natural salt pans and marsh ponds, natural levees along channels and bayfronts, and alluvial fan/terrace ecotones. Plant communities and species which are now locally extinct or in severe decline depended on natural variation in marsh structure and composition.

Therefore, the Plants Focus Team recommends that potential restoration sites be examined carefully for their potential contribution to restore geographically unique, atypical, or important local marsh systems. Geographically specialized marsh restoration plans, which fully consider opportunities to incorporate regionally scarce components of estuarine marsh systems, are preferable to generic marsh restoration plans.

3. Restoration opportunities which link tidal marshes to upland and alluvial soils, seeps, and drainages should be given high priority in restoration planning. Most tidal restoration sites are currently indented pockets in levee systems, separated from the historic margin of the Estuary by subsided diked lands. The upper edge of such restored marshes are typically steep, disturbed levee slopes on unnaturally elevated bay mud substrate which often supports weedy vegetation. Most floristic diversity in tidal marshes was concentrated along the upper marsh edge, where transitions between high tidal marsh and local soils, seeps, and drainages created ecologically important variation in environmental conditions. Many rare or locally extinct plant species had high affinity for, or ecological dependence on, these transitional and diverse environments.

Therefore, the Plants Focus Team recommends that opportunities to restore sites which connect tidal marshes to upland soils, creeks, seeps, and drainages be given at least as much priority as marsh restoration sites located adjacent to tidal sloughs.

4. The ecological restoration design of the upper marsh transition zones (ecotone) should be given as much priority as intertidal marsh. Upper marsh transition zones between high marsh and upland conditions are usually designed as buffer zones for wildlife, tidal refugia for wildlife, flood control components, public access and viewing areas, and maintenance access areas — predominantly pragmatic management considerations rather than ecological ones. In contrast, intertidal marsh is usually designed as wildlife habitat or ecosystem restoration for its own sake. Because most floristic diversity in tidal marshes would occur in the upper marsh transition zone, restoration plans should treat it as a high priority area for restoration based on natural models and reference sites.

5. Exotic vegetation control and maintenance of existing native plant communities should be given consideration equal to restoration of marsh at new sites. San Francisco Bay is subject to rapid invasion by exotic plant species which dominate whole marsh zones and displace native plant species (e.g., *Lepidium latifolium* and *Spartina alterniflora*). Some exotics displace rare and declining plant species and communities, such as upper marsh transition zones. Many newly restored marshes — perhaps most — are subject to rapid invasion and dominance by non-native marsh plants, significantly reducing the long-term ecological benefits of marsh restoration for biological diversity. Suppression of exotic plant invasion to newly restored marshes, which are less resistant to invasion than established marshes, is critical to the integrity of the plant communities they will support.

Therefore, the Plants Focus Team recommends that restoration efforts be directed not just to restoration of new tidal marshes in degraded diked baylands, but also to restoration, enhancement, and management of existing estuarine marshes, including systematic efforts to suppress the spread of invasive exotic marsh vegetation, and eventually reduce and control their abundance. Highest priority should be given to early eradication of small, local invasions before they require major control efforts after "latency" (e.g., *Spartina densiflora*, *S. patens*); eradication of outpost "guerilla" colonies of established invaders (e.g., isolated outlier populations of *Spartina alterniflora*); and large-scale population control in habitats supporting rare plants which are at risk of being excluded by the invasive species (e.g., *Lepidium latifolium* in habitats of *Cordylanthus mollis* or *Cirsium hydrophilum*)

Natural, passive recruitment of marsh vegetation is appropriate as a restoration tool only when local dispersal rates by exotic plant species to the restoration site are low. Where recruitment rates of exotic species are unavoidably high, planting of native vegetation to provide a competitive advantage to native species is often justified. No large-scale tidal marsh restoration should proceed before local infestations of invasive exotic plants are suppressed. Exotic plant control should be considered to be an integral component of site preparation for restoration projects, equal in priority to earthmoving.

6. Reintroduction and introduction of rare plant species should be employed selectively as a restoration tool when appropriate opportunities arise. Some plant species in San Francisco Bay have become locally extinct because of urbanization, such as California sea-blite (*Suaeda californica*, federally listed as endangered) and California saltbush (*Atriplex californica*), or have become very rare in the Estuary (e.g., *Lasthenia glabrata*, *Lasthenia platycarpha*, *Castilleja ambigua*, *Cordylanthus mollis*, *Cordylanthus maritimus*, *Lilaopsis masonii*).

Locally extinct plant species cannot disperse to potentially receptive restored habitats in San Francisco Bay from remote populations in a human time-scale. They should therefore be reintroduced from appropriate remnant populations outside the San Francisco Estuary when opportunities to restore receptive habitats for them arise. Furthermore, restoration projects should seek opportunities to establish receptive habitats for these species when feasible.

Rare plant species which still persist in the Bay may be limited by dispersal between artificially fragmented suitable habitats, as well as by scarcity of suitable habitat. Reintroduction is an appropriate tool to compensate for artificial fragmentation of rare plant populations in the Estuary. However, reintroduction should be designed to avoid adverse homogenization of genetically differentiated populations of rare species. Introduction of rare plant species to restoration sites which are not historically recorded to have supported them, but are within the ecological and geographic range of the species, is also appropriate for marsh restoration plans.

Attempted translocation of rare estuarine plant populations to restored marshes as compensatory mitigation for degradation or elimination of rare plant populations at impact sites is unacceptable and should not be permitted, since replacement of an established rare plant population by an uncertain and potentially unstable one is inherently adverse for the conservation of the species.

7. Dredged materials should only be used selectively for marsh restoration. Bay mud and other sediments dredged from the Estuary should be employed selectively in marsh restorations. Mineral-rich estuarine sediments should not generally be deposited at or above tidal elevations at which peaty organic material or adjacent upland soils would typically dominate the soil profile. Bay muds should not be deposited in the uppermost soil horizon of upper marsh transition zones unless used as a foundation material and are thickly capped with soil from terrestrial or alluvial (non-estuarine) sources. These restrictions are recommended because many rare marsh plants and associations of tidal marshes depend on the soil characteristics of peat-rich marsh soils and salinized, weathered upland mineral soils at the upland marsh edge, where soil texture and mineral composition is variable. Because marsh vegetation patterning is dependent on marsh drainage patterns, deposition of dredged materials above local Mean High Water, which inhibits differentiation of drainage patterns in subsequent marsh, should be discouraged (except where required for rapid development of endangered species habitat). Sites which historically supported relatively rare marsh substrates (e.g., sandy silts, sands, and interbedded alluvial sands, silts, clays) in the upper marsh zone should be restored with appropriate sediments. Levees used to contain dredged materials during filling operations should be removed to the greatest extent possible after placement of sediment, since levees screen out tidal litter that may be important in creating disturbance patches in tidal marsh.

8. Dry-season fresh wastewater discharges should be discouraged and reduced over time. Fresh wastewater discharges are a potentially useful resource for marsh restoration, but year-round high levels of discharges have contributed significantly to conversion of scarce salt marsh to brackish-fresh tidal marsh plant communities.

9. Refugial floras of diked wetlands should be surveyed before tidal restoration is proposed. While many diked wetlands are rich in exotic weedy species and poor in native species, some may (and do) act as refugia for species which were formerly found in tidal marsh edge environments, or adjacent seasonal wetlands, including species found in subsaline/alkaline soils of vernal pools. Since urbanization and agriculture have eliminated the original habitats of these species, their presence in diked wetlands may provide important refugia for geographically distinct populations. Diked wetlands should be subjected to careful seasonally timed surveys for spring flora species before diked wetland vegetation is presumed to be uniformly low in ecological value. Some diked baylands, particularly in the North Bay, should be conserved and artificially managed for hydroperiods that support surrogate grassland communities, including vernal pool plant species.

10. Marsh restoration plans, designs, and objectives should be based on empirical data. The use of generalized or arbitrary designs for plant community composition and vegetation structure should be discouraged. Plant community objectives should incorporate consideration of local geographic variability and historic conditions at the local and regional scale.

11. Outboard levees should be graded down to marsh level over long segments when tidal action is restored to diked basins, with some relict high fills left for tidal refugia used by marsh mammals and birds. This is to enable wave-driven debris (e.g., wracks, plant litter, peat rafts) to be dispersed across marsh plains during extreme tides, and to allow waves to propagate across shallow basins during brief periods of extreme inundation. These episodic disturbances — dispersion of tidal litter, drift-smothering of vegetation, and wave erosion of substrate at the high tide line — are important long-term cyclic processes for creating vegetation gaps, and regenerating natural disturbances on which some rare plant associations and species depend upon.

12. Hypersaline microflora conservation (specialized microalgal and bacterial flora adapted to hypersaline conditions) should be achieved in the absence of a large industrial salt production system by any of three alternative methods:

(1) construction, operation, and maintenance of small-scale salt production systems at the pre-modern geographic scale (early 20th century family operated system, a few hundred acres), established by sub-dividing portions of the salt pond system at feasible locations (e.g., portions of Alameda shoreline).

(2) construction and maintenance of "short-circuited" managed salt evaporators within a restored tidal salt marsh complex, designed to produce only moderately hypersaline brine before internal dilution by large bay water intake during dilute winter tides. This would require construction of new or upgraded levees set back from the erosional open bay edge, and installation of additional tidegates for water management.

(3) construction of naturalistic, unmanaged facsimiles of historic marsh pans and salt ponds at appropriate locations within restored tidal marsh complexes. These would depend on construction of very low berms (less than 0.3 m above MHHW) across shallow basin floors near MHW elevation, passive overtopping by spring tides, and evaporative concentration of brines. Topography within the large basins should be irregular, so that internal relief causes variation in pond depth and isolation of variable pockets of brine of different salinity during evaporative fall in pond levels. The concentration of brines would vary from hypersaline to crystallization in the largest basins. Such ponds would be constructed near the landward edge of restored tidal marsh in

Alameda County. These may be derived by construction of internal levees within existing salt ponds which are restored to tidal action, or they may be established in part by engineered placement of suitable dredged material. Pans equivalent to the smaller, mid-marsh depressions frequently flooded by spring tides ("drainage divide ponds") should be established artificially within some restored marshes to support near-marine salinity, to conserve viable populations of *Ruppia maritima*, and to support diverse macroalgae beds. Such pans would probably take many decades or more to form naturally.

To ensure adequate diversity of salinity regimes that control biological diversity of hypersaline microflora, the cumulative area of reconstructed salt ponds should be intermediate between the modern inflated extent, and the historic extent of the late 19th century. This is because the vast number of isolated, independent marsh pans that supported variability in hypersaline environments cannot be regenerated within the time-scale of restoration planning for tidal marshes.

13. Pace and scale of tidal marsh restoration should be regulated to avoid needless replication of design errors which become evident during monitoring, and to avoid excessive homogenization of even-aged restored marshes. Marsh diversity early in succession may reflect discontinuous, contingent events, such as rainfall variation, storm deposits of sediment, extreme tides, pulses of nutrients, freshwater flows, wrack deposits, variation in sediment supply or wind-driven sediment resuspension, etc. Results of large-scale pilot projects of tidal marsh restoration should be evaluated before regional conversion to tidal habitats is commenced in force. Such pilot projects, on the scale of 500 – 1,500 acres, should be initiated as soon as possible, and incorporate replicated variation in various restoration designs and techniques.

Estuarine Fishes and Associated Invertebrates Focus Team

Recommendations

This paper summarizes the Fish Focus Team's habitat recommendations and restoration principles. Information is presented for each of the key habitats that fish utilize. For additional information regarding the fishes that occur in the baylands and adjacent waters of San Francisco Bay, please refer to the individual species narratives that will be compiled in the Goals Project's Species and Community Profiles Report.

Shallow Bay or Strait (unvegetated)

Recommendations:
- Avoid any net loss of this habitat through solid bay fill.
- Restore shallow subtidal habitat in Suisun Bay (benefits Delta smelt, splittail, steelhead trout, etc.).
- Restoration of shallow subtidal habitat is encouraged in previously maintained and/or created artificial deepwater areas (e.g., former navigation channels or berthing areas).
- Maintain or create linkages to tidal marsh to maximize value for fishes.

Restoration Principles: (None advanced).

Benefits:
- In addition to those identified above, see **Table 1**.

High/Mid-Tidal Marsh

Recommendations:
- Preserve this habitat throughout the region, particularly in Central San Francisco Bay where the decline has been the most dramatic.
- Maximize restoration of this habitat throughout the remaining subregions (i.e., Suisun Bay, San Pablo Bay, and South San Francisco Bay), particularly in historic diked baylands where the best opportunities appear to exist.

Restoration Principles:
- Create large, continuous patches of high/mid-tidal marsh which will support a wide variety of channel orders (e.g., 3rd and 4th order for maximum edge), within an appropriate range of salinity, seasonality of water flow, and other features of the natural hydrograph. This will particularly benefit marsh resident species (e.g., longjaw mudsucker) and juveniles of seasonal residents (e.g., splittail, Chinook salmon, etc.).
- There should be significant linkages to low tidal marsh and adjacent upland habitats to maximize functional values for fish, invertebrates, and all marsh species, as well as promote a self-sustaining capability.
- There is a need for dead-end sloughs in Suisun Bay, particularly those with emergent and submerged vegetation. Beneficiaries include, splittail, Delta smelt, tule perch, and opossum shrimp.
- There should be potential for freshwater streams to connect within the marsh during high flow years — this promotes species diversity and genetic exchange.

- Encourage the presence and maintenance of high tidal marsh pans for the benefit of certain invertebrates (e.g., California horn snail).

Benefits:
- In addition to those identified above, see **Table 2**.

Low Tidal Marsh

Recommendations
- Preserve all existing low tidal marsh areas throughout all four subregions of the Estuary.
- Restoration efforts for low tidal marsh should be focused in areas of historical distribution or as transition zones in conjunction with high tidal marsh development plans.

Restoration Principles:
- Restore large, continuous patches (> 200 acres) of low tidal marsh in areas, particularly within the Suisun Bay subregion, where suitable land elevations exist near important rearing sites (i.e., shallow water areas of Suisun, Honker, and Grizzly bays) for juvenile fishes (e.g., Delta smelt, Chinook salmon, etc.). Tidal marshes adjacent to these open bays, especially the northern shore, are even more valuable to Chinook salmon and Delta smelt than are dead-end sloughs in the inner marsh.
- Low tidal marshes should occur at the mouths of all small streams and creeks entering San Francisco Bay. Marsh benefits include foraging and smolting and protective habitat for salmonid juveniles and adults.
- Linkages to high/mid-tidal marsh and intertidal flat should be maintained and/or created.
- Low tidal marshes should have an array of channel types, especially some within a short distance of the bay or strait which are not de-watered at low tide. Diverse and abundant native fish populations are found in these types of channels, as they probably function as refugia from major predators.
- Tidal marshes should be exposed to a full tidal range and not controlled by tide gates or muted with artificial or maintained structures. By controlling tidal range or amplitude, fish movements are limited, temperatures may increase, and some water quality parameters may decline. Former tidal marshes, which have subsided and are subsequently opened to controlled tidal action, may not develop to a more "natural marsh," including deeper channels which function as refuge from predators. Refuge is an important issue in areas which are maintained at relatively shallow depths, as predation, especially by birds, may be high in such areas.
- No actions should be taken that interfere with physical processes which may cause a transition to high/mid-tidal marsh.
- Restoration management plans for low tidal marsh should include eradication of deleterious invasive plant species (e.g., *Spartina alterniflora*).

Benefits:
- In addition to those identified above, see **Table 3**.

Intertidal Flat

Recommendations:
- Protect all intertidal flats at current levels and locations in Central San Francisco Bay where increases from historical levels are relatively low and, at a minimum, protect at historical levels in the other three subregions.
- We do not recommend restoration efforts for this habitat except as part of larger projects where it is a necessary transition zone between low tidal marsh and shallow bay (i.e., shallow subtidal), or as compensatory mitigation for direct losses of intertidal flat.

Restoration Principles:

- Since intertidal mudflats are an integral part of the channel system within tidal marshes, habitat characteristics advanced previously for those habitats (e.g., channel complexity) should be adhered to.
- Intertidal mudflat should be protected from low-growing eastern cordgrass, *Spartina alterniflora*.

Benefits:

- In addition to those identified above, see **Table 4**.

Salt Ponds

Recommendations:

- Relative to mature tidal marshes, salt ponds provide minimal habitat value to fishes and aquatic invertebrates; therefore, where possible, they should be converted to tidal marsh and other aquatic habitats by opening them to full tidal action. Depending upon the location of the restored ponds, different species and functions would be supported.

Restoration Principles:

- See tidal marsh and intertidal flats as described above.

Benefits:

- Same as above.

Eelgrass

Recommendations:

- Due to its unusually high value to fish and wildlife resources, all existing eelgrass beds within the region need to be identified and vigorously preserved.
- Eelgrass restoration efforts should be located within South San Francisco Bay, Central San Francisco Bay, and San Pablo Bay as a result of the apparent influence of fresh water on its distribution.

Restoration Principles:

- Restoration should take place only in those areas where key water quality features (e.g., water clarity, well-oxygenated sediments, etc.) indicate a high likelihood of success.
- Enhancement of existing eelgrass beds should be limited to the revegetation of unvegetated areas within the bed's margins.

Benefits:

- In addition to those identified above, see **Table 5**.

Tidal Rivers, Creeks, and Streams

Recommendations:

- Protect what we have region-wide.
- To the extent feasible, restore the area of dead-end sloughs to historical levels.

Restoration Principles: (None advanced).

Benefits: Maintenance of existing support values.

TABLE 1 Functional Support for Target Species by Shallow Bay and Strait Habitat

Species	Suisun Bay	San Pablo Bay	Central S.F. Bay	South S.F. Bay
leopard shark			spawning & forage	spawning & forage
bat ray				forage & protection
white sturgeon	forage & movement	forage & movement	forage	forage
Pac. herring		forage	spawning, forage, & movement	spawning, forage, & movement
splittail	forage & protection	forage & protection		
Delta smelt	forage			
longfin smelt	forage	forage		
no. anchovy			spawning & forage	spawning & forage
steelhead trout	forage & movement	forage & movement	forage & movement	forage & movement
Chinook salmon	forage & movement	forage & movement	forage & movement	
topsmelt		forage		forage
jacksmelt		forage	forage	forage
plainfin midshipman			spawning, forage, movement, & protection	
brown rockfish			forage & protection	
Pac. staghorn sculpin		forage & protection	forage & protection	forage & protection
striped bass	forage	forage	forage	forage
white croaker			spawning & forage	
shiner perch		forage	forage	forage
arrow goby		spawning, forage, & protection		spawning, forage, & protection
bay goby			forage & protection	
Ca. halibut			forage & protection	
starry flounder	forage & protection	forage & protection	forage & protection	
opossum shrimp	forage	forage		
softshell clam		spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection
amphipods	spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection
Ca. bay shrimp	forage & protection	forage & protection	spawning, forage & protection	forage & protection
blacktail bay shrimp			spawning, forage, & protection	
Dungeness crab		forage, movement, & protection	forage, movement, & protection	forage, movement, & protection
rock crabs			spawning, forage, & protection	
mud crab		spawning & forage	spawning & forage	spawning & forage

TABLE 2 Functional Support for Target Species by High/Mid-Tidal Marsh Habitat

Species	Suisun Bay	SanPablo Bay	Central S.F. Bay	South S.F. Bay
splittail	forage & protection	forage & protection		
Chinook salmon	forage & protection	forage & protection	forage & protection	forage & protection
rainwater killifish	spawning, forage, movement, & protection			spawning, foraging, movement, & protection
topsmelt				forage
three-spined stickleback	spawning, forage, & protection	spawning, forage, & protection		spawning, forage, & protection
prickly sculpin	forage & protection	forage & protection	forage & protection	forage & protection
striped bass				forage
tule perch	spawning, forage, & protection	spawning, forage, & protection		
longjaw mudsucker		spawning, forage, & protection		spawning, forage, & protection
Assiminea californica	spawning & forage	spawning & forage	spawning & forage	spawning & forage
California horn snail			spawning & forage	spawning & forage
ribbed mussel				spawning, forage, & protection
amphipods	spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection
mud crab		forage & protection	forage & protection	forage & protection

TABLE 3 Functional Support for Target Species by Low Tidal Marsh Habitat

Species	Suisun Bay	San Pablo Bay	Central S.F. Bay	South S.F. Bay
bat ray				forage & protection
white sturgeon		forage & protection	forage & protection	forage & protection
splittail	forage & protection	forage & protection		
Chinook salmon	forage & protection	forage & protection	forage & protection	forage & protection
rainwater killifish				spawning, foraging, movement, & protection
topsmelt				forage
three-spined stickleback	spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection	spawning, forage, protection
prickly sculpin	forage	forage	forage	forage
Pac. staghorn sculpin		forage	forage	forage
striped bass	forage	forage	forage	forage
tule perch	spawning, forage, & protection	spawning, forage, & protection		
arrow goby		forage & protection		forage & protection
longjaw mudsucker		spawning, forage, & protection		spawning, forage, & protection
starry flounder	forage & protection	forage & protection	forage & protection	
Ca. horn snail			spawning & forage	spawning & forage
opossum shrimp	forage			
amphipods	spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection
Ca. bay shrimp	forage & protection	forage & protection	forage & protection	forage & protection
Dungeness crab		forage	forage	forage
mud crab		spawning & forage	spawning & forage	spawning & forage

TABLE 4 Functional Support for Target Species by Intertidal Flat (Mud and Sand) Habitat

Species	Suisun Bay	San Pablo Bay	Central S.F. Bay	South S.F. Bay
leopard shark			forage	forage
bat ray				forage & protection
splittail	forage & protection	forage & protection		
Chinook salmon	forage & movement	forage & movement	forage & movement	
jacksmelt		forage	forage	forage
plainfin midshipman			spawning, forage, movement, & protection	
Pac. staghorn sculpin		spawning & forage	spawning & forage	spawning & forage
striped bass	forage	forage	forage	forage
white croaker			forage	
shiner perch		forage	forage	forage
arrow goby		spawning, forage, & protection		spawning, forage, & protection
longjaw mudsucker		spawning, forage, & protection		spawning, forage, & protection
Ca. halibut		forage & protection	forage & protection	forage & protection
starry flounder	forage & protection	forage & protection	forage & protection	
Ca. horn snail			spawning & forage	spawning & forage
softshell clam		spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection
amphipods	spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection
Ca. bay shrimp	forage & protection	forage & protection	forage & protection	forage & protection
Dungeness crab		forage	forage	forage
mud crab		spawning & forage	spawning & forage	spawning & forage

TABLE 5 Functional Support for Target Species by Eelgrass Habitat

Species	Suisun Bay	San Pablo Bay	Central S.F. Bay	South S.F. Bay
white sturgeon		forage	forage	forage
Pac. herring		forage	spawning & forage	spawning & forage
Chinook salmon		forage	forage	forage
topsmelt				spawning & forage
jacksmelt		spawning & forage	spawning & forage	spawning & forage
Pac. staghorn sculpin		forage & protection	forage & protection	forage & protection
shiner perch		spawning & forage	spawning & forage	spawning & forage
amphipods		spawning, forage, & protection	spawning, forage, & protection	spawning, forage, & protection
Ca. bay shrimp		forage & protection	forage & protection	forage & protection
mud crab		spawning & forage	spawning & forage	spawning & forage

Mammals, Amphibians, Reptiles and Invertebrates (MARI) Focus Team

Recommendations

This paper summarizes the MARI Focus Team's habitat recommendations. The recommendations are presented for each of the four Project subregions. For additional information regarding the MARI species that utilize the baylands and adjacent habitats, please refer to the individual species narratives that will be compiled in the Goals Project's Species and Community Profiles Report.

Suisun Bay Region

While the taxa selected by the MARI Focus Team are genetically quite diverse, most are small and vulnerable to predation, disperse poorly, and have very limited tolerance for prolonged deep flooding. Therefore, while exceptional species will be discussed below, the following general recommendations are possible:

(1) Preserve and/or create large areas (at least several hundred acres) of dense vegetative cover, centered around known populations of target species;

(2) Connect these protected areas with corridors sufficient to allow periodic exchange of genetic material and re-population in the event of local extirpation;

(3) To minimize disturbance (especially by predators) from outside the protected areas, design the protected areas with central areas far from the borders and/or provide buffer strips between the protected areas and potential sources of disturbance (including residential areas); and

(4) Provide sufficient topographic relief within and/or adjacent to the protected areas to afford refuge during the highest flood water depths.

In addition, while high salinities are generally not detrimental to these taxa, as long as plant cover is not reduced, excessive freshness can be a problem if it promotes a mix of plant species (e.g., pepper grass, cattail, some *Scirpus* spp.) that displaces more favorable plant species (especially pickleweed and other mid- to high-elevation halophytes). Therefore, (5) restoration projects should be designed to promote hydraulic conditions, including salinity regimes, that encourage vigorous growth of upper elevation halophytes. To the extent possible, this recommendation should be balanced by a general preference for projects and management schemes that (6) require minimal ongoing application of external energy (e.g., pumping, levee maintenance).

Another consideration, which is harder to evaluate, is the significance of tidal hydrology as an independent variable, apart from its influence on vegetation. While the vegetarian salt marsh harvest mouse and California vole have been trapped in abundance in diked or muted tidal marshes with typically tidal marsh vegetation, the insectivorous Suisun shrew and salt marsh wandering shrew are apparently limited to "natural tidal salt and brackish marshes" (MacKay and Shellhammer, this project), and are not seen in diked marshes. It is not clear whether this is due to food availability or to other causes. In addition, although river otters have been observed in diked marshes with abundant crustaceans, sea otter, river otter, harbor seal, and California sea lion are all essentially aquatic animals, presumably supported by open water and unrestricted channels. Thus, it is generally recommended that (7) restoration of full tidal action to diked marshes is desirable, where such restoration will not unacceptably reduce other wetland functions and values.

These considerations are not essentially different from those noted in the recommendations for other regions, but their application in the Suisun Bay/Carquinez Strait region can differ for a number of reasons:

1. The generally fresher water conditions in the Suisun Bay area, compared to other Project regions, means that fully-tidal, mid-elevation marshes often do not produce the plant communities associated with high densities of our target taxa, especially in the southeastern reaches of this region. In addition, planning around salinity means and extremes is difficult, for salinity patterns depend not only on weather conditions, but also on legal decisions and the operation of specific pumps and dams. On the other hand, relatively low populations (i.e., little treated wastewater) and small local watersheds mean that there are few areas where local freshwater inputs are significantly affecting habitat.

   Desired plant communities, especially in the southeast, are often associated with high elevations relative to tidal datums and/or with muted tidal regimes, both of which encourage salt accumulation in soil.

2. Most of the historical tidal marshes of this region have been diked, and many have subsided as a result. In addition, the Carquinez Strait is a significant bottleneck to heavy winter flows in the Sacramento or San Joaquin rivers, and tidal elevations can be much higher than San Francisco or San Pablo bays. Thus, while the subsidence is not generally so extreme that tidal restoration will result in permanent lagoons, marshes "restored" by dike breaching alone are often so low that flood stages can eliminate mammal populations, especially in sites without connections to adjacent vegetated uplands.

   Sediment accumulation following reintroduction of tides can restore pre-diking elevations, but access to sediment supplies varies considerably through the region, and marshes at the headwaters of long channels may build up very slowly. Marsh surfaces can also be artificially raised with dredge spoils, and the Montezuma Wetlands Project on the southeast corner of the region is a major proposal of this type. Serious concerns about toxics and other potential problems have been aired, however, and it is unclear how widely this idea will spread.

3. While many of this region's marshes are very low, a relatively high number of them are associated with extensive, relatively undisturbed, adjacent uplands. This is a situation which can provide an unusually high potential for long-term survival of species, but only if these areas remain extensive and relatively undisturbed.

4. The diked marshes of Suisun Bay are far more likely to be managed for relatively dense marsh vegetation cover than in other regions, where diked marshes are usually managed for salt production, agriculture, flood control, and/or open water or mudflat habitats. While the current management regimes of Suisun Bay diked marshes are often not ideal to MARI target species, changes in water management can potentially promote MARI taxa without requiring complete restoration of free tidal action.

In light of these general recommendations and special conditions, we recommend the following habitat goals for the Suisun Major Subregion, based on promoting the long-term viability of the target taxa of the MARI Focus Team:

I. **Suisun Marsh Minor Subregion**

A. Protect and enhance the existing populations of target species along the periphery of this subregion, by protecting, enhancing, and restoring appropriate hydrology and vegetation, in units of at least several hundred acres each, around the six known centers of small mammal population. This can be accomplished either by restoration of full tidal action or, in some cases, by modified water management on diked sites. By focusing initially on the areas outside Grizzly Island, we emphasize protection of areas with associated uplands, and we minimize risk to the central areas from future encroachment by residential or industrial development.

1. *Southwest Unit.* The Benicia/Moth Ball Fleet shoreline has known or suspected populations of salt marsh harvest mouse, California vole, ornate shrew, and river otter; the highest average salinity in this region; relatively low urban/industrial encroachment; and a large number of current restoration projects. These projects should be encouraged and additional tidal restoration/enhancement should occur to ensure the largest contiguous zone of tidal marsh possible. Where restoration on full tidal action is not possible, changes in water management to encourage halophytes is desirable.

   One priority for restoration planning in this area is responding to the relative lack of undisturbed uplands adjacent to the marshlands, especially where Interstate 680 runs just above the edge of the marsh. High water refugia are essential for small mammals, and where undisturbed transitions to extensive uplands no longer exist, island creation or other selective placement of fill on parts of the marsh may be appropriate.

2. *Northwest Unit.* The Cordelia Slough/Chadbourne Slough area has known or suspected populations of salt marsh harvest mouse, California vole, Suisun shrew, and river otter; significant areas of adjacent uplands; and sparse residential or industrial development in the vicinity. While most of this area is currently managed for ducks or other (dry land) hunting, significant areas of good habitat for mice, voles, and shrews have been observed. Both tidal restoration and improved water management should be encouraged in this area, with emphasis on creating a contiguous habitat area of 1,000 acres, with adjacent uplands.

   General restoration priorities in this area include improving water exchange under the Southern Pacific railroad line to maximize tidal exchange and minimize winter flooding, and restoring sufficient acreage to tidal action to maintain regional salinity in the face of projected increases in fresh water discharge into the head of Cordelia Slough.

3. *North Central Unit.* On the western side of Potrero Hills, Hill Slough, Rush Ranch, and Japanese Point, areas provide extensive acreage of known and suspected populations of salt marsh harvest mouse, California vole, Suisun shrew, and river otter, and some very good connections to undisturbed uplands. The proximity to rapidly developing areas around Fairfield makes protection of this areas a high priority.

   A restoration priority in this area is providing habitat continuity, given the steep topography and lack of marsh on the extreme western edge of Potrero Hills. Parcels northwest of Hill Slough and west of Suisun Slough should also be protected.

4. *Northeast Unit.* On the eastern side of Potrero Hills, Nurse Slough, and Denverton Slough are extensive areas with known and suspected populations of salt marsh harvest mouse, California vole, Suisun shrew, and river otter, and excellent connections to uplands, both in Potrero Hills and on Bradmoor Island. Ideally, this unit would be extensive enough to connect to the North Central Unit with a continuous habitat band along the southern side of Potrero Hills — this might require habitat protection on the extreme northern side of Grizzly Island. As with the North Central Unit, development pressures in adjacent areas make this a high-priority area.

   The channel water in this area has relatively low salinity. Therefore, a restoration priority is project design that encourages moderate salt accumulation in marsh soils.

5. *Southeast Unit.* On the eastern side of Montezuma Slough are known populations of most target mammals and good connections to adjacent uplands. Development pressure is lower here than in the more northerly units, although a serious future concern. The Montezuma Wetlands Project proposes restoration of over 1,000 acres of potentially high-value habitat in this area, using a combination of dredge spoils and natural sedimentation.

In addition to potential difficulties with toxics in the sediment, restoration challenges include low channel salinities and subsided sites, and steep slopes on the western flank of Kirby Hill, which apparently rule out a continuous habitat corridor east of Montezuma Slough. Restoration priorities should include encouragement of desired vegetation, and restoration and protection of appropriate habitat on the eastern side of Grizzly Island.

6. *Channel Islands Unit.* Most of Chipps, Ryer, and Roe islands currently appears to be good habitat for target mammals. While adjacent uplands are lacking, and channel salinity is low, the large acreage and near-complete protection from development pressure (Ryer and Roe, in particular, are owned by the Navy) makes these good candidates for protection and enhancement, though with lower priority than the units described above.

B. Provide for habitat corridors for small mammal movement between the units described above. While potential connections have already been described between the North Central and Northeast, and Northeast and Southeast units, it is less clear how best to connect the Southwest and North Central population centers. If extensive areas of mammal habitat are protected in the Cordelia Slough area, than these can potentially serve as stepping stones. Other options include Joyce Island or the northwestern side of Grizzly Island, either of which would require extensive new levees or the restoration of tidal marsh vegetation on large parcels.

C. Enhance the management of the Grizzly Island complex, including Wheeler Island, Simmon's Island, and Van Sickle Island, for mammals. Large-scale tidal restoration of the complex is not considered essential for preservation of the target species, and it is not clear that it would be desirable, given the subsidence and lack of adequate uplands on the islands, and the freshness of the surrounding water. On the other hand, relatively small-scale projects to enhance halophytic vegetation on site, to promote habitat corridors as discussed above, and/or to restore specific areas to tidal action should be supported.

II. **Contra Costa North Shoreline Minor Subregion**

A. Protect and enhance existing habitats and population centers, including restoration of tidal action as feasible. The degree of industrial, military, transportation, and residential development adjacent to these marshlands is high. On the other hand, the early development of industrial and military facilities on rocky zones along the coast probably discouraged residential expansion or management of wetlands for agriculture or waterfowl; therefore, the mammal populations of many of these marshes are high.

1. *West (Peyton/Pacheco) Unit.* Abundant populations of salt marsh harvest mouse and river otter are known from the marshlands between I-680 and Pacheco Slough; adjacent uplands are available with minimal disturbance; and the mean annual salinity is relatively high. Therefore, the potential for maintaining viable mammal populations justifies additional efforts to restore the undeveloped diked marshes in the vicinity to tidal action.

2. *West Central (Point Edith/Hastings Slough) Unit.* Abundant populations of salt marsh harvest mouse are known or suspected in much of this area, and the presence of ornate shrew is suspected. Some adjacent upland is available, salinities are moderate, and extensive restoration efforts are underway. Restoration priorities include responding to subsidence, rail lines with insufficient drainage, buried contaminants, and flood risk to adjacent structures.

3. *East Central Unit.* The area from Port Chicago (Seal Bluff) to the Pittsburg power plant contains known and suspected populations of salt marsh harvest mouse, California vole, ornate shrew, and river otter. Protection from further development is strong, adjacent uplands are available, residential impacts are slight, and the feasibility of connecting the marshes is high.

Constraints to restoration, which should be addressed, include buried contaminants, railroad lines, and existing land use (industry and a harbor). Protection of existing marshlands and adjacent uplands and buffers is important throughout the unit. In addition, tidal enhancement is feasible in areas, and where infeasible, improved water management can improve vegetation.

4. *East Unit.* A relatively small area of shoreline between Pittsburg and Antioch support known populations of salt marsh harvest mouse, California vole, and ornate shrew. While these populations should be protected, extensive enhancement is not justified, given the small acreage and the lack of adjacent undeveloped land.

5. *Channel Islands Unit.* Brown's and Winter islands are both large expanses of potentially good habitat for salt marsh harvest mouse, California vole, and ornate shrew, with low development risk. Brown's Island is undiked and has not subsided; protection is probably adequate. Winter Island is diked and managed for waterfowl. Given its subsidence, the lack of uplands, and the freshness of the surrounding waters, enhancement for halophytes is a higher immediate priority than tidal restoration.

B. Provide for habitat corridors for small mammal movement between the units described above. The Peyton and Point Edith units are probably well-enough connected as long as the marshlands at the mouth of Pacheco Slough are protected. The most important corridors to promote would connect the Point Edith and East Central Units, across the relatively sparsely developed tidal area of the Concord Naval Weapons Station. In addition, the connection should be improved within the East Central Unit between the marshlands west and east of the General Chemical plant. The connections north of McAvoy Harbor and across Mallard Slough should be protected. Connecting the marshes west and east of Pittsburg is not feasible.

III. Carquinez Strait Minor Subregion

While mammal populations are known from Southampton and Martinez Waterfront marshes, neither area is large enough and free enough of development to justify elaborate efforts to promote mammals. In addition, the steep rocky shorelines and the railroad along the Contra Costa shore argue against creation of wetland habitat corridors along the Strait.

North San Francisco Bay Region (San Pablo Bay)

The North Bay region begins on the western side of the Bay at Point San Pedro in Marin County and extends north to include the Petaluma River and associated marshes north to the City of Petaluma. This region extends east to include the Napa River and associated marshes south of the City of Napa. Turning south, the region includes the lands west of the Carquinez Bridge and continues to Point San Pablo. The majority of the development in this region is concentrated along the Highway 101 corridor, in Vallejo at the mouth of the Napa River, and in Contra Costa County. This region has a large amount of undeveloped land and has the greatest opportunities for marsh restoration of any of the Bay regions.

After a great deal of discussion among the members of the MARI team, it was decided that we would designate only parcels we believed were the minimum necessary to provide for the needs of the target species. Since the majority of the mammalian target species inhabit tidal salt marsh, parcels designated for restoration are generally adjacent to San Pablo Bay or to tidally influenced reaches of rivers that flow into the Bay. Undesignated parcels on our maps were left to allow the other focus teams flexibility to provide for the needs of their target species. Although we recognize the value of these undesignated parcels to the overall health of the North Bay marshes, we felt that specific habitat designation by the MARI team was not necessary to achieve our goals.

The areas we selected in North Bay were based upon several assumptions that the MARI team believed would best preserve the target species in perpetuity. A basic assumption that guided the recommendations was that large continuous patches of tidal salt marsh with existing populations of salt marsh harvest mouse should be preserved. Where an existing salt marsh is insufficient to support viable mouse populations in perpetuity, it should be expanded to provide a large block of tidal marsh. Parcels were selected that would be large enough to develop the dendritic slough channel pattern and salt pans characteristic of historic bay marshes. The wetlands should be large enough to require little or no maintenance once restored. Although corridors connecting the various tidal salt marsh blocks were discussed, it was decided that, in North Bay, the need for corridors was not paramount due to the large amount of existing salt marsh and the potential for restoration of large self-sustaining blocks. Small, isolated wetlands in areas where a large block of tidal marsh does not exist and could not be restored were not recommended to be connected with corridors because we felt they were too small, even with connections, to sustain salt marsh harvest mouse populations in perpetuity. Additional considerations included the current land use and amount of existing infrastructure in the area, resulting in only areas that could reasonably be restored to tidal action being recommended for restoration. The presence of adjacent uplands or the potential to create and preserve adjacent upland refuge habitat was another important consideration for the team when selecting the blocks of salt marsh for preservation and/or restoration. The transition habitat that provides refugial habitat during high tide events is extremely important to the long-term viability of a tidal salt marsh for small mammal species. This upland transition/buffer habitat can also provide seasonal wetland values for other target species, and its value cannot be overstated. We also included parcels that were already being restored or would soon be restored (Sonoma Baylands and Tolay Creek wetlands) whether we believed these parcels to be essential to the area or not.

Originally, the North Bay was divided into five separate areas that we believe could independently sustain viable populations of salt marsh harvest mouse, Suisun shrew, and San Pablo vole. The five areas were, beginning in Marin County and moving around the North Bay in a clockwise direction:

1. The Hamilton/Bel Marin Keys wetlands, an area roughly north of Las Gallinas Creek to Novato Creek.
2. The Petaluma Marshes extending from the mouth of the Petaluma River north to just south of the City of Petaluma on both sides of the Petaluma River.
3. The south Napa Marshes extending from Sonoma Creek to the Napa River and bounded to the north by Napa Slough, South Slough, and Dutchman Slough.
4. The Napa River wetlands including Coon Island, Fagan Slough wetlands, and the lands on the west side of the Napa River south of the Newport North development.
5. The Point Pinole wetlands extending from Wilson Point southwest around Pinole Point to Point San Pablo.

After discussions with several of the other focus teams, particularly the Other Baylands Birds team and the Shorebirds and Waterfowl team, we modified a portion of one of the areas — the south Napa marshes, to preserve specific parcels with high existing values for several bird species. Pond 1, Pond 1A, and the West End Club originally proposed for restoration to tidal action are now recommended for preservation. The new description for the Napa marshes now includes the existing marshes south of Highway 37 between Sonoma Creek and the Napa River as well as the Cullinan Ranch and Guadalcanal Village north of Highway 37. In addition, Pond 3 (Knight Island), Pond 2A (south half of Pond #2), and Pond 4 (the southern half of Russ Island) are now included with these wetlands. The result of this modification is that the south Napa wetlands and the Napa River wetlands are connected and are combined into one large tidal wetlands complex, leaving four, not five distinct areas.

The Hamilton/Bel Marin Keys wetlands currently support good pickleweed marsh outboard of the levees at the south end of Hamilton Army Air Base (AAB) property and the Silvera and St. Vincent properties. These marshes are valuable and must be preserved. To ensure the long-term viability of salt marsh harvest mice in Marin County, however, it will be necessary to expand this wetlands complex and provide for areas of upland refugial habitat. The Hamilton AAB site is being considered for restoration to tidal action as part of the base closure/clean up process. The western edge of Hamilton should be restored to an upland buffer that gradually changes from tidal marsh to the existing inboard levee. The adjacent State-owned antenna field could be included as part of the Hamilton AAB tidal restoration. There is currently little or no marsh outboard of the levee along most of the Bel Marin Keys property. Existing mouse populations around the mouth of Novato Creek are isolated from populations immediately to the south. The restoration of at least the eastern portion of the Bel Marin Keys site would provide continuous tidal marsh extending from Las Gallinas Creek to Novato Creek. Upland buffer should also be provided along the western edge of the Bel Marin Keys parcel as a necessary component of the restoration.

The marshes along the western side of the Petaluma River north of San Antonio Creek are the largest block of tidal salt marsh remaining around San Francisco Bay. Although these marshes have been ditched for mosquito abatement purposes, and levees constructed along portions of the eastern edge for an unrealized filling of the marsh, this wetland complex remains the least disturbed tidal marsh in North Bay. The restoration of tidal wetlands south of San Antonio Creek to the mouth of the Petaluma River is considered vital to the future health of the salt marsh harvest mouse populations in this area and important to the vitality of the marsh system as a whole. We recommend restoration of significant amounts of former tidal marsh on the eastern side of the Petaluma River to create a block of tidal marsh large enough to provide for genetic variability and population stability of salt marsh harvest mouse populations in this area.

The lands along the eastern side of the Petaluma River should provide a transition from tidal wetlands into uplands resulting in needed refugial habitat. It is not possible to create this upland habitat on the western side due to the existing railroad line at the western boundary of the existing wetlands. Another component of this marsh complex extends from the mouth of the Petaluma River to Tolay Creek. Portions of this area are already tidal marsh or are being restored to tidal action (Sonoma Baylands and Tolay Creek south of Highway 37). However, the most benefit will be realized when the steep levees that presently separate the tidal marsh from adjacent lands are removed and a buffer established that gently slopes from salt marsh to upland.

The Napa marshes include the existing tidal marshes south of Highway 37 between Sonoma Creek and the Napa River. Portions of these marshes around Mare Island support some of the highest densities of salt marsh harvest mice in the entire North Bay. For this reason, some of the former military lands of Mare Island are proposed for restoration to tidal action. The remainder of the Napa marshes wetlands are on the western side of the Napa River and extend upriver to just south of the City of Napa. Much of this acreage is former Cargill Salt Division salt ponds presently owned by the California Department of Fish and Game (CDFG). CDFG currently has plans to restore a number of the salt ponds to tidal action, as does the U.S. Fish and Wildlife Service on the Cullinan Ranch, which it owns. The restoration of the parcels along the western side of the Napa River will provide a solid tidal salt marsh block on the northeastern side of North Bay and up the lower Napa River that should support healthy populations of salt marsh harvest mouse independent of other populations.

The Point Pinole wetlands constitute the best opportunity to support a viable population of salt marsh harvest mouse in the East Bay. This area is also extremely important because the San Pablo Creek marsh is the only locality for the endemic San Pablo vole. Restoration and enhancement of this area will protect this subspecies and should provide sufficient habitat for its continued survival. The possibility of restoring large tracts of tidal salt marsh in the East Bay is limited due to extensive fill and development. Although a number of small, healthy unconnected patches of wetlands can be found along the Contra Costa shoreline in North Bay, we believe that they are too small and too isolated for long-term mouse viability. The MARI team recognizes that this area is considerably smaller than the other three recommended areas and may be too small to support target species without some maintenance efforts in the future. However, these wetlands represent the best opportunity to preserve/restore a block of tidal marsh with uplands on the eastern side of the Bay in this region. In addition to the four major wetland complexes recommended in North Bay, there are a number of specific areas that our Focus Team believed merited special protections:

1. The marshes near San Clemente Creek at Corte Madera and south of San Rafael Creek in Marin County are important because they support a small population of the southern subspecies of salt marsh harvest mouse. This is the only area where this subspecies is known to occur north of the San Mateo Bridge and is the northern-most extent of the range of this subspecies.
2. The Corte Madera Marsh is also important because it serves as a harbor seal haul-out and pupping site. This site has deteriorated over the past few years from shoreline erosion and would be greatly enhanced if wave action were reduced and the haul-out site stabilized.
3. There is a small area near Sears Point that supports a healthy population of red-legged frog that warrants protection and enhancement.
4. The slough channels throughout the marshes and salt ponds between Sonoma Creek and the Napa River provide habitat for river otter and the enhancement of adjacent marshes could benefit this species.

Central San Francisco Bay Region

The Central Bay region extends on the western side of the Bay from Point San Pedro (Marin County) in the north to Burlingame (San Mateo County) in the south. On the eastern side, it begins at Point San Pablo (Contra Costa County) and goes south to Mulford Landing, just north of the flood control channel in San Lorenzo (Alameda County). Thus, the northern boundary coincides with the narrowest stretch of San Pablo Strait, while the southern boundary is an arbitrary line drawn about 4 1/2 miles north of the San Mateo Bridge. The Bay margins in this region carry the highest human densities in the entire San Francisco Bay Area, and correspondingly sustain the greatest anthropogenic impacts.

Historically, the Central Bay region had only 7% of the estimated acreage of tidal marsh in the Bay system, although it had 27% of the intertidal mudflats (EcoAtlas version 1.021). Proportionally, it has suffered greater losses in both of these habitat categories than has the Bay as a whole: 94% of its tidal marshes (82% in the entire Bay), and 71% of the mudflats (59% in the entire Bay) (EcoAtlas version 1.021). Those remaining habitat patches are small and widely scattered. A few hundred acres of tidal marsh pans are estimated to have been present originally within the tidal marsh habitat. This represents 2.5 to 4.5% of the total estimated acreage of pans in the Bay system (EcoAtlas version 1.50). Presently, no significant pan habitat remains in the Central Bay region.

The habitats of greatest concern to the MARI team are the tidal marshes, adjacent uplands (including freshwater sites), and riparian corridors. In addition, salt (intertidal) pans probably represented unique habitat for some terrestrial invertebrates. Because these critical habitats survive in Central Bay only in small, isolated fragments, we have few site-specific recommendations for this region. Our general recommendations are:

1. In general, the remaining wetland fragments are too small and isolated to support secure source populations for our target species.
2. Surviving wetlands should be protected and where possible enhanced, because (a) they serve as important stepping stones for the movements of organisms within the Bay system; (b) such sites can at least temporarily support populations of the target species and hence contribute to overall metapopulation survival; (c) small populations can contribute to maintaining genetic variability within the Bay system and as refuges from unanticipated disasters in the source populations (disease, predation, pollution); (d) even small wetlands can serve as temporary feeding or resting sites for more mobile species (such as birds); and (e) Central Bay wetlands are important esthetic and educational resources.
3. When opportunities arise, enhancement and enlargement of existing wetlands should be pursued. An example of such an unanticipated opportunity is the current 71.5-acre restoration project in San Leandro Bay adjacent to Arrowhead Marsh (Martin Luther King, Jr. Regional Shoreline Wetlands Project). Significantly, this project will create two islands and an adjacent uplands buffer zone. The marsh-upland ecotone has all but vanished from the Bay Area, and yet is of critical

importance to a number of our target species. Other feasible enhancements include the cleaning up of marshes (e.g., Emeryville Crescent), the provision of corridors to connect small existing wetlands (e.g., East Bay Shoreline Park in Richmond and Albany), and the restoration of creeks flowing into the Bay.

Site-specific recommendations:

1. A small existing freshwater marsh in Millbrae along the western side of the San Francisco airport should be preserved, and if possible, enhanced for the benefit of the San Francisco garter snake and red-legged frog. Enhancements should include expansion of adjacent upland habitat.
2. The Strawberry Spit area in Richardson Bay (Marin County) has been used as a haul-out site for harbor seals, and this could be enhanced by reducing human disturbance.
3. The Corte Madera marshes could be greatly increased in value if upland buffers were established on its periphery. It can also serve as a haul-out and pupping site for harbor seals.
4. The San Rafael Bay Marsh should be maintained as a source habitat for other wetlands, current or future, along the Marin County bay edge.
5. The Castro Rocks near the Richmond-San Rafael Bridge are an important haul-out and pupping site for harbor seals, and should be protected.
6. A small marsh (now in private ownership) at the end of the Tiburon Peninsula (Keil Pond, near Bluff Point) should be preserved and enhanced for the benefit of red-legged frogs.
7. We support the development of tidal marshes in association with Crissy Field in San Francisco, and any other similar projects within the city.
8. It would be highly desirable if the existing Arrowhead Marsh (Alameda County) could be connected to upland habitat while preferably maintaining its isolation from red fox and other predators.

South San Francisco Bay Region

We subdivide the South San Francisco Bay region into seven sectors starting from the northeast and swinging around to the northwest aspect of the South Bay: (1) (Landings Sector) the area from Highway 92, i.e., the San Mateo Bridge highway, north to the San Leandro Marina or Mulford Landing and named after Johnson, Hayward, and Robert's Landings along its edge, (2) (Baumberg/Alameda Flood Control Sector) the area between Highway 92 and Coyote Hills Slough, the second of the large flood control channels south of Highway 92, (3) (Coyote Hills Sector) the area between Coyote Creek Slough and Highway 84, the Dumbarton Bridge road, (4) (Refuge Central Sector) the area between Highway 84 and Mowry Slough, (5) (Alviso Sector) the area between Mowry Slough and Stevens Creek just west of Moffett Field, (6) (Palo Alto Sector) the area from Stevens Creek to Highway 84, and finally (7)(Bair/Greco Islands Sector) the area from Highway 84 to Highway 92. A simplified table follows:

Geographic location	Name of Sector
North of Hwy. 92, East side	Landings
Hwy. 92 to Coyote Hills Slough	Baumberg/Alameda Flood Control
Coyote Hills Slough to Hwy. 84	Coyote Hills
Hwy. 84 to Mowry Slough	Refuge Central
Mowry Sl. to Stevens Creek	Alviso
Stevens Creek to Hwy. 84	Palo Alto
Hwy. 84 to Hwy. 92, West side	Bair/Greco Islands

There are some important and fairly large marshes still present in South Bay. They include the string of marshes that make up the Landings Sector; the Baumberg Tract within the Baumberg/Alameda Flood Control Sector; the Dumbarton, Mowry, and Calaveras marshes in Refuge Central Sector; Bair and Greco islands in Bair/Greco Islands Sector; and to some degree the Palo Alto Educational Center Marsh in the Palo Alto Sector. Many of the marshes within the Alviso Sector, with the exception of the Calaveras Point Marsh, have been or are being converted rapidly from saline to brackish vegetation that does not support salt marsh harvest mice and to some extent either salt marsh wandering shrews or California voles. The loss of much of the Alviso Sector has resulted not only in the loss of many salt marshes, but has produced a major barrier to gene flow between the populations of mice, shrews, and voles on the eastern and western sides of the southern end of the South San Francisco Bay (hereafter, we will call it South Bay). Indications are that parts of the large Calaveras Point Marsh are also beginning to become brackish; its loss would be a tragedy because it appears to contain the largest single population of the southern subspecies of the salt marsh harvest mouse.

Aside from the few remaining large blocks, most of the tidal salt marshes of South Bay are narrow, strip marshes (many two meters wide or less) with little to no upper edge of peripheral halophytes (the escape cover salt marsh harvest mice need and without which such marshes often lose their harvest mice). The poor quality of most of the salt marshes in South Bay makes the pre-existing large marshes listed previously extremely important to the long-term survival of the southern subspecies of the salt marsh harvest mouse, especially since any long-term conversions of salt ponds to tidal salt marshes may take five to 25 years or more.

Recommendations without major conversions of salt ponds.
Here are our recommendations for marsh enhancement before the many salt ponds we have identified are returned to tidal action.

1. Connect the large, protected tidal or muted tidal marshes of the Landings Sector with corridors of at least 100 yards wide and composed of halophytic (salt tolerant) vegetation appropriate for the salt marsh harvest mouse and the shrews. Protect the upper edges of the present marshes, as well as corridors, if possible, with areas of marshy, ruderal, and/or grassland vegetation at least 100 yards deep to act as buffer zones for them. We think that corridors need "edges" as much as, if not more than, larger marshes.

2. Expand the areas of salt marsh within the Baumberg area within the Baumberg/Alameda Flood Control Sector by at least twice the size that is presently under restoration.

3. Enhance the Alameda Flood Control "marshes" just north of Coyote Hills Slough and running from the Bay towards the south Union City area, and then south and west towards the hill just north of the Slough and the Coyote Hills to the south of that hill, and manage them for year-round use by small rodents (not just winter flood control use). These marshes need better connections between units, and the total area of salt marsh needs to be expanded by at least one-third. We have no short-term recommendations for the salt ponds of the Coyote Hills Sector. Long-range plans involve opening some or most of them to tidal action.

4. The Dumbarton Point Marsh and the marshes along Newark Slough west of the refuge headquarters hill in the Refuge Central Sector need expansion and increased protection. Marshes along Newark Slough east of the hill, i.e., south of Thorton Avenue and west of Newark (the Jarvis Landing Area), need to be expanded and protected from urban build-out. Part of the eastern end of this area is within the City of Newark. Enhancement includes better water management, adding a 100-yard buffer of marsh or grassland vegetation and conversion of adjacent salt ponds to tidal action and connecting them to existing units wherever possible.

5. The Calaveras Point Marsh within the Alviso Sector needs to be expanded by opening the two outer salt ponds between Mowry Slough and Coyote Creek to tidal action. The Calaveras Point

Marsh extending eastward along Coyote Creek is extremely important to the harvest mouse, and the Mowry Slough marshes are important to the mouse, shrew, vole, and harbor seal.

6. The "Triangle" Marsh, north of Alviso and west of the railroad tracks and bordering Coyote Creek within the Alviso Sector, has been virtually lost to the harvest mice and shrews by the effects of brackish waters. The only salvation of this former highly productive salt marsh is saltier water. This area has almost completely turned into brackish vegetation because of non-saline sewage water entering the Bay from the San Jose-Santa Clara Water Treatment Control Plant. Many of the marshes of the Alviso Sector (Albrae Slough, Mud Slough, Upper Coyote Creek, and Artesian Slough) are similarly dependent on increased salinities for re-conversion back to saline marshes. They also need to be expanded from their present narrow, strip-like character to be of much value to mammals; however, to increase the width of these strip marshes will require the conversion of some to many adjacent salt ponds, as there is no intermediate step possible in the most southern South Bay.
7. The New Chicago Marsh, in the Alviso Sector and within the San Francisco Bay National Wildlife Refuge Complex, has some water management, but additional funding is needed for management and pump improvements. The Refuge Complex needs more biologists and better funding from the U.S. Fish and Wildlife Service, in general, to manage the enormous variety and size of their holdings, especially if many to most of the salt ponds in South Bay are eventually converted to tidal action.
8. The marshes between Charleston Slough to Cooley Landing in the Palo Alto Sector, including the Palo Alto Education Center Marsh, need more upland buffers, better protection from illegal entry, more alien predator management and better marsh corridors or connections between present marshes. Again, the 100-yard minimum rule and appropriate vegetation rule applies to both buffers and upper edges. The Palo Alto Marsh continues to change in vegetation (for the worse) and the upland edge of the marsh is very abrupt and needs modification.
9. Bair Island (Bair/Greco Islands Sector) needs to have more marsh habitat now that it looks like it will be protected.
10. The strip marsh along Ravenswood Point (Bair/Greco Islands Sector) needs to be expanded to the south by opening the adjacent salt ponds to tidal action.
11. Greco Island (Bair/Greco Islands Sector) needs better protection by opening up areas south of Westpoint Slough to tidal action.

Recommendations for major conversions of salt ponds to tidal action.
We think it is important to preserve, expand, and improve the existing marshes previously identified wherever and however possible. But to ensure the long-term survival of the southern subspecies of the salt marsh harvest mouse and probably the salt marsh wandering shrew and California vole in South Bay, as well as many species of birds, other vertebrates, and invertebrates, we recommend that most of the salt ponds of South San Francisco Bay be opened to tidal action. We assume commercial salt production will cease some day in the South Bay, either when the salt company stops making salt and sells its assets or if it is bought out as mitigation for other modifications within the Bay. Unless the salinity of the waters of the southern part of South Bay is increased (i.e., returned more towards historical salinity), marsh development in many of these areas will result in brackish rather than saline marshes. There are plans to open the Knapp Property, the bayward "thumb" of the former salt ponds between Alviso and Guadalupe sloughs in the Alviso Sector, to tidal action. While it will be an important conversion, it will do little by itself for the endangered and threatened small mammals of the southern end of South San Francisco Bay.

The very large tidal salt marsh complexes that will be created if most of the ponds are opened to tidal action are expected to be multiple-use, in that levees and saline pans can be left within them to support resting and feeding sites for various species of birds. Small ponds or areas of open water can be included, as long as the salinity levels of such areas of water do not have to be maintained. The large marshes can have complex shapes and surround or otherwise be integrated with other types of saline plant or water environments. What is paramount to save the various species of mice, as well as the California clapper rail, is that the new complexes be tidal salt marshes, not brackish marshes. The marshes need to be very large ones (1,000 acres or more) with extensive and wide margins of both peripheral halophytes and grassland buffers of at least 100 yards, but preferably more than 200 yards in width. And where corridors are needed to connect isolated marshes to increase the overall size of the connected marshes (such as are needed between the marshes of the Landings Sector), the corridors should be wide (at least 100 yards), be composed of appropriate salt marsh vegetation, have gently-sloping edges of approximately 100 yards, and be at least partially protected from intrusion by humans and non-native predators, such as the red fox, and be managed to control such predators on a continual and perpetual basis. We recommend large corridors be established or maintained between large marshes, but that corridors much less than 100 yards be established or maintained between small marshes of one or two to ten acres. The wider the corridor and the more appropriate the vegetation, the more likely the corridor will facilitate movement between marshes, but in the short run, just connecting small marshes is a very important first step. We recommend smaller connections, but think that the recovery effort should proceed beyond them as more land for both corridors and marshes becomes available.

Studies needed prior to major salt pond conversions.
We think it is imperative that a series of studies be carried out before many of the large salt ponds, especially those in the most southerly and most subsided portion of South Bay, are breached and returned to tidal action. These studies need to identify such things as how long it will take for restoration to occur in various parts of South Bay, and how the ponds and levees can be engineered to provide the greatest benefit to the most species and at the lowest maintenance costs. We need to determine whether mudflats and ponds will be created in ways to help support various species of waterfowl and wading birds, as well as other vertebrate species, many of which are dependent on and often endemic to the tidal marshes of San Francisco Bay.

More money needs to be provided to the California Department of Fish and Game (CDFG) to allow them to actively manage the salt ponds and newly developing marshes of the San Pablo Bay. The CDFG can provide valuable information about marsh restoration around the entire Bay if they can proactively manage those marshes. Several other marshes are being restored in South San Francisco Bay, i.e., parts of the Baumberg Marsh on the eastern side and several marshes between Charleston Slough and Highway 84 on the western side. None of these “experiments” are in the deeply subsided southern tip of the Bay. Marsh restoration in this latter area needs to be modeled by physical and biological scientists working together.

South San Francisco Bay was once filled with marshes and mudflats, as well as smaller salt pans and tidal ponds. We think it should be returned to that general condition, but not before studies are done to model the effects of converting salt ponds to tidal action, especially in the most subsided portions of the Bay. Such studies need to be carried out soon. And increased funding sources need to be identified, as the management of South Bay will become more costly in the future no matter what scenario takes place.

Shorebirds and Waterfowl Focus Team

Recommendations

This paper summarizes the Shorebirds and Waterfowl Focus Team's habitat recommendations. Included are our focus team tenets, some brief information regarding each of the key species, and habitat recommendations. We also have included some of the research needs that we believe need to be addressed. For additional information regarding the shorebirds and waterfowl species that utilize the baylands and adjacent habitats, please refer to the individual species narratives that will be compiled in the Goals Project's Species and Community Profiles Report.

Introduction

Shorebirds and waterfowl are characterized by their mobility and strong dependence on aquatic and wetland habitats. The San Francisco Estuary is renown as a major North American refuge for many species of shorebirds and waterfowl during their migration and wintering (August through April) periods, and it provides breeding habitat during the summer for a few species (e.g., snowy plover and mallard). The Estuary is recognized as a Western Hemisphere Shorebird Reserve Network site of international importance for more than a million shorebirds and as the winter home for more than 50% of the diving ducks in the Pacific Flyway (Accurso 1992), with one of the largest wintering populations of canvasbacks in North America.

The current populations of shorebird and waterfowl species are a reflection of alterations in the development of the Estuary (see Nichols et al. 1986) which may have resulted in increased numbers of some of these species while other populations have decreased. We do not know how many distinct populations depend on the habitats of this ecosystem and contribute to diversity and stability of continental populations. For example, northern pintails in South Bay have little interchange with birds in the Central Valley, and they may represent a distinct subpopulation (Miller, pers. comm.). Western sandpipers show strong site fidelity to small areas in South Bay and do not leave that subregion during the winter (Warnock and Takekawa 1996).

The loss of more than 90% of the wetlands in the Estuary have greatly altered the ecosystem, which has resulted in the proposed listing or protection of more than one hundred species, many associated with tidal salt marsh habitats. Many projects to rehabilitate or restore wetlands in the Estuary, especially tidal salt marsh, have been proposed to benefit listed species. However, results of wetland restoration efforts are highly variable (Race 1985), and the efforts to complete successful salt marsh restorations for certain species may come at the expense of shorebird and waterfowl populations that use the existing habitats, including salt evaporation ponds. We lack specific information relating abundance of current populations to the amount of their habitats (for more specific information, see the individual narratives). Thus, we are unable to predict how reduction of present wetland habitat used by these species may affect their populations. We advise care in implementing large scale changes and encourage further study of critical habitats and better delineation of the regional populations present in the ecosystem.

Focus Team Principles

1. There should be no net loss of shorebird and waterfowl resources and populations in the ecosystem.
2. The San Francisco Bay ecosystem has been altered, and we will not be able to return it to historic conditions, nor is that necessarily desirable. Some habitats have actually increased from historic levels in some areas.

3. Shorebirds and waterfowl species are unlikely to benefit from tidal marsh conversions when the conversion is from another wetland type. As conversions do occur, we must enhance the remaining habitats for shorebirds and waterfowl.
4. Engineered tidal marsh and non-tidal wetland and salt pond restorations have unpredictable outcomes. In fact, this field is very young and few restorations have been deemed to be successful.
5. No large conversions should be undertaken without pilot projects in advance. These pilot projects should include testing habitats and elements of habitats which replace lost habitat values for shorebirds and waterfowl.
6. San Francisco Bay is a crucial area within the Pacific Flyway. The region is as important to continental shorebird and waterfowl species, as are specific parcels to endemic populations within the Estuary.
7. Critical habitats for shorebirds and waterfowl include tidal flats, sparsely vegetated wetland elements (levees, islets, beaches), managed wetlands, salt evaporation ponds (which are not inherently bad as wildlife habitat and have increased some species while preserving areas from development), large, persistent seasonal ponds with lots of open water, and inactive salt ponds.
8. Managed wetlands (water control, predator control, muting tidal flows) may be more beneficial than natural wetlands in some cases.
9. Disturbances and flight obstructions (e.g., power lines) between feeding and roosting areas should be minimized.
10. Seasonal wetlands have important habitat values for shorebirds and waterfowl, but are poorly quantified or understood. More research is needed to clarify how the habitats are used and how much is needed for sustaining populations.

Shorebirds

Shorebirds are aquatic birds with cylindrical bills varying considerably in length and curvature among the 31 species encountered regularly on San Francisco Bay. These species, which range from the sparrow-sized least sandpiper to the duck-sized long-billed curlew, feed primarily on invertebrates obtained on tidal flats, salt ponds, managed wetlands, and other habitats. Recent survey information collected by Point Reyes Bird Observatory indicates that San Francisco Bay supports very high numbers of shorebirds of most species during migration and winter, compared to other wetlands along the U. S. Pacific Coast. San Francisco Bay has been recognized as a site of hemispheric importance to shorebirds by the Western Hemisphere Shorebird Reserve Network.

Key Species

We selected seven "key" species as a basis for defining regional wetland habitat goals for shorebirds and provide detailed information on these species in the species accounts. Five species represent groups of shorebirds that use specific habitat types, one (snowy plover) is federally listed as a threatened species, and one (red knot) is especially dependent on San Francisco Bay as a wintering area.

Western Sandpiper (*Calidris mauri*) — The western sandpiper represents small sandpipers and plovers, including least sandpiper, dunlin, and semipalmated plover. The western sandpiper is the most abundant shorebird in the Bay at all seasons. The least sandpiper and dunlin are also abundant. All four species breed in Arctic or sub-Arctic regions and occur in San Francisco Bay both as migrants and winter residents. On the Bay, tidal flats are their most important feeding habitat. At high tide these birds are forced from the tidal flats to roosting and auxiliary feeding areas including salt ponds, managed wetlands, and seasonal wetlands.

Marbled Godwit (*Limosa fedoa*) — The marbled godwit was the selected representative for the large sandpipers and plovers which include willet, long-billed curlew, whimbrel, black-bellied plover and American avocet. These species breed in Arctic, sub-Arctic, or temperate regions and occur in San Francisco Bay both as migrants and winter residents. Hundreds of avocets also breed in San Francisco Bay, primarily in salt ponds. Tidal flats are the most important foraging habitat for all these species except, possibly, the avocet which also forages extensively in salt ponds. At high tides these birds move from the tidal flats to roost in salt ponds, managed wetlands, seasonal wetlands, and other habitats above the high tide line.

Red Knot (*Calidris canutus*) — Although not abundant, the red knot was selected as a key species because San Francisco Bay is one of only three wetlands on the Pacific coast of North America supporting as many as several hundred wintering individuals. Red knots are Arctic breeders which occur in the Bay during migration and in winter. They often associate with black-bellied plovers and short-billed dowitchers, but are more restricted than these species in their distribution within the Bay. Tidal flats of Central Bay and South Bay are the knots' primary foraging habitats and salt ponds serve as the primary high tide roosting habitat.

Long-billed Dowitcher (*Limnodromous scolopaceus*) — The long-billed dowitcher was selected because of its use of fresh and brackish habitats. In addition to tidal flats, managed wetlands and seasonal wetlands are important foraging habitats for long-billed dowitchers and its associates. The other species associating with long-billed dowitchers in managed and seasonal wetlands are greater and lesser yellowlegs, dunlin, black-necked stilt, and American avocet. This group of shorebirds was singled out as potentially deriving more benefit from managed brackish water wetlands and seasonal wetlands than other shorebirds. Managed wetlands also are used by two members of the group, black-necked stilt and American avocet, for nesting. Although not closely associated with any of the above species, because of its more solitary nature and preference for more vegetated habitats, the common snipe is the other shorebird which makes heavy use of the managed and seasonal wetlands as foraging and roosting habitat during winter.

Black Turnstone (*Arenaria melanocephala*) — The black turnstone represents shorebirds that make the most use of gravel to rocky intertidal habitat. Also included in this group are ruddy turnstone, American black oystercatcher, wandering tattler, surfbird, and spotted sandpiper. None of these species are abundant in the Bay, numbering at most in the tens to low hundreds of individuals at any time. Small numbers of American black oystercatchers regularly nest in the Bay, as does an occasional pair of spotted sandpipers.

Snowy Plover (*Charadrius alexandrinus nivosus*) — The Pacific Coast population of western snowy plover was selected as a key species because it is federally listed as a threatened species. About 10% of the listed population has been recorded breeding on San Francisco Bay, primarily in South Bay salt evaporation ponds. Although there is no evidence this species bred in the Bay prior to the construction of the evaporation ponds, playas that existed on the inboard margins of the salt marshes may have supported nesting snowy plovers.

Wilson's Phalarope (*Phalaropus tricolor*) — The Wilson's phalarope was chosen to represent those shorebirds that, in addition to the snowy plover, are most dependent on the salt ponds for foraging habitat. Some members of this group, including the Wilson's and red-necked phalarope, occur only during spring and fall migration, while the others, including black-necked stilt and American avocet, are present year-round. The latter two species also nest in the Bay, primarily in South Bay salt ponds, but also in other areas of ponded water such as the managed wetlands of Suisun Bay. Surveys conducted by the U.S. Fish and Wildlife Service indicate that occurrence in salt ponds by these species is related to salinity, with the highest use by foraging stilts and phalaropes in ponds with salinities ranging from 130–180 ppt. Anecdotal historical information suggests that numbers of American avocets, black-necked stilts, and Wilson's phalaropes have increased significantly since salt pond construction.

Habitat Considerations
Except for anecdotal information suggesting an increase in use of the Bay by shorebird species using salt ponds as their primary foraging or breeding habitat, there is no historic information on changes in abundance of shorebirds in the Bay during the past 150 years when most human-induced habitat alterations have occurred. The most recent mapping of historic and current Bay habitat by the San Francisco Estuary Institute (SFEI) indicates that tidal flats outboard of salt marsh have increased in the north and south subregions of the Bay, but that the total amount of tidal flat has decreased in all subregions, primarily due to loss of tidal flat along slough channels in salt marsh. Since the majority of the shorebirds in the Bay use tidal flat as their primary foraging habitat, foraging conditions in the Bay may have declined for these species — unless gains in secondary foraging habitats, such as salt ponds and managed wetlands, have compensated for the tidal flat losses. Thus, the shorebird populations in San Francisco Bay may have declined commensurably.

For the majority of shorebirds that forage primarily on tidal flats, loss of subsidiary foraging areas, such as salt ponds and managed wetlands, might be mitigated (by an unpredictable degree) by creating wide, gently-sloped tidal flats along large channels in restored tidal marsh. Tidal salt marsh and slough channels do not, however, provide high tide roosting habitat for most shorebird species, which require barren to sparsely vegetated sites above the high tide line. Thus, suitable roosting areas will need to be constructed to replace roosting areas that are converted to tidal marsh. Roosting areas must be in reasonable proximity to tidal flat foraging areas.

For the salt pond specialists, substantial areas of salt pond habitat should be maintained in the northern and southern regions of the Bay. If portions of the salt pond systems of the north and south regions of the Bay are converted to tidal marsh and managed salt ponds, it will not be feasible to set aside ponds with important shorebird habitat in a piecemeal fashion. Instead smaller salt pond systems should be retained and re-engineered to produce salinities and water depths most favorable to shorebirds and the other aquatic species targeted for protection. Low, wide, barren to sparsely vegetated internal levees with fine scale topographic relief should be incorporated into the pond design as nesting and roosting substrate. In addition, salt marsh restoration efforts should attempt to re-create playas that occurred in historic salt marshes.

Since the success of marsh restoration efforts are likely to be highly unpredictable and the value of slough mudflats and salt marsh playa for shorebirds is not well understood, incorporation of these habitats into restored marshes should not be counted as replacement habitat for shorebirds. Further research must be undertaken to estimate the amount of salt pond habitat that should be managed for shorebirds and other target species. The maintenance of at least the current numbers of shorebirds relying extensively on salt pond habitat will require an adequate acreage of suitable ponds for 25,000 wintering American avocets, 5,000–7,000 wintering black-necked stilts, tens of thousands of migrating Wilson's and red-necked phalaropes in fall, and 500 breeding snowy plovers.

Waterfowl
The San Francisco Bay region is identified as one of the 34 waterfowl habitat areas of major concern in the North American Waterfowl Management Plan (U.S. Fish and Wildlife Service 1989). More than 30 species of waterfowl are found in the San Francisco Bay ecosystem. These species are commonly divided into dabbling ducks, which feed at the surface or in shallow water to the depth of their body length, diving ducks, which forage underwater to 5 m in depth, and swans and geese, which feed on plants by grubbing in sediments of wetlands or fields. Mid-winter waterfowl surveys conducted by the U.S. Fish and Wildlife Service on San Francisco Bay and in the Delta include more than 700,000 waterfowl, and surveys of the open bays and salt ponds (Accurso 1992) include more than 300,000 individuals, a 25% decrease from the earliest surveys in the 1950s. In 1988–1990, dabbling ducks comprised up to 57,000 of the waterfowl in the open bays and ponds of the Estuary, while diving ducks comprised up to 220,000 of the total. For this review, we selected six species as representative taxa of the waterfowl and the habitats they use in the San Francisco Bay ecosystem.

Northern Pintail (*Anas acuta*) — The northern pintail historically has been the most common dabbling duck in the ecosystem. Continental population declines have been severe, but even larger declines (90% in Suisun

Marsh) have been recorded in the San Francisco Bay region. In addition, birds in the South Bay subregion may represent a distinct population that interchanges little with birds in the Central Valley (Miller, pers. comm.). Peak numbers usually occur in October when dabbling ducks account for 50% of the waterfowl in the open waters of the San Francisco Bay. Nearly 9,000 northern pintails have been reported in October, with 5,000 ducks observed in mid-winter; maximum counts have exceeded 12,000 individuals. Pintails use a wide variety of habitats, including managed marsh, seasonal wetlands, open bay, and salt ponds. Species commonly found in similar habitats are green-winged teal (*A. crecca*), the northern shoveler (*A. clypeata*), and American wigeon (*A. americana*). American wigeon peak abundance includes 6,000 individuals or 1–2% of waterfowl in the open bays and salt ponds, but northern shovelers are the third most abundant species in the open bays and represent 13% of the waterfowl. Total dabbling ducks peak at over 50,000 birds, and represent 8–30% of total waterfowl.

Mallard (*Anas platyrhynchos*) — Mallards are dabbling ducks with large economic and recreational importance as a hunted species and are commonly found in managed marshes. The mallard was selected as a representative of dabbling ducks such as Cinnamon teal (*Anas cyanoptera*) and Gadwall (*Anas strepera*) which migrate to the San Francisco Bay ecosystem during the winter. Gadwall numbers peak at 3,000 individuals, <1% of the waterfowl in the Estuary (excluding Suisun Marsh). All three of these species represent resident breeding populations in the San Francisco Estuary as well. The largest population of mallards occurs in the Suisun Marsh subregion. Mallards have also been recorded as the most abundant dabbling duck in diked baylands of the San Pablo Bay and South San Francisco Bay subregions, most often using seasonal wetlands habitats and low salinity salt ponds.

Canvasback (*Aythya valisneria*) — The canvasback is a diving duck that forages on aquatic plants or benthic invertebrates in mouths of rivers or channels, on large wetlands, or in brackish marshes. Sixty thousand individuals were counted in the mid-1960s, though historic populations were thought to be much higher. While the continental population of canvasbacks has not increased greatly in the last 20 years, based on mid-winter surveys (U.S. Fish and Wildlife Service 1955 – 1998) its population in the Estuary has continued to decline. However, San Francisco Bay supports the largest population of canvasbacks (nearly 30,000 birds) on the Pacific Flyway and represents one of the three largest wintering areas in North America. Associated species that use similar habitats in the Estuary include: common goldeneye (*Bucephala clangula*), greater and lesser scaup (*A. marila* and *A. affinis*), and very small populations of redhead (*A. americana*) and ring-necked ducks. San Francisco Bay is a major wintering area for scaup which have shown an unexplained continental decline in the past decade. Scaup comprised more than 40% of the open bay and salt pond waterfowl counted (Accurso 1992), up to 140,000 birds.

Ruddy Duck (*Oxyura jaimaicensis*) — The smaller diving ducks of the Estuary include the ruddy duck and bufflehead (*Bucephala albeola*), which use a variety of managed marsh areas and salt ponds in the baylands. The ruddy duck is widespread, but the population found in the San Francisco Bay ecosystem during the winter is one of the largest in North America. The maximum population has been estimated at about 28,000 birds. It is the fourth most abundant waterfowl species in the Estuary, representing 7–8% of the total. As many as 7,000 bufflehead also are found in the Estuary.

Surf Scoter (*Melanitta perspicillata*) — Surf scoters are the least studied of the North American waterfowl. San Francisco Bay appears to be the most important inshore habitat in the eastern Pacific, south of the Straits of Georgia and Puget Sound. This species is representative of sea ducks that primarily use deeper, open-water, marine habitats. Associated species are white-winged scoters (*M. fusca*), black scoters (*M. nigra*), and red-breasted mergansers (*Mergus serrator*). Surf scoters are the second most numerous species in the ecosystem, with estimates as high as 73,000 birds in 1991 (Trost 1997, unpublished data).

Tule Greater White-fronted Goose (*Anser albifrons gambeli*) — Tule geese were chosen as the key species to represent the geese and swans group, which also includes Pacific greater white-fronted goose (*Anser albifrons* *frontalis*), Canada goose (*Branta canadensis*), Aleutian Canada goose (*B.c. leucopareia*), lesser snow goose (*Chen caerulescens*), and tundra swan (*Cygnus columbianus*). Tule geese are associated primarily with managed wetlands and agricultural lands. The Suisun Marsh subregion is one of the few wintering areas in California and North America for tule geese. The geese and swans are of economic and recreational importance as four of the six members of this group are hunted, and overpopulation of geese may cause large urban and agricultural damage. Formerly, geese were present in the ecosystem in larger numbers, but are now down to a remnant few, primarily in Suisun Marsh. For example, a population of what was perhaps a few hundred greater white-fronted geese, which may have been the tule subspecies, now number less than 20 individuals in North Bay (Allen, pers. comm.). Greater white-fronted geese are found primarily in Suisun and North Bay; Canada geese, all sub-regions; Aleutian geese, Suisun and Central Bay; snow geese, all sub-regions; and tundra swans, Suisun and North Bay.

Habitat Considerations

Salt Evaporation Ponds — In 1988–1990, salt evaporation ponds supported 30–41% of the waterfowl in the ecosystem, 9–14% in the former North Bay ponds, and 21–27% in the South Bay ponds. Many of the birds found in the Estuary during migration (September–October, March–April) were found in these areas.

In the North Bay ponds, up to 42,000 diving ducks have been counted, including 30% of the ruddy ducks in the Estuary, 59% of the canvasbacks, and 38% of the bufflehead. As many as 15% of the dabbling ducks were also found in these ponds, including 19% of the northern pintail and 47% of the mallards. Eighty-three percent of waterfowl were found in 54% of the salt pond area with salinities of 20–93 ppt, with most birds preferring 20–33 ppt areas. Pond size explained much of the variation in counts, with less than 2% of the use on small ponds < 150 ha, and most diving duck use on ponds 200 to 550 ha.

South Bay salt ponds supported up to 76,000 or 27% of the Estuary's total waterfowl. This area provided the largest haven for ruddy ducks (up to 67% of the population), and supported 17% of the canvasbacks, 50% of the bufflehead, and up to 86% (47,000) of dabbling ducks, including the majority (90%) of northern shovelers. Waterfowl were concentrated in lower salinity (20–63ppt) ponds, with few birds present in ponds above 154 ppt. Most waterfowl used ponds of moderate size, from 50 to 175 ha.

Open Bay Areas — Up to 50% or 140,000 of the diving ducks surveyed in the Estuary during the winter were counted in the North Bay subregion. Densities were as high as 653 birds/100 ha. The populations include up to 35% of the scoter, 26% of the canvasbacks, and 12% of the scaup. Most of the use was in water depths < 4 m, although much of the open bay area was less than 6m. The Central Bay supported 17% of the waterfowl, or up to 53,000 birds, including 20% of the diving ducks. This area was important for scoter (up to 50%), scaup (16%), and bufflehead (13%), but only 1% of the dabbling ducks. The South Bay supported 9–11% or 36,000 of the waterfowl in the Estuary, and was important for scaup (18%) and scoter (16%). The open waters of Suisun Bay supported only 12% of waterfowl in the Estuary, including up to 15% of the diving ducks (17% of scaup, 16% of scoter, and 16% of canvasbacks).

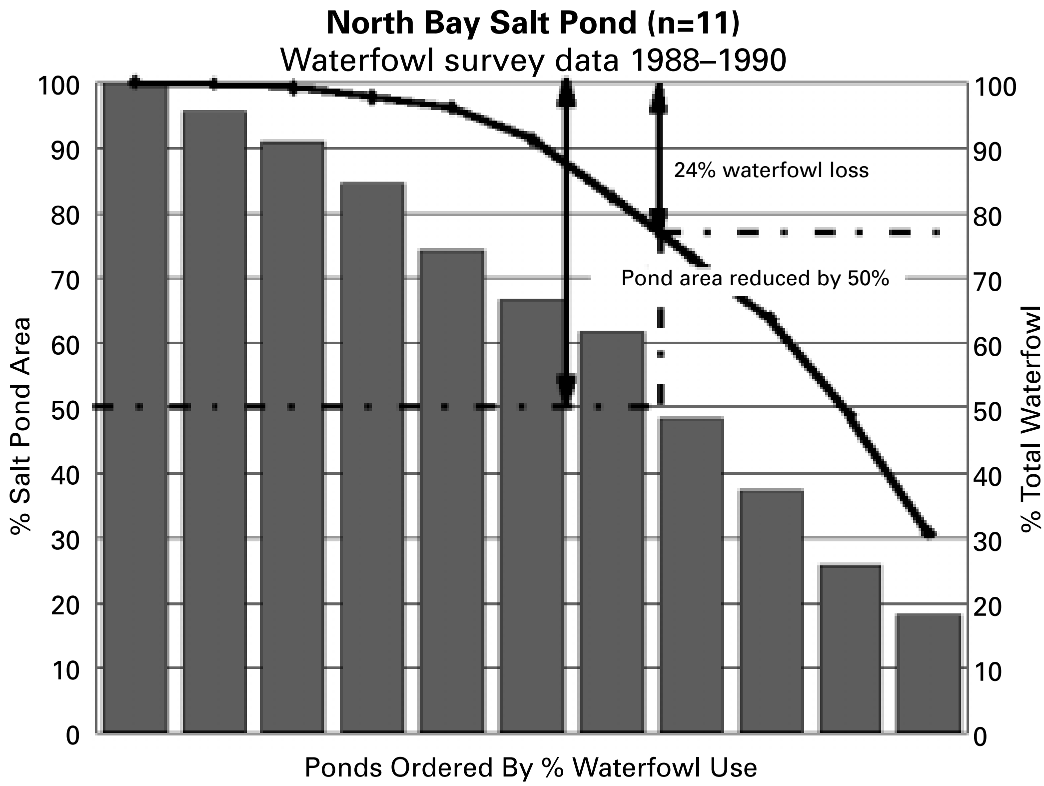
General Recommendations

It is important to maintain existing populations of shorebirds and waterfowl in the Bay while increasing habitat for other species that are dependent on salt marsh. Increasing the acreage of salt marsh will come at the expense of other habitats, especially salt ponds and managed wetlands that are important for shorebirds and waterfowl. Maintaining current shorebird and waterfowl populations will thus require increasing the carrying capacity of remaining salt ponds and managed wetlands or re-creating their function in new locations.

Subregions

Suisun Bay — Although these wetlands are managed primarily for waterfowl habitat by private land owners, populations of one of the major target species, northern pintail, have decreased by as much as 90%. Thus,

FIGURE 1 **Waterfowl Use of Salt Ponds in the North Bay Ordered from Most to Least Waterfowl Use.**



Reduction in the total salt pond area is related to the estimated decrease in waterfowl numbers. For example, a 50% reduction in salt pond suggests a 24% reduction in waterfowl.

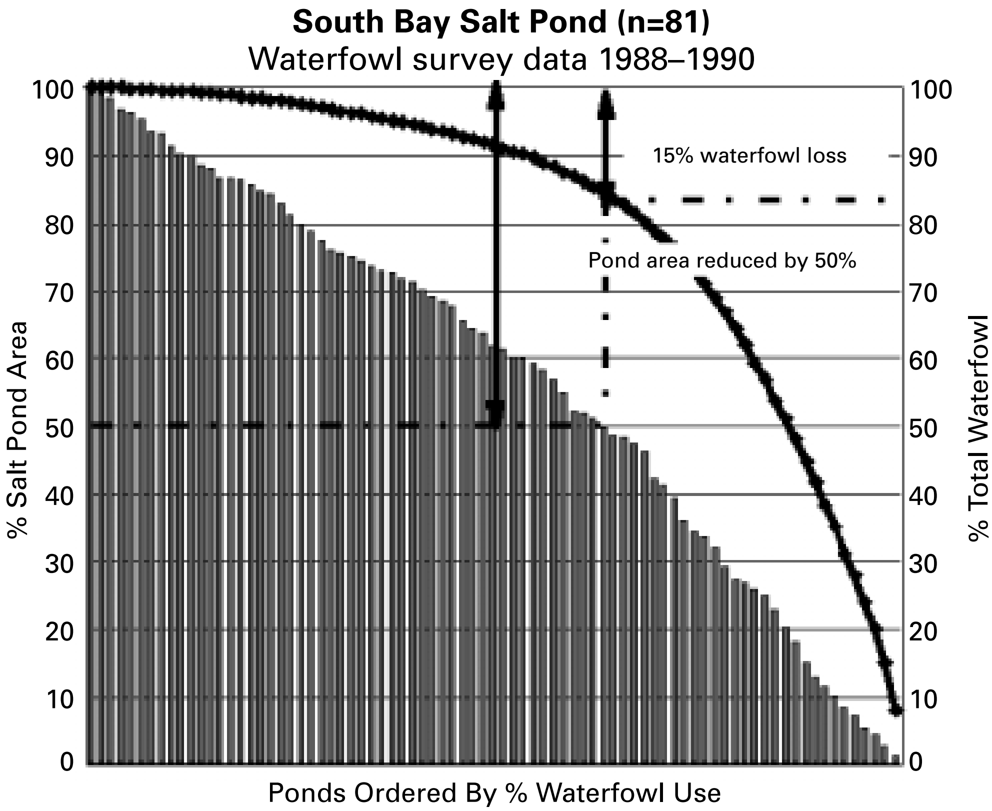
despite the best management efforts, populations of waterfowl in the Suisun Marsh have decreased. Any conversion of managed wetland habitats will result in a loss of waterfowl. Conversion of this area should proceed gradually to provide time to evaluate population changes and the effects of the loss of habitat. Conversion or loss of this habitat type must be offset by enhanced management of existing areas or mitigation with alternative areas. Shorebirds are present in the tens of thousands. Management should be promoted to improve areas for their populations.

North Bay — The former salt evaporation ponds in this region are a critical area for shorebirds and waterfowl. Ongoing conversion should be linked to enhanced management of existing areas or mitigation. In this subregion, conversion of 50% of the former salt ponds may result in loss of 24% of the 42,000 waterfowl that are counted in these ponds (**Figure 1**; Takekawa, pers. comm.). Change in salt pond areas may already be resulting in reduction of waterfowl numbers. Thus, there is an immediate need to develop alternative managed marsh areas in this subregion. Although mudflat habitats seem abundant in the North Bay, shorebird roosting habitats may be limiting and should be increased.

Central Bay — This subregion is highly urbanized and is used least by both shorebirds and waterfowl. Any additional roosting habitat that can be protected from disturbance would be beneficial in maintaining or improving existing populations. Restoration of any large, shallow ponds would likely benefit shorebirds and waterfowl. Wetland rehabilitation in urban areas should be encouraged.

FIGURE 2 **Waterfowl Use of Salt Ponds in the South Bay Ordered from Most to Least Waterfowl Use.**

Reduction in the total salt pond area is related to the estimated decrease in waterfowl numbers. For example, a 50% reduction in salt pond suggests a 15% reduction in waterfowl.



South Bay — The majority of the shorebirds and waterfowl in the South Bay use the salt evaporation ponds for roosting or feeding habitat during the winter. Conversion or loss of this habitat type must be offset by enhanced management of existing areas or mitigation with alternative areas, including created salt ponds, managed wetlands, and seasonal wetlands. For example, analysis of waterfowl survey data from 1988–1990 (Takekawa, pers. comm.) suggests that if 50% of the salt ponds are converted, 15% of the 76,000 waterfowl may be lost (**Figure 2**). An increasing number of waterfowl would be displaced if more area was converted.

Although mudflat foraging habitat seems adequate, with salt pond conversion, suitable roosting habitat for shorebirds may become limiting. Little is known about how salt ponds and seasonal wetlands provide food for shorebirds and protected microclimate areas during adverse weather. Thus, we recommend not more than 50% or 15,000 acres of salt ponds in South Bay be converted to other habitats without careful planning for habitat mitigation for shorebird and waterfowl populations. We also recommend an increase in seasonal wetlands as migration habitat and roosting areas.

Enhancing Tidal Marsh Restoration Projects for Shorebirds and Waterfowl

Shorebirds and waterfowl may use several elements in tidal salt marshes. As restoration or rehabilitation is undertaken, these elements should be provided when possible.

1. Larger channels with large mudflats are often used by shorebird and waterfowl species and should be encouraged in tidal marsh design.
2. Muted tidal areas provide temporal diversity which may provide good habitat, especially for diving ducks.

3. Unvegetated levees and islets with gradual slopes that are durable, and bare areas that remain unvegetated with limited management should be constructed as roosting sites.
4. A diverse mix of pans and ponds should be retained in marsh plains for high tide roosting and foraging areas.
5. Designs should be made to minimize disturbance by people, pets, and predators.
6. Surveys of shorebirds and waterfowl should be conducted prior to restoring areas to tidal salt marsh so losses may be evaluated and suitably mitigated.

Research Needs

Relationships among habitat change and change in populations of waterbirds have been studied in other estuaries (see Goss-Custard et al. 1997). We should learn from these efforts and develop a research program in the San Francisco Estuary to examine questions raised in the Goals process, including the following topics:

1. Determine the feasibility of designing ponds or systems from the existing salt evaporation ponds which can support the current populations of shorebirds and waterfowl.
2. Evaluate what constitutes a good roosting area for different species of shorebirds, including distance from feeding areas. Areas used within tidal salt marshes should be included.
3. Estimate the size and composition of shorebird populations in Suisun Bay subregion.
4. Determine the importance of non-mudflat habitats, such as salt ponds and seasonal wetlands, as foraging areas, especially during inclement weather.
5. Examine seasonal wetland use and extent (not available in the EcoAtlas), including diked farmland, grazed baylands, diked marsh, managed marsh, and ruderal baylands through wet and dry years.
6. Test differences in shorebird and waterfowl response to different actions in managed wetlands by measuring use-days and numbers.
7. Relate diving ducks use of wetlands by area size and water depth.
8. Quantify shorebird foraging and roosting in wetlands other than intertidal flats, including intertidal pans, low and medium salinity ponds, managed marsh, diked marsh, muted tidal, and seasonal ponds. Include factors such as tidal cycle, salinity, vegetation, and distance to intertidal flats.
9. Describe use of wetlands by salinity and prey differences for shorebirds and waterfowl.
10. Provide more information about the effects of disturbance on shorebirds and waterfowl to develop suitable habitat buffer zones.
11. Determine the effects of channelization, levee alteration, and use of dredged-spoil on mobilization of contaminants sequestered in soils or sediments and bioaccumulation in shorebirds and waterfowl.
12. Characterize hydrology, biology, and chemistry of salt ponds heavily- and lightly-used by shorebirds and waterfowl to examine the differences.
13. Determine habitat values and use by waterfowl and shorebirds of managed wetlands versus tidal wetlands.
14. Investigate the effect of non-native invertebrates and plants (e.g., *Potamocorbula amurensis*, *Spartina alterniflora*) on shorebirds and waterfowl.

15. Evaluate methods to reduce effects of non-native predators on shorebirds and waterfowl.

16. Examine the effects of contaminants on breeding birds.

17. Pilot Projects — encourage monitored experiments in wetland restoration or mitigation:

    a. Include repeatable waterbird surveys before and after project actions.
    b. Examine maintenance or creation of salt pond systems, including low- to mid-salinity ponds in the absence of commercial production. Habitat values and use should be maximized while minimizing maintenance costs.
    c. Test methods of constructing habitat elements with low maintenance requirements, such as bare roosting islands, intertidal pans, and non-tidal seasonal ponds.
    d. Examine differences in use of different wetland unit sizes.
    e. Test methods of increasing shorebird and waterfowl use of managed marshes.
    f. Increase monitoring efforts on existing projects with habitat elements valuable for shorebirds and waterfowl.
    g. Employ adaptive management by applying earlier findings to change design elements through time.
    h. Preliminary sampling for contaminants of areas designated for salt marsh restoration.
    i. Preliminary sampling of salt ponds for invertebrate community, salinity, and other water quality characteristics.

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Other Bayland Birds Focus Team

Recommendations

Introduction

The baylands of the San Francisco Bay support a diverse assemblage of bird species. The Goals Project has divided these species into two groups: (1) shorebirds and waterfowl, and (2) other baylands birds. Representatives of the other baylands birds group include gulls, terns, grebes, pelicans, egrets, raptors, rails, and many species of songbirds. This report presents the recommendations of the Other Baylands Birds Focus Team, which was formed to address the needs of this group of birds, and the term "other birds" will be used throughout when referring to them.

The U.S. Fish and Wildlife Service's *Diked Baylands Wildlife Study* and the San Francisco Estuary Project's *1992 Status and Trends Report on the Wildlife of the San Francisco Estuary* identify 184 other bird species. The baylands provide important support for many of these species during migration and during the winter (warblers, grebes, and raptors), and support breeding during the summer, particularly for resident species (clapper rail and song sparrows).

The abundance and distribution of other birds using the Estuary is a reflection of the habitat changes which have occurred in the baylands over the last 150 years. These changes have resulted in dramatic declines in some species (clapper rail) and increases in other species (eared grebe or meadowlark). Changes are most pronounced in species which are dependent on tidal marsh and those which have been able to exploit new habitats resulting from diking and filling of the Bay. From the historic record and inference about how species use the existing baylands, we are able to identify changes in abundance. Unfortunately, little information is available to allow us to fully understand the range of support functions provided in the historic condition.

The changes which have occurred over the last 150 years have altered the mix, abundance, and distribution of habitats within the baylands and adjacent uplands significantly. The habitat most affected has been tidal marsh, which has been reduced by 80 percent. Much of what remains today is recently formed, fragmented, and poorly developed and does not provide the levels of support which could have been expected in the historic marshes. This can be inferred by comparing current tidal marshes to mapping of the baylands in the mid-1800s. With the exception of the Petaluma Marsh, today's tidal marshes are a shadow of the historic marshes which were a diverse mixture of channels, flats, marshes, permanent ponds, salt ponds and pan, areas of seasonal ponding, and ecotones with various upland habitats.

Uplands adjacent to the Bay have also been greatly altered or eliminated, particularly in the South and Central Bay subregions. Based upon historic information developed as part of the EcoAtlas, the uplands surrounding the baylands supported extensive areas of potential seasonal ponding. Examples of these can be seen at the Warm Springs area in South Bay and at areas surrounding Suisun Bay. In many cases, diking of the baylands has created habitats suitable for many upland species which historically occupied adjacent uplands (burrowing owl and meadowlark). These habitats include levees, diked marshes, managed marshes, farmed and grazed lands, and areas of undeveloped fill.

Diking of the baylands has also provided for the establishment of other types of wetlands that were of limited extent or found primarily in the adjacent uplands surrounding the Bay. These include salt ponds, managed marshes, and seasonal ponds. The presence of these habitats in the baylands has been beneficial for many other bird species which prefer these habitats and have been able to exploit them (eared grebe, terns, gulls, and white pelican).

These changes in the baylands have set up a natural tension between species in developing recommendations for the Goals Project. The Other Baylands Birds Focus Team selected evaluation species to represent the habitats of the entire Estuary as a means of identifying needed habitat support functions.

Although the recommendations for restoration of particular features of the ecosystem may benefit some evaluation species and their proxies, there will always be conflicts between the needs of the various evaluation species, and management goals must seek to balance these conflicts.

Tenets

The process of making recommendations for other birds focused on looking outward from the baylands. The emphasis was on making recommendations for species which depended upon the baylands for their primary support. To aid in this process, an attempt was made to place evaluation species in context with their regional and flyway populations. Since the area of the baylands is limited, compared to the distribution of some evaluation species, emphasis was placed on making recommendations for those species whose life requires or local occurrence depend on the support functions provided by the baylands. The focus team agreed that its recommendations should:

1. Emphasize sensitive species endemic to the Estuary over species which have become more abundant or colonized the Bay as a result of habitat alterations.
2. Maintain or restore habitat gradients to express the full range of biodiversity within the Estuary.
3. Strike a balance between the habitat needs of species using the baylands ecosystem. A return to historic conditions may not be possible nor desirable given the alterations which have occurred.
4. Provide large patches of diverse habitat that contain large populations, as these are superior to small patches with small populations. Small habitat patches can provide important connections between larger patches.
5. Use umbrella or keystone species to represent habitat types and larger assemblages of species.
6. Minimize habitat fragmentation.
7. Emphasize restoration of self-maintaining systems. Some degree of management will be needed to maintain populations of species which depend upon habitats created by past alteration of the baylands.
8. Protect and enhance native species.

Evaluation Species

The selection of evaluation species used the following criteria:

1. Requires large, well developed tidal marsh habitat.
2. Uses salt pond or shallow saline pond habitat.
3. Uses higher part of tidal marsh and upland transition.
4. Represents a particular habitat type, including: riparian, seasonal ponds, freshwater marshes, adjacent uplands, channels, open bay, or rocky shores/islands.
5. Relies on a variety of bayland habitats and adjacent areas for nesting and foraging.

7. Represents a broader group of species which use the baylands.
8. Is locally or regionally limited in number and distribution (listed species, species of special concern).

Twenty-seven evaluation species were initially selected from the species identified in the Diked Baylands Study and the Status and Trends Report. The selected evaluation species represented the full range of habitats found within the baylands, as well as the support functions they provided (foraging, roosting, migration, wintering, breeding).

Upon selection, the evaluation species were evaluated for their dependence on the baylands and their regional, statewide, and flyway populations and trends. Additionally, an evaluation was made of what their specific conservation needs were and what the limiting factors to their persistence within the baylands and the region were. This review resulted in a thinning of the evaluation species to 14 species which provided the basis for recommendations made for the other birds.

The recommendations of the Other Baylands Birds Focus Team focused upon those species which represented habitat features present only in the baylands.

Eared Grebe *(Podiceps nigricollis)*. This species uses the Bay primarily for wintering habitat. Historically, it was present in the Bay in low numbers; presence of salt ponds has resulted in higher wintering populations. This species represents other bird species which rely on low- to mid-salinity salt ponds.

Western/Clarks Grebe (*Aechmophorus occidentalis* and *A. clarkii*). These species frequent the Bay during the fall and winter. They characteristically utilized the open bay and larger tidal channels, as well as ponded habitats in the diked baylands, where fish are present.

Brown Pelican (*Peleanus occidentalis*). The brown pelican is a summer and fall visitor to the Bay. This species is representative primarily of the open bay habitat of the Central Bay. It requires disturbance-free roost sites, such as Breakwater Island at the Alameda Naval Air Station.

Snowy Egret (*Egretta thula*). The snowy egret is a year-round resident of the Estuary. It is a generalist in its use of wetland habitats within the Bay. The species breeds within the baylands and is representative of other associated species and island nesting species in the Bay. The primary limiting factor for this species is the availability of nesting sites isolated from predation and disturbance.

Northern Harrier (*Circus cyaneus*). The harrier is a resident raptor which inhabits the baylands. This species uses all the current habitats of the baylands and adjacent open uplands. The species is used to represent other raptor species which utilize the baylands.

California Black Rail (*Laterallus jamaicensis*). The State listed threatened black rail is a resident of high tidal marshes of the San Pablo and Suisun bays. The species is representative of brackish tidal marsh species.

California Clapper Rail (*Rallus longirostris*). The State and Federally listed endangered clapper rail is a resident of the tidal marshes of the Estuary. The species characteristically inhabits the more saline marshes of the Bay. Highest populations are found in large tidal marshes with well-developed channel systems.

Forster's Tern (*Sterna forsteri*). This is a resident tern of the baylands. It uses salt ponds and managed wetlands with islands or appropriate structures for nesting. It forages in both managed wetlands and the open Bay and channels. It is representative of species which rely on salt ponds for nesting habitat.

California Least Tern (*Sterna antillarum browni*). This State and Federally endangered species breeds in the Bay, nesting on bare open sites in close proximity to areas of shallow open water. The species historically nested on beaches, but has been displaced to areas of unvegetated fill adjacent to the Bay. The species also relies on low-salinity salt ponds for post fledging foraging.

Burrowing Owl (*Speotyto cunicularia hypugaea*). The burrowing owl is a species of special concern. It is characteristic of open grasslands adjacent to the Bay. Much of its historic habitat particularly in the South Bay has been lost to development. It represents species which inhabit the upland grasslands adjacent to the baylands. In many cases the species is found in diked baylands predominated by annual grasses.

Yellow Warbler (*Dendroica petechia*). The yellow warbler is both a resident and migrant in the riparian habitats at the edge of the Bay. The species is used as a representative for those species which depend upon riparian and willow thicket habitats.

Salt Marsh Yellowthroat (*Geothlypis trickas sinuosa*). The yellowthroat is found in fresh and brackish marshes, tidal marshes, swampy riparian thickets, and weedy fields and grasslands bordering wet habitats. Yellowthroat territories frequently include the ecotones between these communities.

Savannah Sparrow (*Passerculus sandwichensis*). The savannah sparrow is found in the transition zone between tidal marsh habitats and adjacent open uplands. This species is representative of species found in the grasslands within the baylands and transitions from marsh habitats to open uplands.

Song Sparrow (*Melospiza melodia*). Three subspecies of song sparrows are found in the tidal marshes of the San Francisco Bay. All are considered species of special concern due to their limited distribution and loss of habitat. These species are characteristic of tidal marshes and depend upon adjacent uplands for refugia.

Based upon the tenets identified above and the selected evaluation species, the following recommendations are made concerning future management and restoration of the baylands. From the discussion above, the emphasis of the recommendations is on restoration of tidal habitats, particularly tidal marsh, due to the substantial reductions of this habitat and the number of listed or sensitive species they support. While the recommendations of the Other Baylands Birds Focus Team emphasized tidal habitats, it is recognized that diked habitats provide support functions for some other bird species, but more so for shorebirds and waterfowl. Consequently, maintenance and enhanced management of retained diked baylands will be an important feature for insuring that competing species needs are balanced. Additionally, it is important to provide upland habitats contiguous with the baylands as refugia and buffers from disturbance.

Recommendations

A. Increase the amount of tidal marsh in all subregions of the Bay. Tidal wetland acreage within the Bay has been reduced by approximately 82 percent. Much of the tidal marsh that remains is recently developed and often linear with a high perimeter-to-area ratios. These tidal marshes in many cases are poorly developed, lacking topographic variation, extensive tidal channels and pannes. Consequently, they are of reduced value to many species which depend upon them. Evaluation of current tidal marshes within the Bay indicates that approximately 50 percent of the current acreage is of good habitat quality for other bird evaluation species which depend upon this habitat type.

- Create large blocks of tidal marsh with a minimum of upland within the marsh. The ratio of upland edges to marsh area should be minimized. Restoration of tidal marsh in areas of higher salinity should be a priority for recovery of the California clapper rail. In areas where tidal marshes are restored, flood control levees should be removed.
- Provide connections between tidal marshes (corridors), particularly in Suisun Marsh for Suisun song sparrows, and in South Bay for clapper rails and Alameda song sparrows.

- Reduce or eliminate unseasonable freshwater inflows to the Bay (e.g., wastewater discharges).
- Provide high tide refugia by developing supratidal marsh features (e.g., vegetated channel levees) and retaining levee remnants and other artificial features where possible. These features should be at or slightly above MHHW.

B. Connect tidal marshes to uplands in natural gradients in all subregions of the Bay. Where possible, site marsh restorations at locations where such connections can be restored naturally. Restoration of such connections will be important for accommodating a rise in sea level.

C. Maintain low- and mid-salinity salt ponds in the absence of salt production, (e.g., intake ponds and adjacent evaporators), as well as other open water habitats. Several ponds operating in series are needed to provide concentration of brines to provide the array of salinities preferred by species using salt ponds. Siting of several such pond complexes around the Bay should be located so that the discharge point could be used to add salinity to large wastewater discharges.

- Manage salt ponds of low- and mid-salinity to provide important habitat for species, such as terns, eared grebes, and white pelicans. Ongoing salt production maintains these important habitat attributes.
- Allow for discharge of medium salinity brines back into the Bay, i.e., to areas where they exceed background levels.
- Develop nesting islands for terns and other avian species within retained salt ponds. Such features are also important for shorebirds.
- Consider muted tidal regimes when managing intake ponds.

D. No special emphasis should be placed on managing for primarily upland species within the baylands (e.g., meadowlark). Protection and enhancement of transitional and adjacent uplands and seasonal and managed wetland areas will provide an appropriate habitat.

E. Development of permanent freshwater emergent wetlands should not be a priority where it would preclude restoration of tidal wetlands or convert existing wetlands within the baylands. Development of such habitats should be focused in upland areas adjacent to the Bay. Development of fresh to brackish marshes using treated wastewater can provide important habitat for other bird species, such as egrets and waterfowl (e.g., Hayward Treatment Marsh). Such wetlands should be carefully sited and designed to avoid direct and indirect impacts to existing wetlands.

F. Riparian and willow thicket (sausal) habitats should be enhanced and developed where possible around the Bay to provide habitat for migrants and resident species. These habitats should be distributed as evenly as possible. Use of treated effluent could be used to enhance flows in streams tributary to the Bay which would help to expand and maintain riparian habitats. Setback levees should be encouraged in flood control planning to restore or maintain flood plain and riparian habitats where possible.

G. Within the historical extent of the Bay, farmed and grazed lands can be maintained as long as they are in ongoing production. Farming practices that enhance wildlife and which are compatible with agricultural production should be encouraged, particularly enhancement of seasonal ponding. These lands provide support for many species, although the level of support varies widely depending upon the agricultural practices and climatic factors which affect the degree of ponding and quality of habitat for wildlife.

H. Opportunities to protect and enhance upland transitional habitats should be identified and given priority. Development of upland transitions should be incorporated into tidal marsh restorations where possible. They should be incorporated as they would naturally occur. For tidal marsh restorations where levees will be required, the levees should be constructed to mimic naturally occurring transition zones between tidal marshes and uplands. The levee slopes should be designed with gradual slopes. Where feasible, areas of seasonal or high tide ponding should be incorporated into the transition zone.

I. In areas now largely developed, remaining wetland parcels should be retained and/or enhanced where possible, especially where such parcels are adjacent to larger wetlands, to function as dispersal corridors for wetland birds moving between larger intact wetlands and other native habitats.

Table 1 displays current and recommended habitat acreage.

Table 1. Other Bayland Birds Focus Team Recommended Habitat Acreage. (Recommendations made in early 1998 based on EcoAtlas version 1.0.)

	Current	Future
Tidal Marsh (acres):		
Estuary:	40,403	112,656
South Bay:	9,345	30,769
Central Bay:	949	949
North Bay:	16,334	44,793
Suisun:	13,775	36,202
Uplands/tidal marsh transition (linear):		
Estuary:	minimal	increase
South Bay:		
Central Bay:		
North Bay:		
Suisun:		
Salt Pond (acres):		
Estuary:	37,210	10,038
South Bay:	28,643	8,515
Central Bay:	-0-	-0-
North Bay:	8,567	1,523
Suisun:	-0-	-0-
Managed Marsh (acres):		
Estuary:	53,815	38,656
South Bay:	1,309	1,309
Central Bay	29	29
North Bay:	4,718	9,130
Suisun:	47,759	28,188
Diked/Farmed Baylands (acres):		
Estuary:	44,224	15,863
South Bay:	4,100	2,610
Central Bay:	1,400	1,400*
North Bay:	31,296	6,910
Suisun:	7,428	4,943*
Riparian (acres):		
Estuary:	limited	increase
South Bay:		
Central Bay:		
North Bay:		
Suisun:		

Tidal marsh = all tidal marsh types.
Salt pond = all salt pond types, inactive and crystallizer.
Diked/Farmed Baylands = diked marsh, ruderal bayland, grazed bayland, farmed bayland.
*subject to further review.

Hydrogeomorphic Advisory Team

Integrating Abiotic Factors in the Goals Project: Tenets of the Hydrogeomorphic Advisory Team

This paper presents information regarding some of the physical considerations associated with restoring bayland habitats. It includes the HAT's organizing principles and other summary points. It also includes questions posed by the focus teams and our brief answers to them.

The information we are providing here is very limited, and we recognize that any large-scale effort to restore the baylands will require substantial regional and site-specific investigation.

I. Organizing Principles

1. The preferred approach to implementation of the Goals should be the restoration of natural, self-sustaining systems that can adjust to changes in physical processes, with minimum ongoing human intervention.
2. In those cases where the restoration of natural, self-sustaining systems is not possible or is not preferred, a phased eventual transition to such systems should be considered. For example, some salt ponds may be maintained to support species currently using this type of habitat. However, it would be preferable to eventually replace these with natural, self-sustaining habitat types, such as mudflats, tidal marshes, salt pans, etc., if this can be accomplished.
3. Restoration planning and design should be based on expected regimes and variability of physical processes, including hydrology, sediment, salinity, water quality, and biogeochemistry.
4. Restoration planning and design should account for both natural causes of variability, such as drought, and anthropogenic causes of variability, such as alteration of freshwater flows.
5. Restoration planning and design should recognize the range of temporal scales. This applies both to the rate of evolution of a restored site in providing wetland functions, such as transition from an intertidal mudflat to a vegetated tidal wetland, and potential changes in the controlling physical factors, such as expected changes in the bay sediment budget.
6. Restoration planning and design should recognize the spatial scale (size and location) of restoration sites. Key examples include uniform sedimentation rates across small sites versus higher sedimentation rates near a levee breach at larger sites, and greater sedimentation rates in South Bay than in Central Bay.
7. Restoration planning and design should consider its effects on regional physical processes, such as sediment transport.

II. Links to External Influences

1. Restoration planning should be conducted in recognition of the links to major and local influences that are external to the Bay itself. These primarily include the oceanic influence, watershed input from the Sacramento/San Joaquin river system, and the local river and creek contributions.
2. The restoration of the Bay ecosystem must be tied to the restoration and maintenance of these external links.

III. Planning and Design Guidance

1. Site design should be focused on the creation of an appropriate "template" which will evolve towards a dynamic equilibrium within the shortest time to provide the range of ecosystem function and complexity characteristic of appropriate reference sites.
2. Preference should be given to the restoration of large sites, capable of providing the complexity of habitat, highest channel order, and ecosystem resilience.
3. Preference for habitat type should recognize those ecosystems which are limited in their potential extent by controlling abiotic factors. For example, intertidal wetlands should be given preference where conditions are suitable because of the extremely limited opportunities for creation.
4. It is recognized that at some sites it will be infeasible to develop a self-sustaining system, and that artificial control structures may be required. Based on experience with these systems, there is a greater uncertainty in site evolution and a greater need for oversight. Therefore, an adequately funded maintenance and management organization is needed to ensure that restoration goals are met in perpetuity.

IV. Advancing Restoration Science

1. The goal of advancing restoration science is to improve the ecological effectiveness of restoration projects.
2. Advancement of restoration science should come from a comprehensive program linking academic research, numerical and physical modeling, pilot projects, monitoring, restoration success evaluation, and information exchange between researchers, practitioners, regulators, and interest groups.
3. This comprehensive program should incorporate natural reference systems, previous restoration projects, and new restoration projects.
4. Principles of adaptive management should be incorporated into all restoration projects. Adaptive management would include both incorporating project-specific monitoring results into ongoing site management, as well as exchanging information for other restoration efforts.

V. Evaluating Restoration Success

1. Adaptive monitoring and maintenance of the systems should be based on conformance to the expected evolutionary trend and to reference conditions rather than specific conditions at any given time.

RMG/Focus Team Questions and HAT Responses

The questions shown below in bold type were submitted to the HAT by the RMG on 3 November 1997, and the HAT members worked together to develop the following responses:

1. How long would it take for marsh "restoration" to take place in areas of subsidence?

As for most of the questions, the response to this depends on the definition of "restoration," as well as a consideration of temporal and spatial scales. The question reflects the understanding that restoration requires raising the subsided marsh plain back to an appropriate elevation in the intertidal zone and restoring the range of functions a tidal marsh provides. A brief review of these will provide some insights regarding the process.

Process

In subsided San Francisco Bay tidal wetlands, restoration will proceed primarily by deposition of suspended sediment (as opposed to the accumulation of organic matter), since most of the marsh plain rise will occur at elevations below that suitable for vegetation. Our observations indicate that deposition will continue until the marsh plain reaches a steady elevation relative to the Mean Higher High Water (MHHW), supporting primarily a pickleweed vegetation cover under saline conditions, or a more diverse cover of pickleweed and other plant species under brackish-saline conditions.

It is important to remember that the processes vary through time and space in ways that preclude any exact equilibrium or steady-state.

Depth of Subsidence

The depth of subsidence in the diked wetlands varies dramatically around the Bay, depending on the various subsidence properties. In the South Bay, maximum subsidence has been about 15 feet (New Chicago Marsh in Alviso), due to both groundwater withdrawal, soil compaction, and oxidation of the organic faction by microbial actions in part. The nearby salt ponds (adjacent to Alviso Slough) appear to have subsided about eight feet. Another salt pond (100-acre site at Cooley Landing in East Palo Alto adjacent to the Dumbarton Bridge) has only subsided one to two feet. In North Bay, subsidence of three feet to six feet appears common in sites studied.

Rate of Deposition

The rate of sediment deposition is affected by numerous parameters; major factors include suspended sediment concentration, depth of water column, local wave climate, salinity regime, presence of vegetation, and others. Some simple models are available incorporating the first two factors for prediction of sediment accumulation rates. Reasonably good field information is available on the rates of deposition at a number of locations around the Bay to predict deposition rates for small to moderate size (up to about 200 acres) subsided sites. These include the Alviso Marina site, Warm Springs Marsh Restoration, and Baumberg Tract in South Bay, and some Petaluma River marshes and other sites in North Bay. These indicate fairly rapid rates of accretion under present conditions for most of the Bay.

For example, the Alviso Marina (about a five-acre site) was last excavated (for boat use) to a depth of about minus 15 feet NGVD (vertical datum that corresponds approximately with mean sea level) in 1976. The Marina accumulated silt rapidly, and was only marginally functional by the early 1980s. By 1990, it had accumulated about 16 feet of sediment, and vegetation began encroaching. By 1995, it was mostly covered with brackish marsh vegetation. This corresponds with monitoring in the Warm Springs Marsh (a 200-acre site), in which initial deposition rates have been extremely rapid (up to five feet per year), and an overall rapid pace of deposition.

Initial rates of over two feet of accretion per year are common in deeply subsided sites. These rates decrease as the marsh plain rises (smaller water column and associated sediment above). Using local data for calibration, it has been predicted that about 10 to 15 years would be required for sediment deposition in a subsided South Bay salt pond (marsh plain elevation currently about minus three feet NGVD) to raise the marsh plain to an elevation where native vegetation would become established. While the amount of sediment available for deposition decreases as the marsh plain rises, the establishment of vegetation accelerates the rate of rise towards steady elevation relative to the tides by reducing turbulence and adding organic matter. This estimate of 10 to 15 years is probably applicable to similar small to moderate sites in South Bay, which has the highest rates of deposition. In North Bay, there are reports of initial cumulative deposition rates of about 1.5 feet per year at the Petaluma River Marsh restoration site. Based on a series of site comparisons, there are estimates that it would require about 35 years for the Sonoma Baylands site to reach a steady elevation relative to the tides.

Temporal Considerations
The above observations are based on the historical and existing suspended sediment concentrations and rates of sea level rise. While these are not likely to change quickly, it is important to recognize that the long-term future sediment supply to, and sediment loss from, the Bay system may change and that the rate of sea level rise may increase. These topics are described more fully in the response to Question 7.

Spatial Considerations
The restoration sites monitored to date have been small (generally less than a couple hundred acres). Concurrent opening of large numbers of subsided sites will require consideration of the regional sediment supply. As an example, at its maximum depth, the 200-acre Warm Springs site aggraded at a rate of almost five feet per year, corresponding to an annual accumulation of perhaps 1.0 to 1.7 million cubic yards. This represents a significant fraction of the total net Bay sediment available of about five million cubic yards per year.

Restoration Process
It is probably clear to all the participants that the term "restoration" is a controversial topic, which covers a wide range of functions and values. As applied to this question, we recognize that the subsided site will evolve through the states of:

- subtidal, unvegetated
- low intertidal (mostly mudflats, unvegetated)
- mid-intertidal (vegetated by lower marsh vegetation)
- high intertidal (mature marsh plain vegetation)

From a process perspective, we can state with some assurance that the evolution will proceed through the above states at a predictable time frame. However, these represent only the broadest categories, and do not reflect the complexity that we see in an ancient marsh compared with a recently restored site. For example, it is unlikely the slough channel system will achieve the multiple channel orders and sinuosity in a recently restored site compared with an unaltered reference site. Likewise, the amount of organic matter and nutrients in the marsh sediments will be less in a site which has undergone extremely rapid rates of mineral soil deposition (such as a subsided marsh reopened to tidal circulation), and the organic matter would be mainly in the uppermost soil layer. Whereas, in the case of a marsh plain that has evolved gradually over thousands of years, the organic matter would be distributed throughout the vertical soil profile down to the contact with ancient mudflat sediments. In view of this, we should not expect recently restored marshes to include this level of complexity for decades or perhaps even centuries. The goal of the restoration plan should be to create the optimum "template" such that the site will evolve towards a condition of maturity and complexity in the shortest time frame, recognizing that some functions can be restored more quickly than others. The monitoring process should be focused on whether the site is evolving along the desired path rather than the specific state at any one time. This approach is emphasized in the HAT guiding principles and recommended research.

2. Can we create and maintain large slough channels in restoration (which provide mudflat foraging habitat for shorebirds)?

Marsh slough channels evolve as nature's most "efficient" way of exchanging water and dissipating energy within the intertidal landscape. At any location within the marsh plain system, the slough channel cross section dimensions and shape reflect a balance between erosion (scour) forces exerted by the tidal flow, which tend to expand the channel bed/banks, and the tendency for deposition of suspended sediment to decrease the channel dimensions. At the most basic level, the maximum channel "order" within a marsh complex, and size of the slough channels at a particular location, are determined by the size (areal extent) of the intertidal zone. Quite simply, to support large slough channels or complex networks of channels of varying order, we need large marshes. Slough channels hundreds of feet wide, with maximum depths of 25 to 30 feet and broad expanses of unvegetated mudflats, were common features of the historical Bay marshes which covered thousands of acres. This image is apparent in the historical view of the EcoAtlas.

The areal extent of restored tidal marsh required to support a given width/depth dimension of a slough channel can be approximated by using the "hydraulic geometry" approach developed in large part by Bay Area wetlands scientists. There is also extensive data collected on how rapidly channels respond to changes in tidal area or tidal prism: In response to decreases in marsh plain area, the channels decrease rapidly in depth to a new equilibrium level, and more slowly in width. The rate of enlargement of channels with increased tidal exchange depends primarily on the erodibility of the underlying sediment (highly consolidated clay material is relatively resistant to erosion and may require excavation).

3. Does marsh restoration decrease mudflat habitat? Will restoring tidal marsh areas reduce bayside tidal mudflats used by shorebird and waterfowl species?

The seat-of-the-pants consensus of the HAT seems to be "not much, if any."

4. Can you estimate the decrease in mudflat area with the increase in tidal marsh at a specific site? For a region?

To check this, some simple calculations were made assuming the following:

1. All sediment to fill a pond comes from mudflats from MHHW to minus six feet MLLW, a depth at which bottom sediments can readily be re-suspended by wind waves.
2. The longshore distance that contributes sediment to a salt pond is equal to the frontage of the pond on the Bay.
3. The pond bottom must be raised three feet (gross estimate from Napa River ponds).
4. No sediment comes from the local watershed.
5. The slope of the resulting mudflat will be the same.
6. The mudflat can not migrate landward.

These assumptions are probably the worst case for mudflats. In reality, some if not most of the sediment that would deposit in the ponds would come from further away in the Bay (or more distant sediment would replenish sediment that moved from the mudflat to the pond) or from the local watershed. These assumptions can be used to calculate the distance the minus six-foot contour will migrate landward. This is the cross-shore distance of mudflat lost.

$$\text{Volume of fill} = AH = L\, dh\, dx\, (1 - dx/x)$$

where A=area of pond, H=depth of pond, L=Bay frontage of pond, dh=distance from -6 ft MLLW to MHHW, dx=distance -6 ft MLLW contour moves toward shore, and x=cross-shore distance from -6 ft MLLW to MHHW.

This approach was tried for two randomly selected salt ponds along the shore of South Bay: the pond east of Mountain View Slough and the pond south of Coyote Hills Slough. For each pond, about 10–15% of the habitat from MLLW -6 feet to MHHW ($dx/x \sim 0.1$ to 0.15) would be lost for this worst case scenario.

5. How should salt ponds be restored through phasing of pilot projects, i.e., which ponds should be restored first, and how long should one salt pond or pond complex take to develop before another is attempted?

Some of the decisions that would have to be made and some of the factors that would affect these decisions can be listed. If a large area of salt ponds were to be restored, a study would be required to answer this question specifically and in appropriate detail for making resource management decisions. So far, as best we know, restoration projects have been small enough where this question has not arisen.

Spatial decisions (what order?):

- Napa or South Bay first (depends on ecological benefit on baywide scale)?
- Restore ponds adjacent to the bay/river shoreline or furthest away from shoreline first?
- For South Bay, restore closer to San Francisco or San Jose first?

Phasing decisions (when?):

- What criteria should be used to decide when to open up additional ponds to tidal action (seasonal, deposition in previous pond, time)?

Hydrologic factors influencing decisions:

- Sediment supply: Is seasonal and varies from year to year.
- Salinity: In and around the ponds should be maintained at an ecologically safe level. This will also be dependent on freshwater flow, which also varies seasonally and annually.
- Tidal currents: May be altered near a restored pond.
- Pond plumbing: The ponds have extensive plumbing to transfer water and produce salt. Restoring tidal action to one pond could affect the flow of water between ponds and thus water quality in the remaining ponds.

Other factors:

- Opportunity: What ponds are available at any given time for restoration.
- Levees: If a levee breaks during a flood, the pond is restored to tidal action.

6. Can you maintain the variation in salinity in salt ponds without continuing to operate the ponds as a evaporative system?

No. In order to produce hypersaline water from seawater, water (H_2O) must be removed (evaporated). An alternative to solar evaporation would be a desalination (reverse osmosis) plant that would produce drinking water and hypersaline water.

7. Comment on the implications of sea level rise in relation to long-term management of both tidal and diked wetlands.

Atwater and others have described the history of the San Francisco Bay on a geologic time scale. Sea level rose rapidly prior to 8,000 years ago and progressively invaded the valleys, creating the San Francisco Bay system. The rate of rise slowed between 8,000 and 6,000 years ago to approximately the present rate. At this slower rate, soil eroded from the land and was transported to the bays, accumulated along the shores, and supported the proliferation of marsh plants. The plants accelerated the rate of deposition of suspended sediment in their midst, as they do today, and continuing accumulation of sediment and plant material raised the surface. As sea level continued its rise, sediment was added to the surface and the rising marsh invaded the land and created the extensive tidal marshes found by the forty-niners.

Sediments enter the bays suspended in the waters of winter freshets. For the Bay system as a whole, the Central Valley drainage provided in excess of 80 percent of the sediment entering the bays, with the remainder contributed by local streams. The importance of local sediment supplies probably increased closer to local sources. For example, it is possible that the relative contribution of sediment from the Napa Creek watershed increased upstream from Mare Island. The material from the Central Valley drainage deposits initially where it enters the broad bays. Onshore breezes generate waves during spring and summer days that suspend the newly deposited material, and tidal currents circulate it throughout the bays. During a year, most of the material either deposits in locations where it is not further suspended by currents or waves, including deposition on marshes, or exits the Golden Gate.

Human activity wrought large changes in the Bay system. Sediment and water inflows have been altered drastically, and most of the marshlands have been diked and drained. Present evidence indicates that prior to 1849, the limited supply of suspended sediment brought into the bays was not quite sufficient to maintain water depths, and the bays slowly deepened. Hydraulic mining contributed 1.4 billion cubic yards of mud deposit in the bays and on the marshes during the period from the early 1850s to the late 1870s.

Vallejo Bay and Northampton Bay became mudflats with the Carquinez Strait channel through them. Large deposits filled the upper bays and added large amounts of material to San Pablo Bay. Most of the marsh south of Highway 37 and the marsh along the western shore evolved on these deposits. Agriculture in the valleys and mountain slopes added to the sediment supply then and since.

The suspended sediment input continued to be higher than natural pre-1850 levels until the water projects began to divert sediment-laden river waters for irrigation and municipal supplies. Total annual input to the system averaged 10.5 million cubic yards during the period 1923 to 1950, and averaged 7.9 million cubic yards during the period 1955 to 1990. The CALFED activities suggest that there will be no further reduction. Water diversion is subject to political and legal forces and to the pressures of population growth; however, the long-term prognosis is uncertain.

The upper bays and San Pablo Bay are now so shallow that suspension by waves and tidal currents move all of the annual winter deposit, except that needed to compensate sea level rise, further down into the system. It circulates and deposits where hydraulic conditions permit. North San Francisco Bay is now slowly filling with accumulating sediment, and there is a plentiful supply to South Bay. About 40 percent of the annual supply exits the Golden Gate.

The central roles of sea level rise and sediment supply in maintaining the elevation of mature marshes is apparent from this description. As long as the sediment supply is sufficient to maintain the elevation relative to MHW, as sea level rises, the marshes will endure. It appears that the present supply of suspended sediment is sufficient for a modest rate increase. An excessive increase in the rate of sea level rise or decreases in sediment supply, however, will lower marsh elevations relative to the tides or submerge them.

Restoration requires higher suspended sediment concentrations than does marsh maintenance. Suspended sediment concentrations are highest where there is wave action on mudflats. Planning restoration of diked former marshlands requires attention to the local supply and to the impacts of nearby large restoration projects on depletion of suspended sediments. Evaluation of such impacts can be made using numerical hydraulic and sediment transport models.

In order to sort out immediate and long-term effects of restoration projects, it will be useful to complete the bay-wide evolution of the bathymetric history, as this integrates variations over time scales of interest. Then we could develop whole bay sediment transport model(s) with resolution on the order of 150–300 feet in conjunction with the bathymetric change surfaces at the same resolution. Higher resolution models of individual restoration projects will be useful in predicting an immediate (one to five years) response, but for long-term stability analysis, a full bay transport model will be required.

Once a model is functional and verified with bathymetric change, for it to be useful in predictive scenarios, we will need accurate estimates of sediment delivered to the Bay including major local streams and elevation maps for potential restoration sites.

8. In the southernmost South Bay, inflows from San Jose may be creating a brackish system. Would large scale restoration in this area work for tidal marsh species? If not, could a marsh system be used to keep the freshwater farther from the Bay?

The answer is yes, but it will be expensive and will require maintenance.

There will always be brackish water where treatment plant effluent having low concentrations of dissolved salts mixes with the more saline South Bay water. The location and configuration of this mixing zone can be changed, and from the question it appears that it would be desirable to locate the mixing zone far from the Bay and have tidal marshes colonized with salt-tolerant plants on the margins of the Bay. It might be noted that the historical condition included some amount of brackish marshland associated with the inflows from local creeks. It might also be noted that there are some historical data to suggest that the historical mean daily flow from South Bay creeks combined was about equal to the allowable mean daily sewage effluent, although the historical natural flow was seasonally much more variable. The ongoing occurrence of some amount of brackish tidal marsh in the far South Bay, in conjunction with salt marsh restoration, would reflect historical conditions.

A portion of the most bayward salt ponds, leveed to protect them against the highest tides and storm waves, can be used for mixing the effluent with saltier tidal water, before release into the Bay environment. In essence, what is required is a forebay. The pond or forebay should be sufficiently deep to prevent the establishment of brackish water plants and should be connected directly to the Bay with a channel dimensioned to maintain itself by flows created by the tidal prism of the mixing pond. Maintenance of the water depths in the mixing pond will require periodic dredging, because the high concentrations of suspended sediment in South Bay waters, combined with the tranquillity of the mixing pond waters, will cause rapid rates of sedimentation. For some years, the dredged material can be used to accelerate the restoration of neighboring marshes.

Dimensions and configuration of the mixing pond and the connecting channel can be determined with the aid of hydraulic and salinity models and specification of acceptable salinities at the discharge. Patterns and rates of sedimentation in the pond can be determined with the use of a sediment transport model.

The large tidal range in South Bay may be sufficient to provide the necessary mixing in the Bay *itself*. A pipeline from the San Jose Wastewater Treatment Plant and a diffuser, possibly located north of the Dumbarton Bridge, would avoid local low salinities. Evaluating this solution and determining the location of the diffuser could easily be completed with conventional models.

The HAT would like to take this opportunity to emphasize the need for the simulation of hydraulics and sediment transport in the design of restoration projects. Even the simple breaching of levees requires that their locations and dimensions be optimized to achieve desired deposition patterns and water circulation. Every project has unique conditions, including shape and elevations of the site and suspended sediment and salt concentrations in the flooding water. Model studies are very inexpensive, compared with construction costs or the costs of an unsuccessful project. The HAT is considering how it might help bridge the gap between modelers (the scientists that develop and test models, but may know too little about their operational application in natural resource management) and managers (the people in government who make decisions based upon model outputs, but who may know too little about their assumptions and uncertainties).

9. Given that shorebirds and waterfowl need certain elements that are contained in artificial salt ponds and managed marshes (e.g., open water, roosting sites within a kilometer of feeding areas, etc.), are there particular sites with restoration potential, or particular design features that could be incorporated into tidal restoration projects, that will provide the elements required by shorebirds and waterfowl?

At this time the HAT will defer discussion of particular sites. We can discuss some of the assumptions about restoration projects.

Some Assumptions

Large-scale tidal marsh restoration on diked historic baylands will occur either through the "natural sedimentation" model or the "dredged sediment/backfill placement" model. This assumption guides the approaches available during and following restoration construction to achieve desired elements.

The desired landscape elements sought within tidal marsh restoration projects are open water areas within the tidal marsh of both shallow (for shorebirds) and deeper (for waterfowl) depths.

Any restoration project proceeds through an evolutionary process from the initial unvegetated (or in some cases submerged vegetation) intertidal or subtidal landscape to early vegetation colonization and ultimately to a vegetated marsh plain dissected with a tidal slough system. The time over which this process occurs can vary widely from site to site and in general cannot be predicted with a high degree of accuracy.

Restored wetlands will be subject to regional sea level rise conditions that will influence the inundation regime of tidal wetlands.

Tidal Marsh Pans as Open Water Areas

At least two types of ponds ("pans" in the Goals Project typology) existed historically in tidal wetlands in the San Francisco Estuary: drainage divide pans located within the vegetated marsh plain between tidal drainage networks, and transitional pans located at the upland boundary of the tidal wetland. Few examples of drainage divide pans remain. Petaluma Marsh is probably the best location to find numerous extant pans of this kind. Hoffman Marsh in Richmond adjacent to Highway 580 had such pans, but they were drained as part of an enhancement project in the mid 1980s. Virtually no historical transitional pans remain, as these areas have been overtaken by land use conversion. Only where tidal wetlands still have a natural upland edge that is not too steep are these pans found. Rush Ranch in the Suisun Marsh is one such example, though mosquito control ditches have taken their toll. The pans along the uplands edge of marshland at the Emeryville Crescent may be analogous to the historical transitional pans.

Drainage divide and transitional pans are characterized as small depressions in the landscape that have some type of topographic containment that defines the top elevation of the water surface. Containment features can be small berms, in which case the pond could be partially or wholly perched atop the marsh plain, with the pond bottom below or at the height of the adjacent marsh plain, respectively. Containment features can also be the marsh plain itself, in which case the pond bottom is below the marsh plain (i.e., a simple depression).

There may be three water sources for drainage divide pans. Most prevalent are tidal inputs, the magnitude and frequency of which are related to the height of the pond containment feature relative to the tides. Typically, it is the higher spring tides that reach these ponds. Consequently, the seasonal variability of ponding relates directly to the seasonal variability of the higher spring tides each year, with the June–July and December–January spring tide series being of particular significance. Direct rainfall can also supply water to these ponds. Finally, emergent groundwater can contribute to surface ponding. Surface water is lost by surface drainage out of pond, groundwater infiltration, and evaporation. Likely the most important characteristic affecting surface water loss is substrate type; the more impervious the substrate (e.g., more clay), the longer the duration of ponding (vernal pools are a good analogy).

Water sources for transitional pans can include all those described for drainage divide pans plus runoff from adjacent upland areas. Consequently, these ponds can have a greater freshwater influence relative to drainage divide pans and, depending on annual climatic variability, they may support greater duration of ponding. Surface water is lost in the same manner as for interior ponds.

The HAT presumes that both types of ponds or pans offer habitat for benthic and aquatic invertebrates as food sources for shorebirds and waterfowl.

Tidal Marsh Channels as Open Water Areas

Channels within tidal marshes are open water areas. Water depth varies with the daily tidal flows and with channel bottom elevation. Minor channels drain at lower tide levels offering exposed channel bottoms through a portion of the tidal cycle, depending on their bottom elevation. Major channels either remain submerged throughout all tides (for the largest channels) or may be drained at some of the lowest tides (for the moderately large channels). The HAT presumes that channels can provide a variety of foraging opportunities for shorebirds and waterfowl, including habitats for benthic and aquatic invertebrates and fish.

High Marsh as Roosting Sites
The HAT presumes that roosting sites are needed for passerines and raptors, as well as for shorebirds and waterfowl. Tidal marshes support roosting sites for passerines and raptors on the tall emergent vegetation along channels and especially along natural levees. Roosting sites are also available along the upland perimeter of tidal wetlands, though such availability is strongly affected and defined by adjacent land use. For moderately high tides that do come out of the channels, the tidal marsh plain covered with low vegetation may serve as a roosting site for shorebirds and waterfowl. The shallow pans of high tidal marsh might also serve as roosting sites for shorebirds and waterfowl.

Creating Shorebird and Waterfowl Habitat in Tidal Marsh Restoration Projects
No built projects we know of have included drainage divide pans in their design and construction. Two proposed projects have included such features (Montezuma Wetlands Project and Redwood Landfill Wetland Restoration) and one planned project may include them (Hamilton Army Airfield). The only built projects we know of that have included transitional pans are Arrowhead Marsh, currently under construction by the Port of Oakland, and Oro Loma Marsh under construction by the East Bay Regional Park District. Both projects include a variation of the transitional pan idea that does not quite replicate the historic condition, but seeks to provide shorebird and waterfowl foraging habitat. The basic issue with pond creation is how to generate the appropriate elevations, perimeter containment features, and substrate, and how to exclude unwanted vegetation colonization.

Under the natural sediment restoration model, ponds may form naturally, but as yet we do not have sufficient understanding about how they form or under what time scale formation may occur. Pond formation probably involves some influence of stagnant water (tidal water entrained in the peats or isolated on the marsh surface) on plant survival. Drainage divide ponds could be created within restoration sites after the appropriate elevations have been reached (i.e., return to the site some number of years after construction and do some follow-up construction work). Though restoration strategies have yet to be developed, what they might entail could be determined through experiments in any existing tidal marsh with appropriate elevations.

Under the dredged sediment/backfill placement restoration model, ponds could be built at the outset by creating the required elevations, containment features, and substrate with the dredged sediment or backfill. Strategies to achieve ponds in this manner have been proposed, but not yet field tested.

Restoration projects can incorporate some flexibility with respect to channel density and size within some constraints. These constraints include providing adequate amount of tidal circulation throughout a restoration site and the natural processes of sediment transport that form and maintain tidal marsh channels through erosion and deposition. Natural marshes exhibit a wide range of combinations of channel density (defined hydrologically as the total length of channel per unit of marsh surface area [though an ecologist might be interested in the total surface area of channel per marsh surface area or the amount of channel edge]) and channel size. For example, Rush Ranch in Suisun Marsh comprises relatively few channels (i.e., low channel density), but these channels are generally fairly large, whereas Petaluma Marsh comprises numerous channels (i.e., high channel density), but these channels are generally not as large. These differences may have to do with several factors that are specific to regions with the Estuary, such as tidal range, degree of riverine influence, and salinity.

10. What is the relationship between natural maintenance of tidal channels large and small, including mudflats along the edges of large channels, and the tidal prism provided by tidal marsh restoration?

As pointed out elsewhere, the form of tidal marsh channels in plan view, profile, or cross section is a result of interactions among the erosional and depositional actions of the flowing tides. In a very general way, channel cross-sectional area increases with tidal prism. For example, channels get larger downstream, toward their tidal source. For smaller channels, say first-order to third-order, the increase in channel size is due more to gains in depth than width. For larger channels, the increase in channel size is due more to width than depth. It is therefore also commonly observed that smaller tidal marsh channels tend to be u-shaped in cross section, whereas the larger channels are more v-shaped. In other words, the banks of the larger channels are less steep. The large channels, therefore, tend to have more area of mudflats, despite the fact that the smaller channels are more likely to completely de-water at low tide.

The relationship between channel form and the tidal prism of the channel has been described for some channels in some areas of the Estuary. The relationship is better described for channels of small to moderate size in saline marshlands. The relationship is not well described for very large channels in any area, or for any size channels in freshwater areas. Historical soundings in tidal marsh channels could be assembled to help describe the relationship between channel size and tidal prism for very large channels, but original field work would be required to explore the relationship for smaller channels in non-saline areas.

A rather crude prediction of the relationship between the size of a tidal marsh restoration project and the amount of channel-associated mudflat could be developed based upon an assumed height of the project plain relative to a local tidal datum, the estimated area of the plain, the expected equilibrium form of the channel in cross section (i.e., the slope of the banks and channel depth relative to the tides) as evidenced by existing data, and the expected plan form (i.e., sinuousity and length) or density (area of channel per unit area of marsh plain) as evidenced by existing data. Another approach would be to quantify the mudflat associated with different size natural marshes as historically mapped by the U.S. Coast Survey.

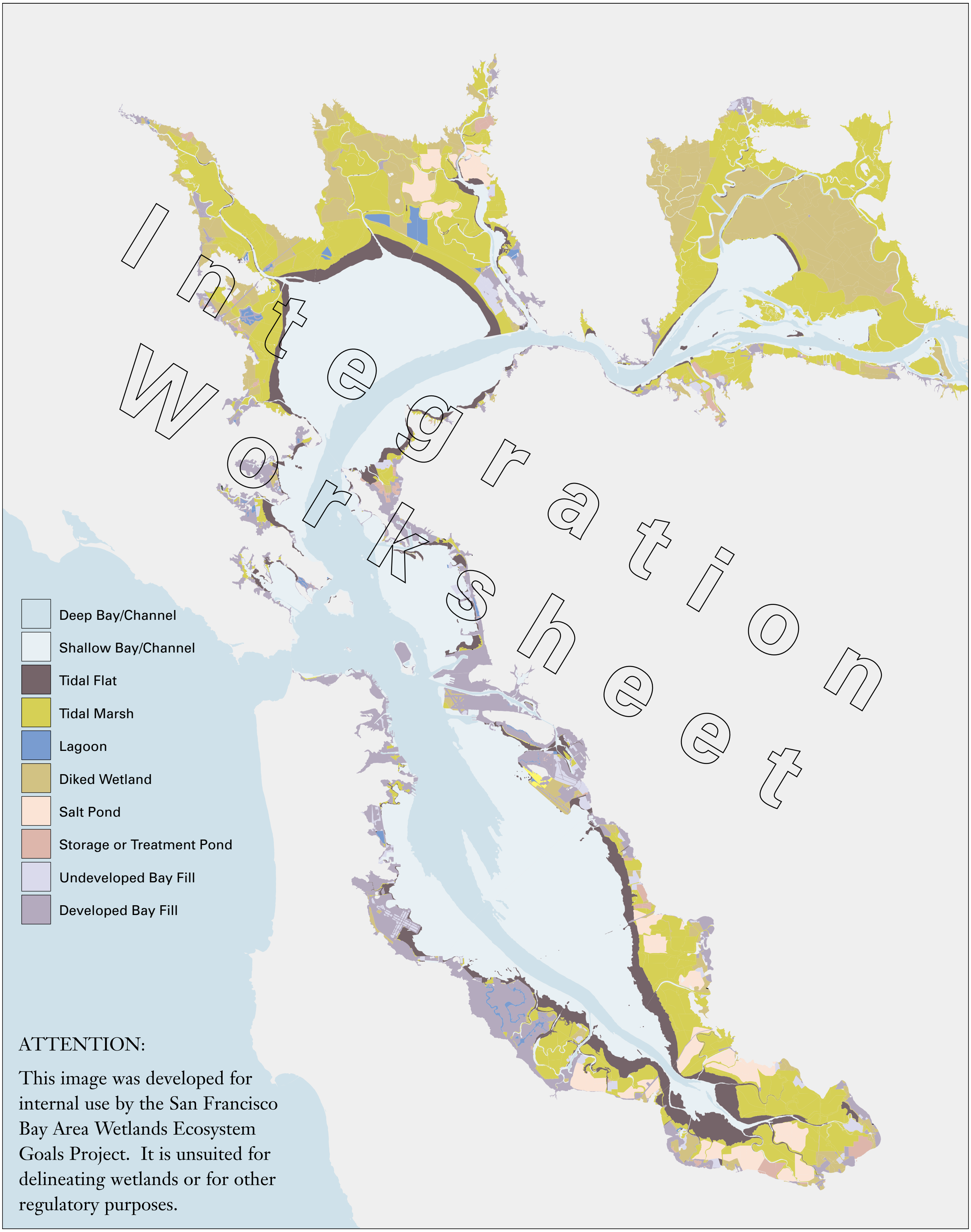
11. What are the local physical controls, including soil characteristics, for seasonal ponding on diked baylands, including farm lands and ranch lands?

The primary control is the distribution and abundance of surface water, as affected by rainfall, levee weep or leakage, groundwater discharge, and on-site water management. For diked baylands, it is generally true that surface water exists only until it infiltrates the soil, or while the groundwater rises above the soil surface. There are variations within and among sites due to the interactions among weather (timing, intensity, and duration of rainfall, evapotranspiration), soil conditions (depth, field capacity and related parameters), depth to groundwater, distance to tidal influence and/or uplands, and water management practices (i.e., types and conditions of water control structures and their methods and timing of use). However, a few basic patterns are self-evident. These are:

- For any given set of weather conditions, the amount of seasonal wetlands tends to be inversely related to the amount of drainage.
- The lack of drainage, or the amount of management to provide drainage, tends to be related to the amount of ground subsidence. Simply stated, lower land is more difficult to drain. Therefore, the potential for seasonal wetlands increases with subsidence.
- Subsidence tends to be greater for organic soils than mineral soils, and greater for deep soils. The most subsidence is observed for deep peaty soils.
- Within the diked historical marshlands, the mosaic of organic and mineral soils reflects the historical distribution of tidal marsh channels, with the organic faction increasing with distance from historical channel banks.
- Within a site, in the absence of land management practices that level the land surface, the mosaic of organic and mineral soils produces differential rates of subsidence, which in turn produce topography, and this topography helps control the distribution of surface water and seasonal wetlands.
- In diked baylands, seasonal wetlands are mainly due to local infiltration of irrigation water or rain that causes the near-surface groundwater level to rise above the ground surface. The influence of the tides and groundwater from hillsides tends to be restricted to areas very near the Bay, perimeter levees, or adjacent to steep upland terrain.

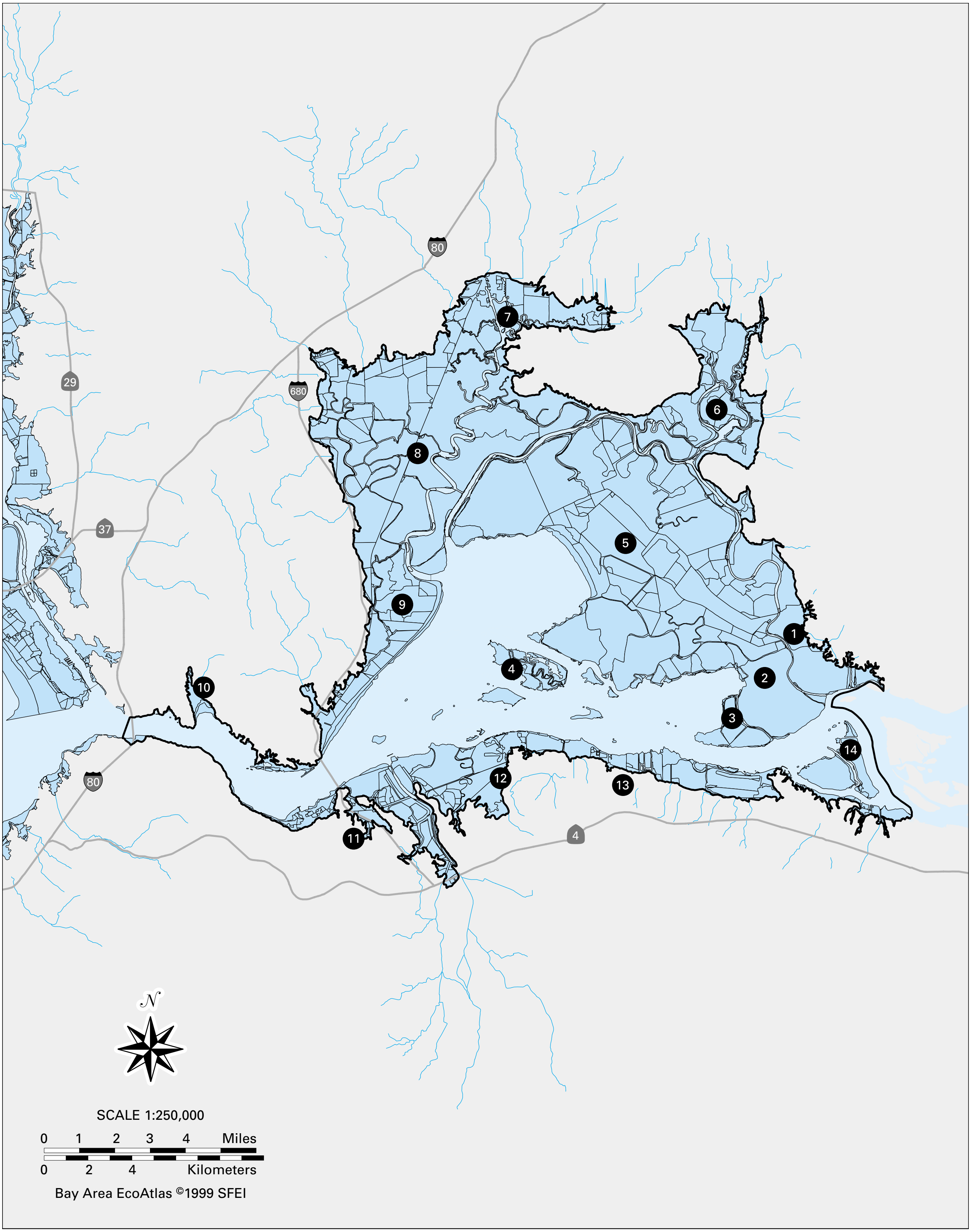
Integration Map

This map, also referred to as the integration worksheet, represents one possible future arrangement of bayland habitats. It was used to derive the habitat acreage recommendations presented in Chapter 5.


Integration Worksheet
Deep Bay/Channel
Shallow Bay/Channel
Tidal Flat
Tidal Marsh
Lagoon
Diked Wetland
Salt Pond
Storage or Treatment Pond
Undeveloped Bay Fill
Developed Bay Fill
ATTENTION:
This image was developed for internal use by the San Francisco Bay Area Wetlands Ecosystem Goals Project. It is unsuited for delineating wetlands or for other regulatory purposes.

Potential Restoration Sites and Projects

Suisun Potential Restoration Sites and Projects



Potential Restoration Sites and Projects

The sites listed in this table and shown on the accompanying figures have potential for habitat improvement. Some of these improvements would be simple and relatively inexpensive to effect. Others would be more complicated and costly. This list does not include all possible habitat improvement sites, but it is offered as a starting point for those seeking to undertake habitat projects.

Site # Recommendation

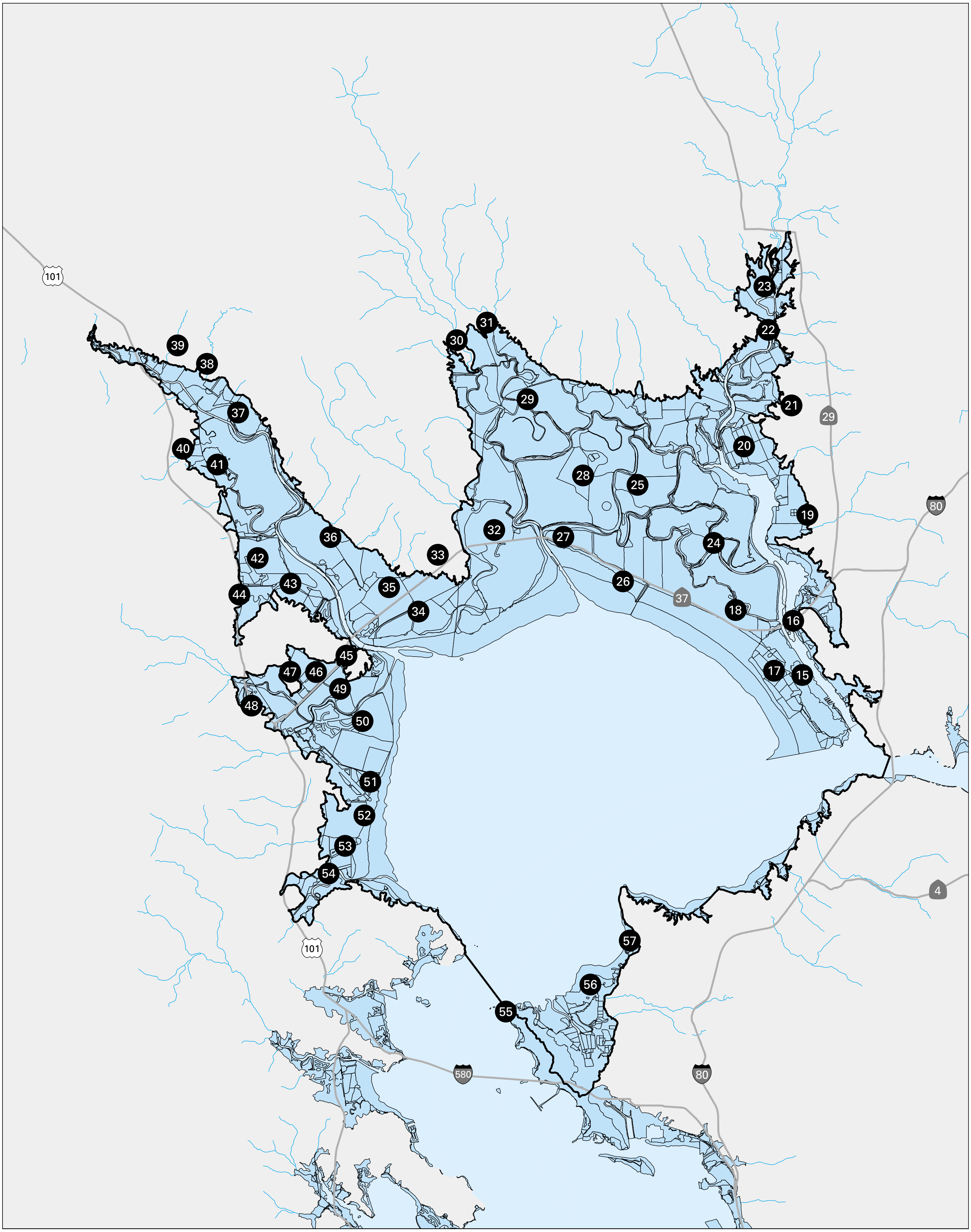
Suisun Subregion

1. **Montezuma Slough:** Restore to tidal marsh a wide band along the eastern side of the Slough from Sacramento/San Joaquin rivers to Nurse Slough. Provide a natural transition to adjacent uplands, and protect vernal pools and other seasonal wetlands.
2. **Roaring River Area:** Restore tidal marsh south of Roaring River on Simmons, Wheeler, and Van Sickle islands, especially to enhance fish habitat.
3. **Chipps Island:** Restore the muted tidal area to tidal marsh.
4. **Ryer and Roe Islands:** Protect existing tidal marsh and enhance tidal action.
5. **Grizzly Island Area:** Enhance managed marsh to improve waterfowl habitat.
6. **Nurse Slough Area:** Restore a large area on both sides of the Slough to tidal marsh, and provide natural transitions to adjacent uplands. Provide protective buffers on Potrero Hills and other adjacent lands, and protect vernal pools, including those on the north of Potrero Hills.
7. **Suisun and Hill Slough Area:** Restore a large area on the north and west sides of Potrero Hills to tidal marsh, including some areas west of the railroad tracks. Provide a natural transition to uplands and buffers.
8. **Goodyear Slough to Boynton Slough:** Provide a tidal marsh corridor connecting the new tidal marsh in the Suisun/Hill slough area to the new tidal marsh in the Morrow Island area. Provide and protect natural transitions to adjacent uplands.
9. **Morrow Island Area:** Restore to tidal marsh a large, continuous band from the confluence of Goodyear Slough and Suisun Slough southward along Suisun Bay.
10. **Southampton Bay:** Protect existing tidal marsh, remove trash, and restore tidal marsh.
11. **I-680 to Pacheco Slough:** Restore diked marshes to full tidal action.
12. **Point Edith and Hastings Slough Area:** Restore a large area of existing diked marsh to tidal marsh.
13. **Port Chicago to Pittsburg Power Plant:** Enhance tidal action and improve water management in existing marshes. Enhance least tern nesting site at the power plant. Protect and expand adjacent buffers where possible.
14. **Winter Island:** Enhance water management.

North Bay Subregion

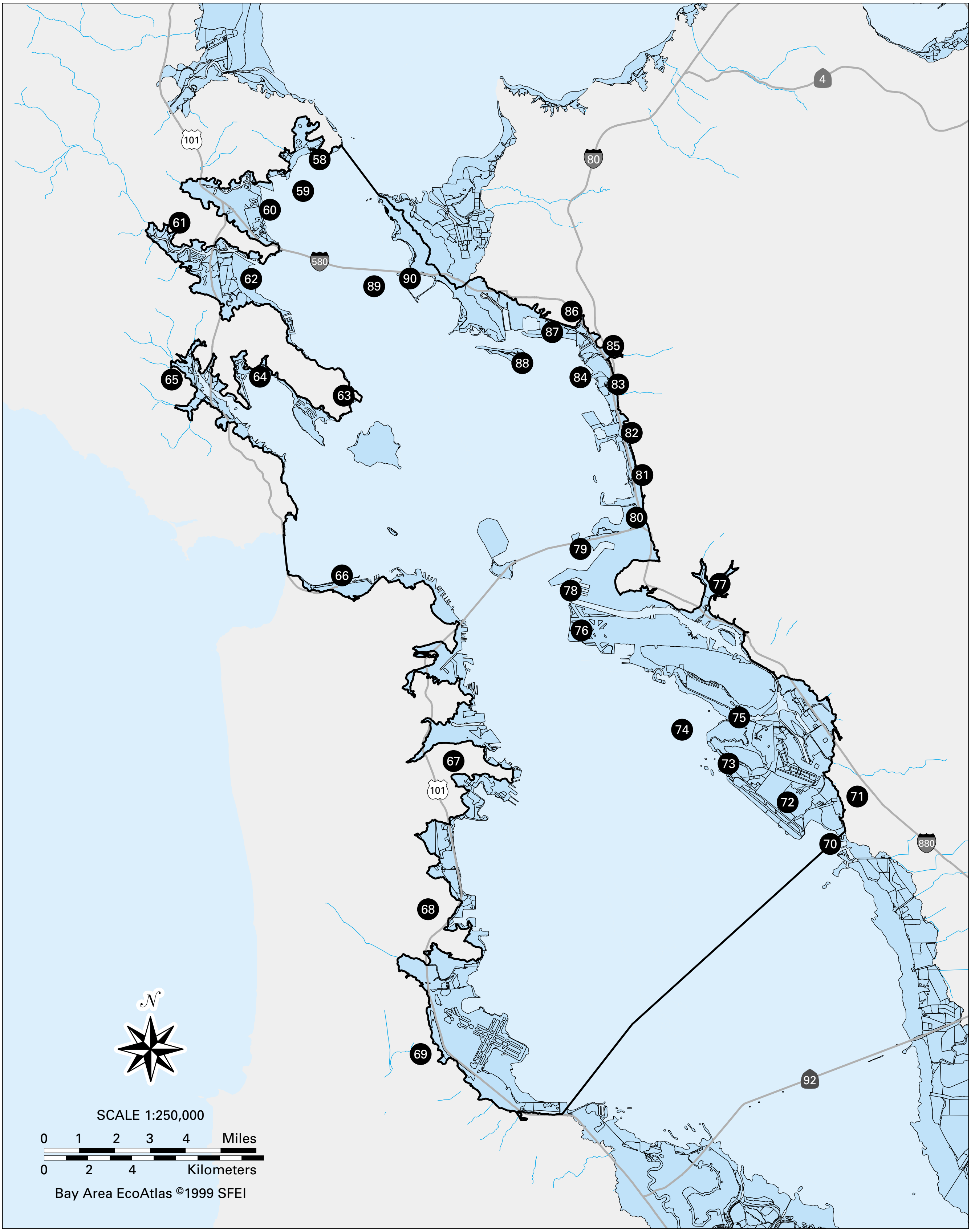
15. **Mare Island Strait:** Enhance habitat for Mason's lilaeopsis.
16. **River Park:** Restore tidal marsh and enhance seasonal pond habitat.
17. **Mare Island:** Enhance seasonal ponding at the dredged material disposal ponds.
18. **Cullinan Ranch:** Restore to tidal marsh.
19. **American Canyon:** Restore tidal marsh and enhance and protect seasonal pond habitat in adjacent uplands.
20. **Crystallizers:** Manage as salt panne and open water habitat.
21. **Green Island Area:** Enhance and protect seasonal pond habitat.
22. **Napa River at Baylands Boundary:** Restore tidal marsh and enhance seasonal ponds at several sites on west side.
23. **South Napa:** Restore tidal marsh and enhance and protect seasonal pond habitat.
24. **West Side of Napa River:** Restore a large area of inactive salt ponds to tidal marsh.
25. **Western Area of Inactive Salt Ponds:** Manage a large complex as salt pond/open water habitat.
26. **Salt Pond Intake Channel:** Remove spoil berm on both sides of channel to enhance tidal marsh habitat.

North Bay Potential Restoration Sites and Projects



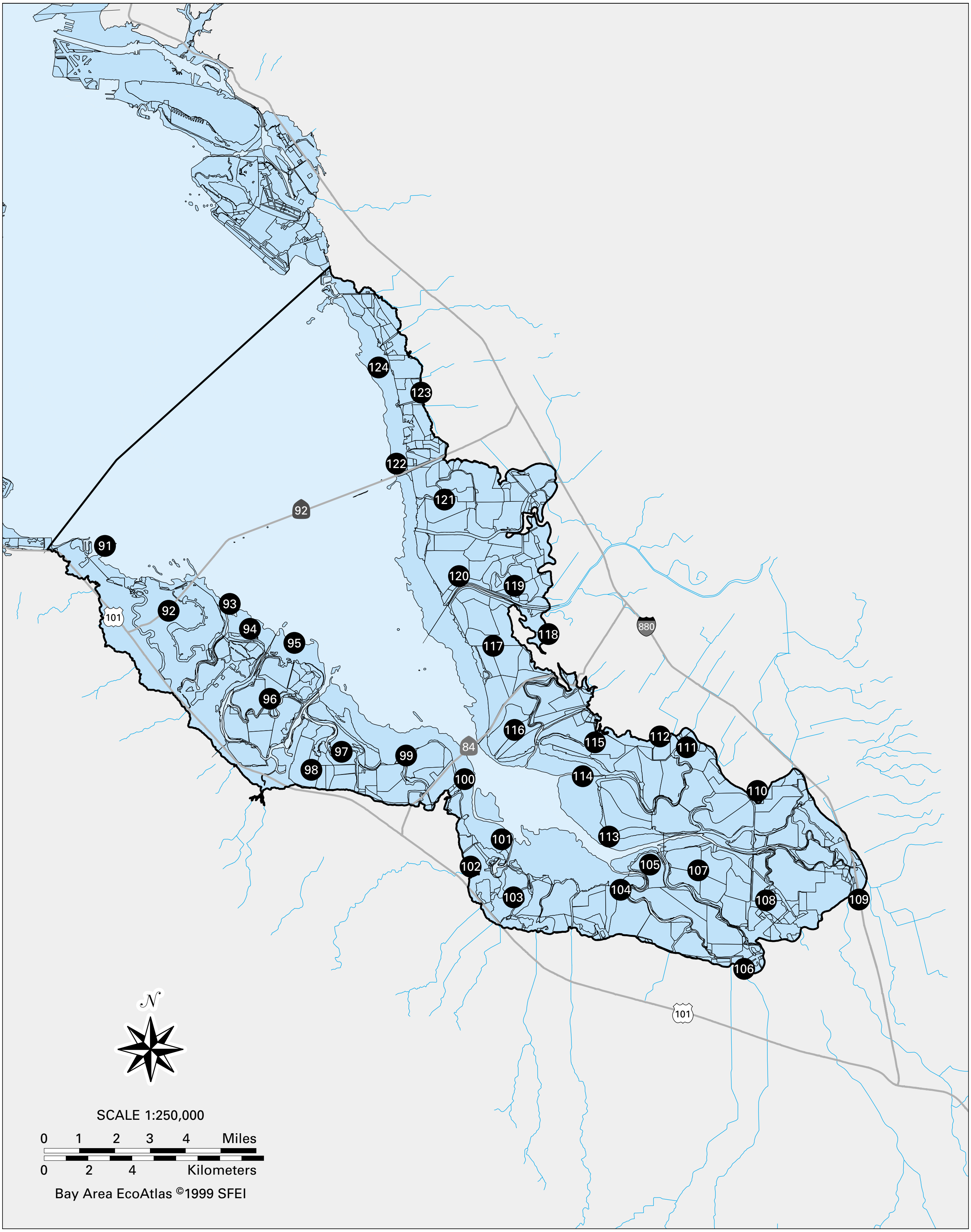
Site #	Recommendation
North Bay (continued)	
27.	**West End/Deetjen's Duck Clubs:** Enhance management for shorebirds and waterfowl.
28.	**Skaggs Island:** Restore portion west of Skaggs Island Road to tidal marsh and enhance seasonal pond habitat on remainder of Island.
29.	**Camps Area:** Restore all or part of Camp 3 to tidal marsh. Enhance seasonal pond habitat on Camps 2, 4, and 5.
30.	**Sonoma Creek Upstream From Camp 2:** Restore tidal marsh on west side of railroad tracks.
31.	**Schellville Area:** Enhance riparian vegetation along Sonoma Creek and seasonal pond habitat in grazed lands.
32.	**West of Sonoma Creek:** Enhance seasonal pond habitat on lands north of Highway 37. Restore to tidal marsh lands south of Highway 37. Protect and restore Tolay Creek.
33.	**West of Sears Point:** Manage existing stock ponds and adjacent lands to protect red-legged frog.
34.	**Tolay Creek to Petaluma River:** Restore the area south of railroad tracks to tidal marsh.
35.	**Highway 37:** Enhance seasonal pond habitat on both sides of Highway 37.
36.	**East Side of Petaluma River:** Restore a large area between the River and the edge of the baylands to tidal marsh, and ensure natural transition into the three small watersheds. Also include some seasonal wetlands.
37.	**Cloudy Bend:** Enhance for seasonal ponds.
38.	**City of Petaluma Sewage Treatment Facility:** Restore tidal marsh on one-half of site and ensure mix of seasonal ponds and marsh on remainder.
39.	**City of Petaluma Marsh Restoration Site:** Enhance the dredged material disposal site with seasonal ponds.
40.	**San Antonio West of Railroad Tracks:** Restore the area adjacent to San Antonio Creek to tidal marsh, with enhanced transition to seasonal ponds.
41.	**North of Redwood Landfill:** Restore tidal marsh and ensure natural tidal marsh transition to upland. Include some seasonal wetlands.
42.	**Gnoss Airfield Area:** Enhance with seasonal wetlands the areas surrounding the airport complex.
43.	**West Side of Petaluma River:** Restore the Central and Western Lowlands at Bahia to tidal marsh.
44.	**Rush Creek and Cemetary Marshes:** Improve water management and water quality in the managed marshes.
45.	**Black Point to Bahia:** Protect the unique oak woodland and mixed evergreen forest and hillslope, and the upland/wetland ecotone at base of slopes.
46.	**Highway 101 to Black Point:** Enhance with seasonal ponds the areas on both sides of Highway 37.
47.	**Deer Island:** Protect oak woodland and mixed hardwood forest.
48.	**Hanna Ranch:** Protect oak woodland on hill near Highway 101.
49.	**North Side of Novato Creek:** Restore the area from the bayfront to Highway 101 to tidal marsh, emphasizing restoration upstream of Highway 37 between Deer Island and Novato Creek.
50.	**Bel Marin Keys:** Restore a wide band of tidal marsh along bayfront, and enhance seasonal ponds on remaining areas.
51.	**Hamilton Field:** Restore primarily to tidal marsh and restore/create an upland buffer with managed seasonal ponds.
52.	**Silveira and Saint Vincent's:** Restore a wide band of tidal marsh on about one-half of the area between railroad tracks and bayfront. Protect and enhance seasonal wetlands and transitional uplands between this new marsh and the railroad tracks. Enhance seasonal ponding west of the railroad tracks and protect seasonal wetlands and oaks.
53.	**Gallinas Creek Wastewater Facility:** Enhance seasonal ponding and transitional uplands north and south of the treatment plant.
54.	**Gallinas Creek:** Restore tidal marsh along north side.
55.	**San Pablo Peninsula:** Protect lagoon on east side of the Peninsula.
56.	**Richmond Landfill:** Restore tidal marsh corridor along eastern edge of landfill to connect Wildcat Marsh and San Pablo Marsh.
57.	**Bruener Property:** Protect and restore to tidal marsh with a connection to Giant Marsh, and restore vernal pools in transitional area.

Central Bay Potential Restoration Sites and Projects



Site #	Recommendation
Central Bay Subregion	
58.	**McNear Quarry:** Restore diked marsh to tidal marsh.
59.	**East and West Marin Islands:** Enhance for colonial nesting birds.
60.	**San Rafael Marshes:** Protect, enhance with seasonal ponds, and improve upland transition area.
61.	**Corte Madera Creek:** Eradicate non-native cordgrass and protect adjacent seasonal wetlands.
62.	**Corte Madera Marshes:** Establish upland buffers on periphery, and enhance seasonal ponding in upland transition zones. Stabilize the shoreline to protect habitat for harbor seal haul-out and pupping.
63.	**Tiburon Peninsula:** Preserve and enhance the small marsh at the end of the Peninsula (Keil Pond, near Bluff Point) for the benefit of red-legged frog.
64.	**Strawberry Spit Area:** Enhance as a haul-out site for harbor seals by reducing human disturbance and protect and enhance habitats on nearby islands.
65.	**Richardson Bay:** Restore and enhance fringing marsh along northwest edge for Point Reyes bird's-beak.
66.	**Crissy Field:** Restore tidal marsh and sand dune habitats.
67.	**San Francisco Shoreline, from China Basin south:** Restore tidal marshes, especially at China Basin, Hunters Point, and along Yosemite Creek, using sandy berms and barrier beaches. Reestablish California sea-blite and associated high salt marsh plant species on sandy edges.
68.	**Oyster Cove/Shearwater:** Restore tidal marsh in subtidal area.
69.	**West of Bayshore Parcel near San Francisco Airport:** Expand and enhance the small existing freshwater marsh for the benefit of the San Francisco garter snake and red-legged frog. Protect adjacent upland habitat.
70.	**San Leandro Marina:** Protect small island at entrance to marina for roosting waterbirds and California sea-blite and other plants.
71.	**Oyster Bay Regional Park:** Enhance burrowing owl habitat.
72.	**Oakland Airport:** Protect and enhance seasonal ponds and snowy plover and least tern nesting habitat.
73.	**Bay Farm Island:** Enhance least tern and snowy plover habitat.
74.	**S.F. Bay near Bay Farm Island:** Protect and enhance existing eelgrass beds.
75.	**Alameda Island:** Restore beach dune and marsh in Elsie Roemer Sanctuary. Eradicate smooth cordgrass.
76.	**Alameda Point (formerly Naval Air Station):** Enhance and protect suitable habitat for least tern, snowy plover, brown pelican, and other species. Protect Breakwater Island from human disturbance.
77.	**Lake Merritt:** Enhance habitat value of lake and slough channel by improving tidal action and restoring tidal marsh, especially along both sides of channel that connect the lake to the Estuary. Consider other shoreline enhancements, including moving or removing public walkways around the lake, as opportunities arise. Reestablish tributary streams and restore riparian habitat.
78.	**Oakland Middle Harbor:** Restore shallow bay, intertidal mudflat, and eelgrass beds.
79.	**Oakland Outer Harbor:** Protect the shorebird roosting sites along the shoreline on south side of toll plaza area.
80.	**Emeryville Crescent:** Protect and enhance shorebird roosting sites by removing debris and restoring native vegetation.
81.	**Berkeley Aquatic Park:** Expand and enhance wetland habitat.
82.	**Berkeley Meadows:** Enhance area between Marina and the freeway with seasonal ponds, provided the fill is of suitable quality.
83.	**Codornices Creek:** Expand salt marsh at mouth of creek.
84.	**Albany Landfill Peninsula:** Enhance roosting habitat at tip of landfill and restore pocket beach on south edge of Peninsula.
85.	**Albany Crescent:** Restore tidal marsh near Central Ave. and create shorebird roosting habitats.

South Bay Potential Restoration Sites and Projects



Site #	Recommendation
Central Bay (continued)	
86.	**Liquid Gold Site:** Restore tidal marsh to connect Hoffman Marsh with the rest of the shoreline.
87.	**Richmond Field Station Marsh:** Clean up (may include remediation of contaminated sediments) and enhance tidal marsh and seasonal wetlands.
88.	**Brooks Island:** Preserve and enhance eroding beach.
89.	**Red Rock:** Protect as seabird and egret roosting habitat and harbor seal haul-out.
90.	**Castro Rocks:** Protect as important haul-out and pupping site for harbor seals and daytime roost for cormorants.
South Bay Subregion	
91.	**Coyote Point Marina:** Restore the dredged material disposal lagoons to tidal marsh.
92.	**Foster City:** Consider improvements in the Foster City canal system that would enhance fish and wildlife habitat.
93.	**Foster City and Redwood Shores Peninsula:** Enhance oyster shell ridges in supratidal zone.
94.	**Redwood Shores Peninsula:** Protect Bird Island from human disturbance, restore tidal marsh in Area H, and enhance diked marsh near radio tower and around the sewage treatment plant. Also, enhance seasonal ponds on Redwood Shores Ecological Reserve.
95.	**Bair Island:** Enhance oyster shell ridges in intertidal zone.
96.	**Bair Island:** Restore Inner Bair, Middle Bair, and most of Outer Bair Island to tidal marsh.
97.	**Westpoint Slough:** Restore the salt ponds adjacent to the Slough to tidal marsh.
98.	**Crystallizer and Adjacent Salt Ponds:** Manage as saline pond habitat.
99.	**Ravenswood Point:** Provide a continuous tidal marsh corridor along bayfront, from Greco Island to Dumbarton Bridge. Manage remainder of area as saline pond habitat.
100.	**Pond Adjacent to Dumbarton Bridge:** Protect and manage as saline pond habitat.
101.	**Cooley Landing to Charleston Slough:** Provide a continuous tidal marsh corridor along bayfront, provide more and wider upland buffers, and improve management to reduce human intrusion and predators.
102.	**San Francisquito Creek:** Reestablish native vegetation in riparian corridor.
103.	**Palo Alto Flood Control Basin:** Enhance management to improve diked marsh habitat.
104.	**Charleston Slough to Alviso Slough:** Restore a continuous band of tidal marsh along bayshore and enhance management of several ponds to create one or two salt pond complexes for shorebirds and waterfowl.
105.	**Knapp Parcel:** Restore to tidal marsh.
106.	**Sunnyvale Baylands:** Enhance seasonal wetlands and burrowing owl habitat.
107.	**Alviso Slough to Mud Slough:** Establish a large managed saline pond complex and restore the remainder of the area to tidal marsh.
108.	**New Chicago Marsh:** Improve habitat through better water management or restore to tidal marsh.
109.	**Coyote Creek:** Enhance and reestablish native vegetation in riparian corridor.
110.	**Mud Slough to Albrae Slough:** Restore to tidal marsh, emphasizing a natural transition between tidal marsh and grassland/vernal pool complex. Establish buffer zone to protect this area from disturbance from development in adjacent uplands. Enhance vernal pools in Warm Springs area.
111.	**Mowry Slough:** Protect and enhance the tidal marsh/upland transition at the upper end of Mowry Slough.
112.	**Pintail Duck Club:** Restore tidal influence, reestablish tidal marsh/upland transition, and improve seasonal wetlands.
113.	**Calaveras Point:** Protect tidal marsh for well established population of salt marsh harvest mouse.
114.	**Lower Mowry Slough:** Protect tidal marsh for well-established population of salt marsh harvest mouse and for harbor seal haul-out.
115.	**Mowry Slough to Newark Slough:** Manage a salt pond complex for shorebirds and waterfowl near and including the crystallizer complex, and restore the remaining area to tidal marsh.

Site #	Recommendation
South Bay (continued)	
116.	**Dumbarton Point to Alameda Flood Control Channel:** Establish a large complex of managed saline ponds and restore the remainder of the area to tidal marsh.
117.	**Coyote Hills, west side:** Restore large area at the base of the Hills to tidal marsh and enhance tidal marsh/upland transition.
118.	**Coyote Hill, east side:** Protect, enhance, and expand muted tidal areas with improved water management. Protect and enhance existing willow grove and seasonal wetlands.
119.	**Turk Island:** Establish a large complex of managed saline ponds.
120.	**Alameda Flood Control Marshes:** Enhance and improve management to support wildlife, including small mammals.
121.	**Old Alameda Creek to Highway 92:** Establish a large complex of managed saline ponds in the Baumberg Tract area, including the southern Oliver Brother's ponds. Create shallow pannes for snowy plover nesting. Restore remainder of site to tidal marsh.
122.	**Northern Oliver Brothers Salt Ponds:** Establish a small complex of managed saline ponds adjacent to and north of Highway 92. Create shallow pannes for snowy plover nesting.
123.	**West Winton Avenue Landfill Area:** Establish natural salt ponds in the diked marshes adjacent to the landfill, and in the old oxidation pond to the south.
124.	**San Leandro Shoreline Area:** Investigate the potential for restoring sandy berms and barrier beach along the shoreline to facilitate reintroduction of California sea-blite and other associated high marsh plant species.

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Back cover
Aerial photography: Joice Island, 1998, Herb Lingl/Aerial Archives
Inset: Diseño, San Leandro, 1840, Bancroft Library
Topographical map: Petaluma River, 1860, US Coast Survey

Front cover
Aerial photography: Turk Island, 1997, and Bair Island, 1999, Herb Lingl/Aerial Archives
Inset drawing: "East Bay shoreline, still there," 1997, Elise Brewster

Teams of Bay Area environmental scientists have assessed the past and present conditions of the baylands ecosystem and recommended ways to improve its ecological health. This report presents the Baylands Ecosystem Goals.