Introduced Tidal Marsh Plants in the San Francisco Estuary

Regional Distribution and Priorities for Control

November 1998

Robin Grossinger,
Janice Alexander,
Andrew N. Cohen,
and
Joshua N. Collins

San Francisco Estuary Institute

Introduced Tidal Marsh Plants in the San Francisco Estuary

Regional Distribution and Priorities for Control

By

Robin Grossinger,
Janice Alexander,
Andrew N. Cohen,
and
Joshua N. Collins

San Francisco Estuary Institute
1325 South 46th Street
Richmond, CA 94804

This report was funded by a grant from the
CALFED Category III Steering Committee
administered by the
California Urban Water Agencies

November 1998

Upper Photograph
Aerial view of young marshland at Cogswell Marsh, Hayward, California 1996. The Atlantic cordgrass *Spartina alterniflora* (bright orange) is the primary plant colonizing the tidal flats here. Photograph by Pacific Aerial Surveys for the East Bay Regional Park District.

Lower Photograph
Native and nonindigenous cordgrasses on the north shore of Bay Farm Island, Alameda, California (October 1993). The nonindigenous *Spartina alterniflora* is the taller and darker plant in the background, which outcompetes the native S. *foliosa* (the shorter and lighter plant in the foreground) and grows further onto the mudflats. Between November 1996 and May 1998, S. *alterniflora* replaced the remaining S. *foliosa* along this shore. Photograph by Andrew N. Cohen.

Acknowledgments

We would like to thank the many people who contributed their time and knowledge to this effort:

The participants in the September 1997 Introduced Tidal Marsh Plants Workshop and everyone who participated in the survey (listed in Appendix 2), for contributing their expertise to the regional prioritization effort and the distribution maps;

Roger Byrne of UC Berkeley, Paul Jones of the Environmental Protection Agency Region IX, and Marcel Rejmánek of UC Davis for their presentations at the Workshop, which placed San Francisco Estuary exotic species issues in a larger context;

Michael May of the San Francisco Estuary Institute and Michael Josselyn of San Francisco State University for sharing their knowledge of the distributions of *Lepidium latifolium* and *Spartina*;

Peter Baye of the U.S. Fish and Wildlife Service for sharing his enthusiasm and expertise, and his willingness to answer our many questions about exotic marsh plants;

Don Strong of UC Davis/Bodega Marine Lab and Curt Daehler of the University of Hawai'i for stimulating comments and discussions on *Spartina* distribution and other topics;

Brenda Grewell of the Department of Water Resources, Joy Albertson of the San Francisco Bay National Wildlife Refuge, and Debra Smith of the East Bay Regional Parks District for sharing their expertise on the marshes in the Estuary that they study and manage;

Janie Civille, *Spartina* Program Manager for the State of Washington, for showing us (in Willapa Bay) what those marshes might become, if *S. alterniflora* has its way;

Zoltan Der and Christina Wong of San Francisco Estuary Institute for their assistance in developing the GIS maps and databases;

Our reviewers, especially Rick Sitts of the Metropolitan Water District of Southern California, for useful comments on the manuscript, and Marcel Rejmanek, for setting us straight on matters of plant taxonomy and biology; and

Peter Jacobsen of the Metropolitan Water District for providing administrative guidance for the project.

We especially wish to thank the CALFED Category III Steering Committee, and the CALFED contributing agencies, for funding this study.

Copies of this report may be obtained from the San Francisco Estuary Institute: SFEI, 1325 South 46th St., Richmond, CA 94804; (510) 231-9539; www.sfei.org

TABLE OF CONTENTS

INTRODUCTION

The San Francisco Estuary Institute (SFEI) received funding in 1997 from Category III of CALFED to assess priorities for the control of introduced tidal marsh plants in the San Francisco Estuary. Several control efforts are underway, planned, or being considered for a variety of introduced plant species, involving different levels of cost, potential for success, and risk of harmful side effects. Because achieving successful control of introduced plants that are distributed across public and private lands will require a regional effort, we endeavored (1) to determine which are the most important species to control and (2) to identify their current and potential locations. Additionally, we assessed research needs to address introduced marsh plant issues. This report details the steps taken and results achieved towards these goals for the management of introduced tidal marsh plants in the Estuary.

Project Goals

1. *Develop an approach to prioritize control efforts for introduced tidal marsh plants.*
2. *Prioritize key species for control.*
3. *Create distribution maps for the priority species.*
4. *Assess the potential future range of these plants and identify needed research.*

METHODS

***Prioritization*:** We prioritized control needs in four steps: (1) we surveyed local experts to gather relevant information; (2) we used this information to initially set priorities, using a number of different approaches to weight and combine the information; (3) we convened a workshop of regional experts to review and recommend amendments to the initial prioritization; and (4) we produced a draft final prioritization, which was further reviewed by several of the local experts. The survey and workshop are described in more detail below.

Current Distribution: We obtained information on the distribution within the Estuary of the priority plants from published reports, herbaria, information from local experts, and our field observations. We acquired much of the information from local experts in a mapping exercise at the workshop. We entered the information in the Bay Area EcoAtlas Geographic Information System (GIS) database, which we used to produce the maps for this report.

Potential Distribution: We assessed the potential distribution of priority plants based upon their known distributions relative to tidal elevation and salinity. We obtained this information from published reports and from discussions with researchers familiar with the distribution of these plants in the Estuary and other settings. These data are presented in narrative form with reference to the regional maps of existing wetland habitats.

Plant Descriptions: To supplement the prioritization and distribution data, we assembled information on the ecology and invasion history of the priority plant species, and efforts to-date for their control, based upon a literature review, information from local experts, and our field observations.

Survey

We designed a direct-mail survey (Appendix 1) to gather local experts' knowledge about the distribution and abundance of introduced marsh plants in the Estuary, and about factors relevant to the prioritization of control efforts. We created an initial list of 17 species reported within the tidal reaches of the Estuary, and asked survey recipients to add additional species of concern. The survey collected information on the abundance of these species within subregions defined by existing regional wetlands planning efforts (i.e., the San Francisco Bay Area Wetlands Ecosystem Goals Project, CALFED, and IEP), and about the level of concern for each species with regard to nine aspects of introduced plant impacts, including their potential spread, impacts, and factors related to control efforts.

We conducted the survey in September and October 1997. We asked the initial survey recipients to identify additional people who should receive the survey. Appendix 2 provides the complete list of survey recipients.

Workshop

We conducted a workshop on introduced marsh plant prioritization and mapping in December 1997. All survey recipients were invited, and there were 33 participants. We suggested some initial prioritization lists as starting points for developing a consensus list of the plants of highest concern and for developing a classification methodology.

Prioritization Session

Prior to and during the workshop, we worked with regional plant experts to develop a number of different methodologies for assessing control priorities. Given the lack of published data on most of the concerns affecting the determination of priorities, we decided that assessment of these concerns would be best done by the professional ecologists and land managers currently working in these habitats.

We determined that the best approach to creating an integrated assessment of priorities for control was two-phased: (1) compilation and synthesis of survey responses and (2) review and revision by the wetlands community of expertise at the workshop. This resulted in a prioritization list that was well-supported by the workshop attendees.

Mapping Session

We coordinated a group mapping exercise using 1:55,000 scale basemaps. We used the Bay Area EcoAtlas, Version 1.50 prerelease 4 (San Francisco Estuary Institute) for Bay Area subregions and the Central Valley Wetland and Riparian GIS (California Department of Fish and Game) for Delta subregions. We produced these maps with only the tidal areas colored to highlight the habitats of the priority plant species. Sites of known populations of the introduced marsh plants were marked with a color-coded “X” and labeled with the scientist’s initials.

GIS Process

Using the maps produced during the workshop, we created an initial point coverage in ArcInfo, using “heads-up” digitizing. Where no discrete point was identified (e.g. hatchmarks, shading, or written descriptions were provided instead), points were created to represent the data as closely as possible, while maintaining the same general scale of detail as in other parts of the map. We gathered additional data from field observations, literature, and direct communication with field researchers.

We estimate that the accuracy of identified locations is within about 2000 feet. Site identification relied upon the expertise of the participating scientists. Where conflicting data were provided that we could not otherwise resolve, we used the most recent observation. Where conflicts could not be resolved, data were categorized with a “low” certainty of presence. Some misidentification of plants may have occurred (e.g. *Lepidium latifolium* mistaken for *Cardaria draba*), but, given the expertise of the participants, the extent of classification error is likely low. Errors of omission are more likely, as expertise in mapping populations was not equally distributed through the Estuary, resulting in less information for the Delta, and for some smaller areas within the Estuary.

RESULTS

Prioritization

The results of the prioritization include a simple structure for classifying species of concern, and the current placement of species into these classes. The structure for classifying concerns may change as it is used. The classification presented here is based upon research and communications in the Winter and Spring of 1997/1998. We recommend periodic reassessment of these priorities, as conditions change and new information becomes available.

Structure of Priority Plant Lists
We chose two parameters of classification, which recognize both basic geography and the need for coordinated regional actions, to address introduced tidal marsh plant concerns. First, three major classes of concern were defined, each associated with differing scopes of recommended actions: Key Species of Concern, Potential Species of Concern, and Watch List Species. Second, we recognized that a grouping of concerns on a scale smaller than the entire Estuary might be important. This subregional classification should increase the local usefulness of the prioritization while addressing the region as a whole.

We initially collected mapping and prioritization data on the basis of the major subregions, but found that the distinctions in distribution and potential concern observed between these subregions were generally correlated with subregional differences in tidal salinity. As a result, we separately defined species of concern for Fresh to Brackish Tidal Marsh and for Brackish to Saline Tidal Marsh. Regional or local salinity gradients exist in all of the major subregions that define general plant associations, although there is substantial overlap among salinity zones.

Relationship to Other Prioritization Efforts
We also compared results from this prioritization to other introduced plant lists. Many of the plants recognized as priorities by the Bay Area wetlands community are noted as statewide concerns as well. The California Exotic Pest Plant Council (CalEPPC) compiled "Exotic Pest Plants of Greatest Ecological Concern in California as of August 1996" based upon information gathered from members, other land managers, botanists, and published research. The CalEPPC effort addresses "plants that are serious problems in wildlands (e.g., natural areas that support native ecosystems, including national, state and local parks, ecological reserves, wildlife areas, national forests, BLM lands, etc.)" (CalEPPC 1996). We also compared these results to the California Department of Food and Agriculture (CDFA) List of Noxious Weeds, which is based on a formal review process (S. Schoenig, personal communication).

CalEPPC places introduced species into six categories:
(1) List A-1: Most invasive and damaging wildland pest plants, widespread.
(2) List A-2: Most invasive and damaging wildland pest plants, regional.
(3) List B: Wildland plants of lesser invasiveness.
(4) Red Alert: Species with potential to spread explosively; infestations currently restricted in size.
(5) Need more information.
(6) Considered but not listed.

CDFA places noxious weeds into three categories:

(1) List A: These species must be targeted for eradication or containment.
(2) List B: County Agricultural Commissioners can decide whether to target these species for eradication or containment in their jurisdictions.
(3) List C: Because these weeds are so widespread, no state or county-funded eradication or containment efforts are endorsed, except in nurseries or seed lots.

Results of our effort agree in major part with the CalEPPC classification, indicating substantial consensus within the community. CalEPPC and CDFA status are reported in the General Information section under each species. Coordination between statewide and more detailed local priorities will be important, particularly with regard to species (e.g., *Lepidium latifolium*, *Arundo donax*, *Carpobrotus edulis*) which affect both estuarine and adjacent freshwater or terrestrial ecosystems.

Priority Plants for Control

Through the survey and workshop, we compiled a prioritized list of 12 plant species (Table 1). Key Species of Concern are the species which should be the focus of research, monitoring, and control efforts. Potential Species of Concern include species which are not currently causing significant negative effects, but could do so in the future. For these reasons, both Key Species and Potential Species should be searched for and monitored. Watch List species are not of immediate concern within the tidal marshes, but should be monitored for increases in spread or effect.

Table 1. Control Priority of Introduced Tidal Marsh Plants in the San Francisco Estuary.

Fresh to Brackish Tidal Marsh	**Brackish to Saline Tidal Marsh**
Key Species of Concern	**Key Species of Concern**
Lepidium latifolium	*Spartina alterniflora*
	Spartina densiflora
Potential Species of Concern	**Potential Species of Concern**
Arundo donax	*Salsola soda*
	Spartina anglica
	Spartina patens
Watch List	**Watch List**
Carpobrotus edulis	*Carpobrotus edulis*
Cortaderia jubata	*Cortaderia jubata*
Cortaderia selloana	*Cortaderia selloana*
Iris pseudacorus	
Lythrum salicaria	

Distribution

The current distributions of Key and Potential Species of Concern are shown in Figures 3 through 10. Current and potential distributions are discussed in the sections below that describe the status of each plant. The general relationships of key physical factors in the environment to the distribution of marsh plants in the Estuary are discussed here.

Aqueous salinity and tidal elevation are the major correlates to the regional and local distribution of native plant species within the Estuary (Atwater *et al*. 1979). Intertidal habitats are distributed along (1) tidal elevation gradients, where tidal flats and low-, mid-, and high-elevation tidal marshes are found between Mean Lower Low Water (MLLW) and Mean Higher High Water (MHHW; Figure 1) and (2) salinity gradients, from saline to brackish to fresh tidal waters (Figure 2). As with native plants, these factors are the major physical determinants of the potential distribution of introduced plants.

Substantial literature documents the changes in plant community composition between saltier and fresher parts of the Estuary (Atwater *et al*. 1979; Harvey *et al*. 1977). Salinity gradients exist locally, associated with sites of freshwater input such as the mouths of major creeks (Grossinger 1995) and wastewater discharge points (Conomos 1979), as well as on the larger regional scale between the Golden Gate and the Delta. These local gradients affect the distribution of tidal marsh plants, and likely are important factors in the distribution of several species of concern.

Some indication of near-surface aqueous salinity gradients in the Estuary prior to European colonization is provided by the Native Landscape View of the Bay Area EcoAtlas (Fig. 2; SFEI 1998a), based upon historical data on marsh form and ecology. Different aqueous salinity regimes result in differences in marsh form (Grossinger 1995) and vegetation (Atwater and Hedel 1976; Atwater *et al*. 1979). For example, *Spartina foliosa* (California cordgrass) would have been generally limited to the saline half of the gradient, and replaced by *Scirpus* species (tules) in the fresher areas (Fig. 2). No corresponding picture of present-day average aqueous salinity regimes is available, but we would expect the same general pattern to be observed, with some important differences based upon alterations in the amount, timing, and location of freshwater inputs.

By conventional definition, tidal flats extend from MLLW to the lower edge of intertidal marsh vegetation, or, if no vegetation is present, to the natural or artificial edge of dry land. In more saline parts of the Estuary, *Spartina foliosa* is the dominant lower marsh plant. In fresher places, *Scirpus* species, particularly *Scirpus californicus*, replace *Spartina foliosa* as the dominant lower marsh plants. Aqueous tidal salinity has a major effect on the distribution of tidal flats in the Estuary, because marsh plants can grow substantially further into the intertidal under fresher conditions. For example, while *Spartina foliosa* grows to Mean Tide Level (MTL) in the Central Bay, *Scirpus californicus* approaches MLLW at Fairfield (Atwater and Hedel 1976), reducing the potential extent of tidal flats.

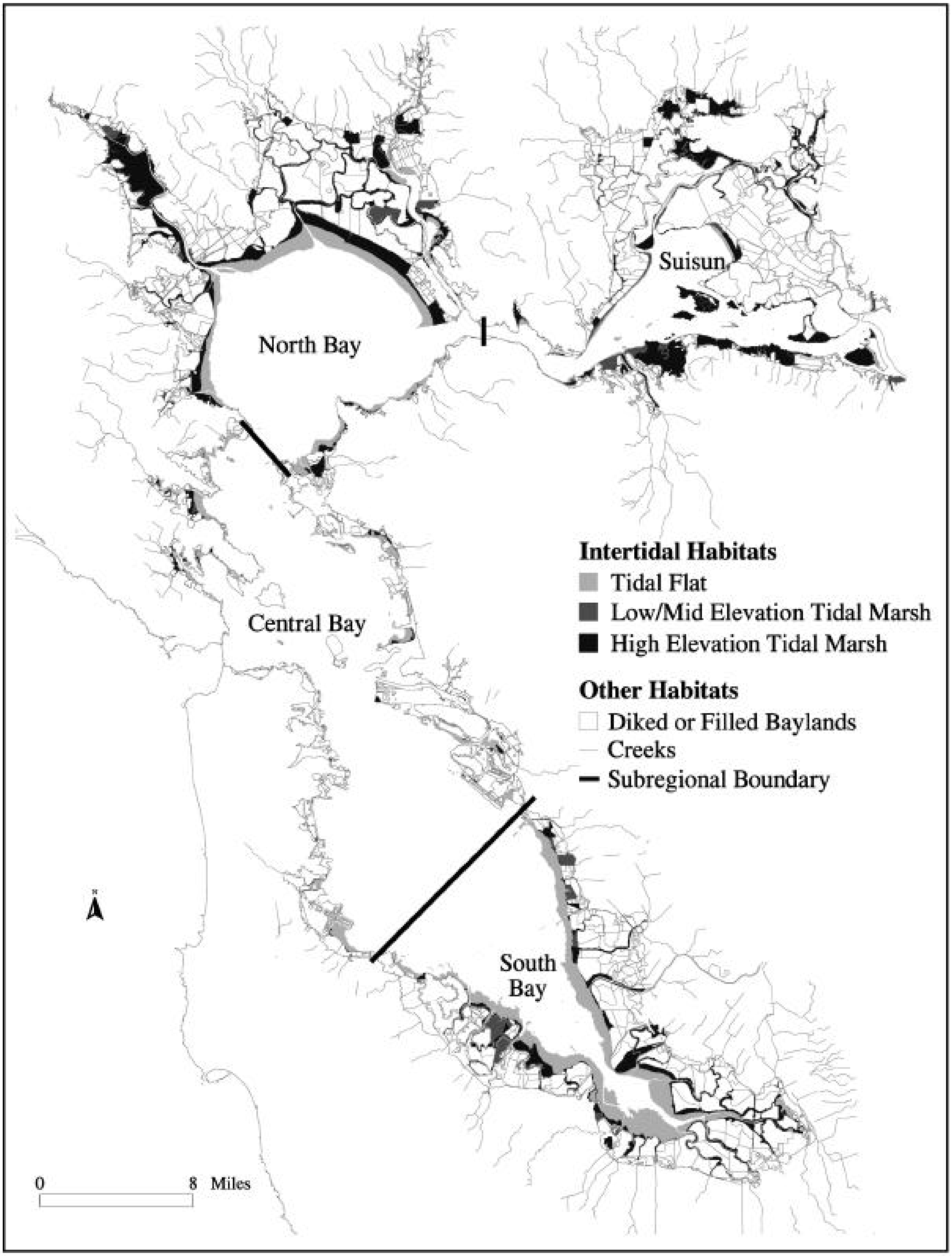

Figure 1. Distribution of intertidal habitats

Compiled by SFEI, 1998 (Basemap: Bay Area EcoAtlas Version 1.50)

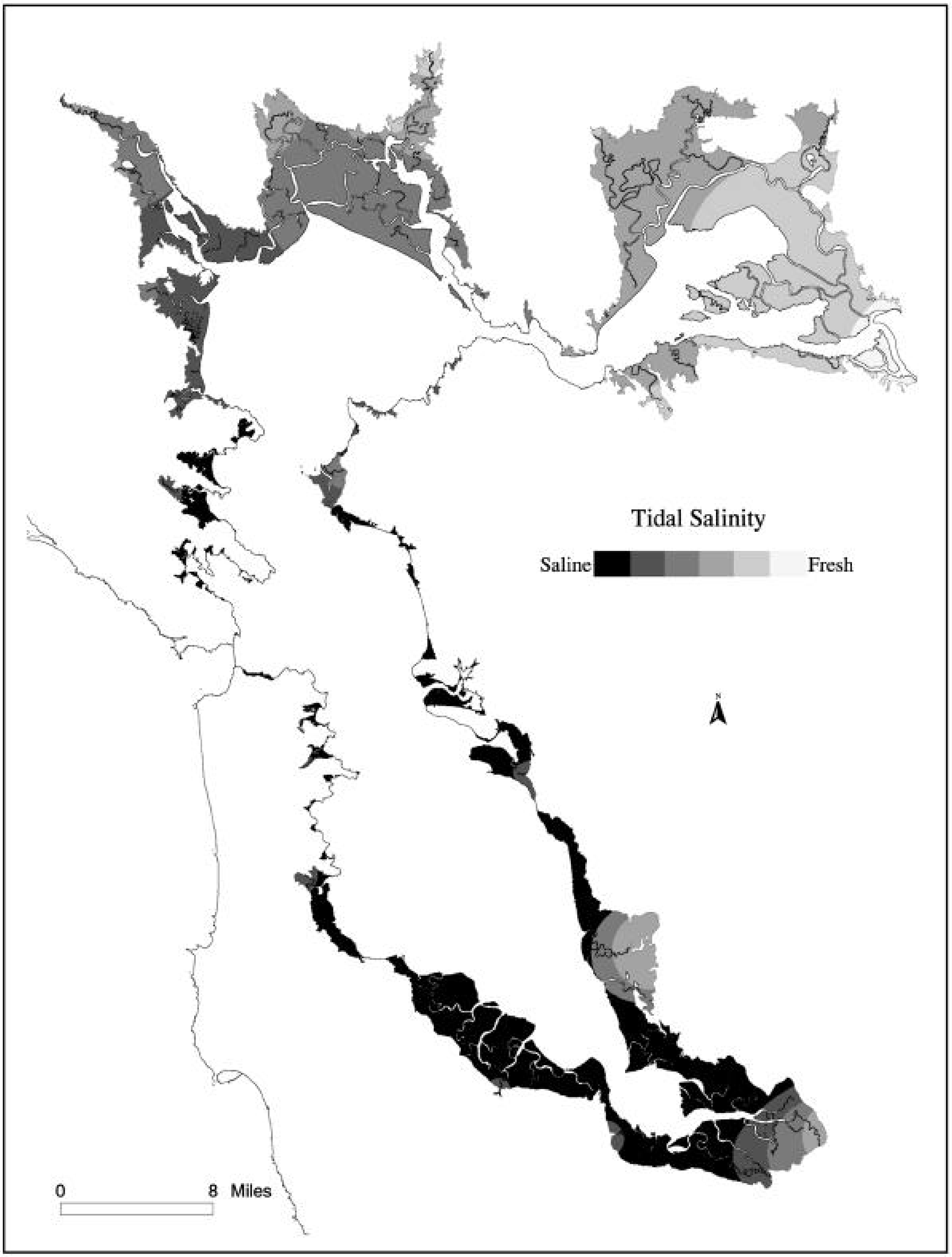

Figure 2. Historical (ca. 1770-1820) tidal salinity regimes

Compiled by SFEI, 1998 (Basemap: Bay Area EcoAtlas Version 1.50)

Status of Key Species

Lepidium latifolium **Linnaeus (Perennial pepperweed)**
General Information: *Lepidium* is a perennial herb that grows on beaches, tidal shores, saline soils and roadsides throughout most of California (Hickman 1993; Young and Turner 1995; May 1995; Young *et al*. 1997). It is native to Eurasia, where it is reported from Norway to North Africa and east to the Himalayan region. It is ranked as a "B"-level plant pest by the CDFA and is on CalEPPC's A-1 List.

Introduction and Spread: In 1941 *Lepidium* was reported to be in San Joaquin and Yolo counties on the edge of the Delta (Robbins *et al*. 1941). Mooney *et al*. (1986) map it throughout the Bay and Delta area by 1960, Madrone Associates (1977) report it from high tidal marsh and diked seasonal marsh in the Napa Marshes, and there are herbarium specimens from Grizzly Island (collected in 1960), Antioch Dunes (1977) and the Bay shoreline at Martinez and Point Pinole (1978; May 1995). It was reported as common in the tidal marshes of the San Francisco Estuary (Atwater *et al*. 1979), and uncommon in the Delta (Madrone Assoc. 1980; Herbold and Moyle 1989). Recently this species has been reported as invasive and spreading in shallow ponds and adjacent moist uplands in the Central Valley wildlife refuges, and in high tidal marsh areas and diked seasonal wetlands in Suisun Marsh (where hundreds of acres on Grizzly Island are affected) and many parts of the Bay (Trumbo 1994; Dudley and Collins 1995; May 1995; K. Malamud-Roam, pers. comm.).

Current Distribution: *Lepidium* is currently found in each subregion of the Bay in varying abundance (Figure 3). Its distribution in tidal areas in the Delta is not well documented; it is present but probably less widely distributed than *Arundo donax* (J. Trumbo, pers. comm.).

Around Suisun Bay, *Lepidium* is spreading along tidal channels and the upland margin of tidal marshes near Potrero Hills, especially at Rush Ranch, and is widespread along the natural channels and mosquito control ditches in the marshes of the Contra Costa shoreline. Smaller populations are found in Southampton Bay and along Montezuma Slough.

Further downstream in the North Bay, relatively large *Lepidium* colonies (~ 0.1 - 0.2 acres; P. Baye, pers. comm.) are found adjacent to Mare Island and additional populations occur in other marshes fringing northeastern San Pablo Bay. *Lepidium* is abundant in Tolay Creek's lower reach, and is also present in marshes in the lower reach of the Petaluma River. In Petaluma Marsh, *Lepidium* colonies are scattered along berms, levees and creek banks. Here it has progressively replaced coyote bush (*Baccharis pilularis*) since 1975, with coverage appearing to wax and wane with increasing and decreasing rainfall (J. Collins, pers. observation). In the marsh bordering Hamilton Air Field, *Lepidium* colonies are widely distributed while at nearby Miller Creek there is a heavier infestation.

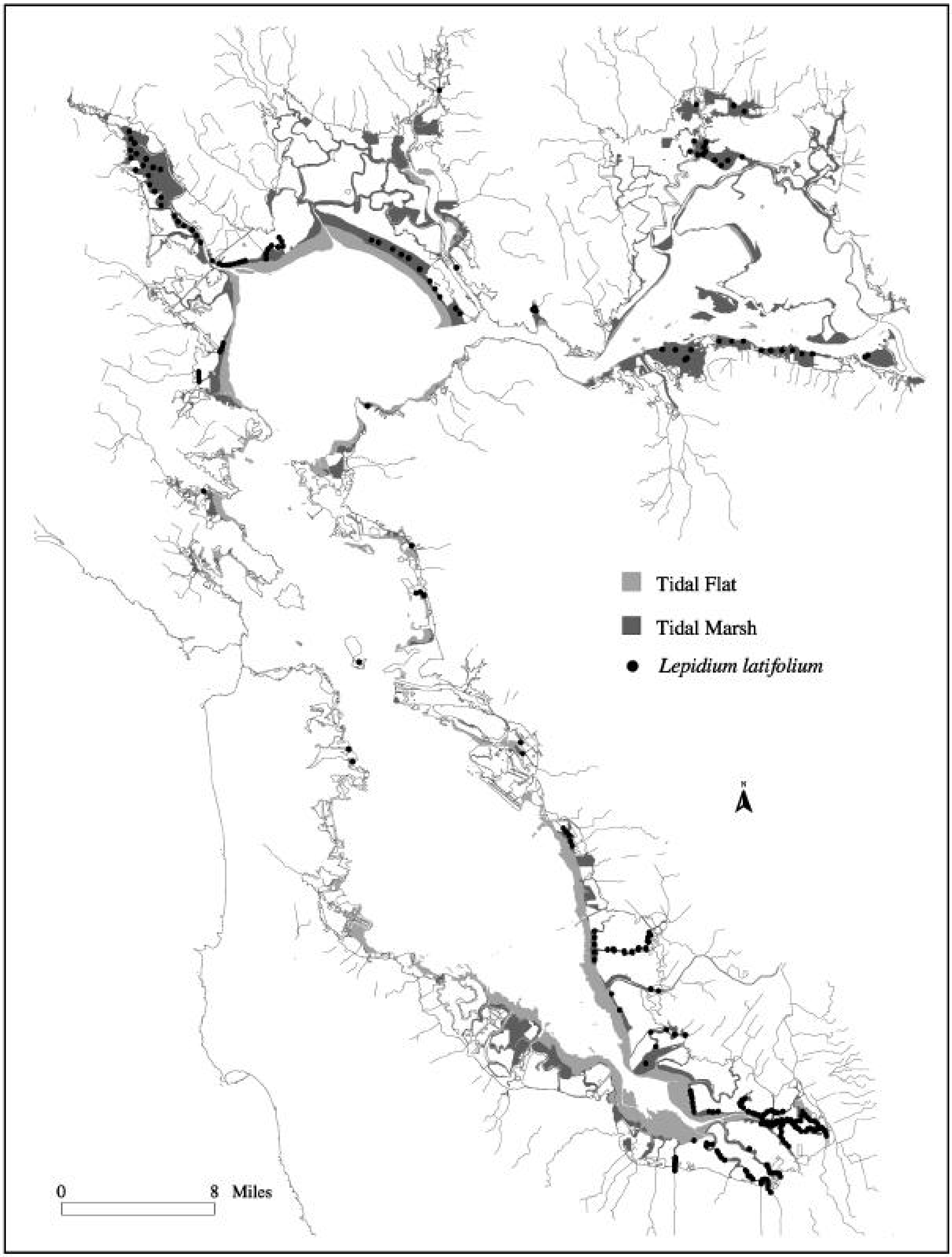

Figure 3. *Lepidium latifolium*

Compiled by SFEI, 1998 (Basemap: Bay Area EcoAtlas Version 1.50)

Lepidium is not often found within the reach of the tides in the Central Bay. There is some *Lepidium* on the beaches at the mouth of Strawberry Creek in Berkeley, at Pt. Pinole, China Camp (P. Baye, pers. comm.; A. Cohen, pers. obs.), and in the higher intertidal surrounding Arrowhead Marsh in San Leandro Bay. It is common in the muted tidal marshes (i.e., those with restricted tidal influence) near Hayward and in the areas surrounding Old Alameda Creek.

Discrete populations of *Lepidium* occur on the east shore of the South Bay, particularly along sloughs. It is a dominant component of marshes adjacent to Coyote Creek (Harvey 1997). *Lepidium* is found on dikes at Warm Springs Marsh, and has been invading pickleweed (*Salicornia virginica*) marsh for the past two years (P. Faber, pers. comm.). Infestations further south and west are limited to Alviso Slough, Guadalupe Slough, and Charleston Slough. *Lepidium* has not been reported on most of the western shore of the South Bay.

Potential Distribution: Optimum germination conditions for *Lepidium* include large fluctuations in daily temperature and a peak temperature of at least 40°C (Miller *et al*. 1986 in May 1995). Although these conditions may not often be met in the moderate climate of the Estuary, this has not halted *Lepidium*'s spread. *Lepidium* demonstrates several trends in distribution within the Estuary, being associated variously with lower salinities, higher elevations and less frequent inundation, or sandier soils (May 1995; P. Baye, pers. comm.; J. Collins, pers. obs.). It seems to grow lower in the intertidal zone in fresher parts of the estuary and higher in more saline areas, though in saline areas it is still associated with freshwater flows (May 1995; P. Baye, pers. comm.; J. Collins, pers. obs.). Frequent inundation may also be a limiting factor (May 1995). As can be seen in the distribution map, *Lepidium* is common in fresher parts of the estuary such as the North Bay, Suisun Bay, the extreme South Bay, and other sloughs and marshes adjacent to local freshwater inputs. In these areas it is found both in *Salicornia* plains and among *Scirpus* species (May 1995; J. Alexander, R. Grossinger, pers. obs.). On the south shore of Suisun Bay, *Lepidium* has been abundant in marsh areas with muted tides (where dikes and restricted channels have reduced the tidal amplitude by perhaps 70-80%) subjected to prolonged retention of fresh floodwaters during the winter and drying periods typically lasting two weeks or so during the summer (K. Malamud-Roam, pers. comm.). *Lepidium* is also associated with sandy beaches at several sites.

Based upon its distribution and spread to-date, *Lepidium* may spread further in high elevation tidal marshes, in fresh-to-brackish marshes, brackish marshes with poor tidal circulation, along natural and artificial levees and berms within marshes, and on sandy beaches. Alterations in local freshwater inputs, such as wastewater discharge sites, may substantially affect local distribution. As marshes mature, their tidal range often becomes muted, so the potential habitat for *Lepidium* may substantially increase as the approximately 5000 acres (SFEI 1998b) of low- to mid- tidal elevation Bay Area tidal marshes mature. The restoration of tidal action to diked areas, which frequently produces marsh areas with muted tides, may provide additional *Lepidium* habitat. In the Delta, low salinity and potential increase in tidal marsh acreage by restoration suggest substantial risk of *Lepidium* spread.

Control Efforts: In Contra Costa County in the 1980s, restoration of full tidal action at a subsided diked bayland caused *Lepidium* to decrease by 70-80% (K. Malamud-Roam, pers. comm.), though it might return to some degree as higher tidal elevations develop (J. Collins, pers. obs.). Herbicides were used by the U. S. Fish and Wildlife Service (USFWS) to control *Lepidium* at the Don Edwards San Francisco Bay National Wildlife Refuge (SFB Refuge) in the 1990s; by California Department of Fish and Game (CDFG) at Grizzly Island in 1994; and by the Alameda County Public Works Agency, mostly near Alameda Creek, for the past couple of years (S. Jones, pers. comm.). More recently (1997), hand-pulling was used to control pepperweed on the SFB Refuge. Participants in a tidal marsh restoration effort at lower Tolay Creek hope to reduce *Lepidium* growth by increasing tidal salinity and the frequency of inundation (P. Jones, pers. comm.). Mowing, burning, and discing have been ineffectual and even counter-productive methods for controlling *Lepidium* (J. Trumbo, pers. comm.).

Table 2. Control Efforts on Key and Potential Species of Concern in the San Francisco Estuary.

Date	**Location**	**Method**	**Agency**
L. latifolium			
1980s	Contra Costa Co.	tidal restoration	Contra Costa Co. Mosquito Abatement District
1990s	SFB Refuge	herbicide	USFWS
1994	Grizzly Island	herbicide	CDFG
1990s-	Alameda Creek	herbicide	Alameda County
1997	SFB Refuge	hand-pulling	USFWS
S. alterniflora			
1994-	Alameda shoreline	herbicide (Rodeo)	Alameda County
1993	SFB Refuge	mowing, covering	USFWS
1994-	SFB Refuge	herbicide (Rodeo)	USFWS
1995	Cogswell Marsh	covering, burning, hand-pulling	EBRPD
1996	Cogswell Marsh	winter mowing	EBRPD
1997-	Cogswell Marsh	herbicide (Rodeo)	EBRPD
1993-	San Bruno Slough	herbicide	CalTrans
S. densiflora			
1996	Pt. Pinole	hand-pulling	EBRPD
1997	Pt. Pinole	herbicide (Rodeo), hand-pulling	EBRPD
A. donax			
	None within the tidal extent of the Estuary.		
S. soda			
	No organized efforts.		
S. anglica			
	None.		
S. patens			
	None.		

***Spartina alterniflora* Loiseleur-Deslongchamps (Smooth cordgrass)**

General Information: *Spartina alterniflora* is a perennial grass that has invaded low tidal marsh and open mudflats in San Francisco Bay. It is native to the coast of eastern North America from Maine to Texas (Muenscher 1944) and has been introduced to Padilla Bay (1910), Thorndyke Bay (1930), Willapa Bay, Camano Island and Whidbey Island in Washington; the Siuslaw Estuary in Oregon; and New Zealand, England (1922) and China (1977) (Chung 1990; Callaway 1990; Callaway and Josselyn 1992; Ratchford 1995). This plant is currently on CalEPPC's List A-2.

Introduction and Spread: *Spartina alterniflora* was introduced to San Francisco Bay in the early 1970s by the U. S. Army Corps of Engineers at Pond 3 at the Coyote Hills Regional Shoreline. Plants from Coyote Hills were later transplanted by Caltrans to San Bruno Slough at the Sam Trans bus terminal. It spread to Alameda Island by 1983 or 1984, and to Hayward Marsh by 1989 (Spicher and Josselyn 1985; Callaway 1990; Cohen and Carlton 1995; P. Kelly, pers. comm.; P. Faber, pers. comm.; M. Taylor, pers. comm.).

Callaway and Josselyn (1992) reported about 650 patches in the Estuary in 1990. By 1995, there were about 1,000 round or donut-shaped patches at southwestern Alameda Island and northeastern Bay Farm Island, San Leandro Bay, Hayward Marsh, Alameda Creek and Coyote Hills Slough (New Alameda Creek), and San Bruno Slough (near the San Francisco Airport), with smaller amounts reported from the Estudillo Flood Control Channel south of the San Leandro Marina, the SFB Refuge and the Cargill salt ponds near Newark, and the SFB Refuge near Alviso (Cohen and Carlton 1995; M. Taylor, pers. comm.; J. Takekawa, pers. comm.; C. Daehler, pers. comm.).

Current Distribution: *Spartina alterniflora* is widespread in tidal marshes and flats south of the Bay Bridge, excepting the extreme southeastern part of the South Bay (Figure 4). At these sites, populations are common at the intertidal flat-vegetated marsh plain boundary along sloughs and younger marshes, but are also observed in some old (present circa 1850) marshes, such as at Newark Slough and Mount Eden Slough.

On the eastern shore of the Central and South Bays, *S. alterniflora* is present in nearly every tidal marsh larger than 10 acres between the Oakland Estuary and Newark Slough. The most extensive populations currently occur at Cogswell Marsh and in San Leandro Bay. While *S. alterniflora* has not been noted at Ora Loma, the largest tidal marsh in this part of the Estuary, this recent restoration project is currently mostly unvegetated, and may be colonized. *S. alterniflora* may be present further south in tidal marshes within the SFB Refuge, but not yet observed because of limited access (J. Albertson, pers. comm.).

On the western shore of the South Bay, *S. alterniflora* has been noted at sites from Potrero Point in South San Francisco to Mountain View Slough. *S. alterniflora* has not been reported from some of the larger tidal marshes on the western shore of the South Bay, such as Greco Island.

North of the Golden Gate, *S. alterniflora* was found at one site, the head of Richardson Bay, in 1997 (M. Josselyn, pers. comm.).

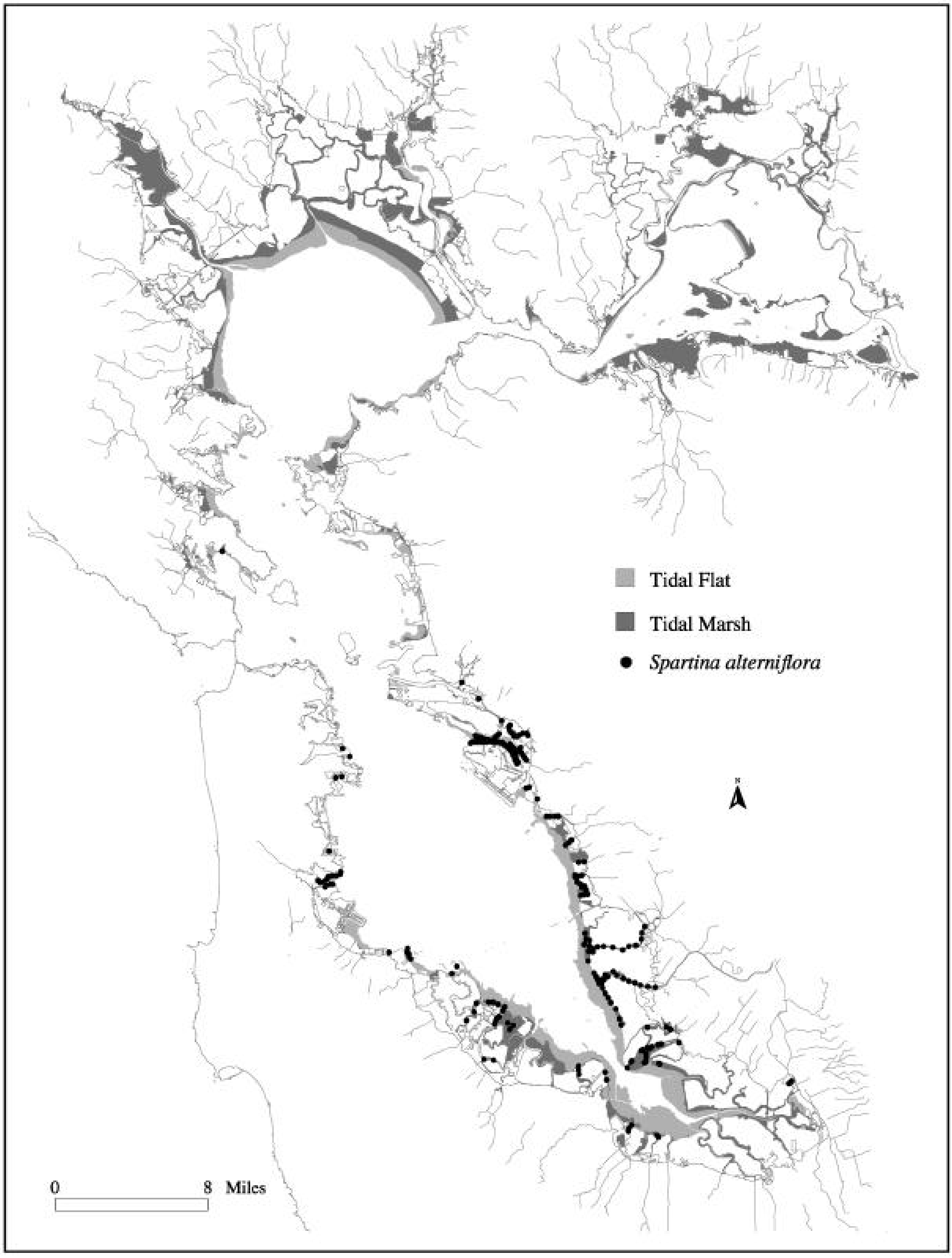

Figure 4. *Spartina alterniflora*

Compiled by the SFEI, 1998 (Basemap: Bay Area EcoAtlas Version 1.50)

Potential Distribution: *Spartina alterniflora* is more tolerant of tidal inundation than *Spartina foliosa* (Josselyn *et al*. 1993; Callaway and Josselyn 1992; Strong and Daehler 1995) making possible the colonization of previously-unvegetated tidal flats. In Willapa Bay, *S. alterniflora* has been reported to within 1 meter of MLLW (Sayce 1988), which would place it within the existing range of *S. foliosa* in the San Francisco Estuary. However, its lower range varies substantially around the world.

McKee and Patrick (1988) developed a relationship between growth range of *S. alterniflora* and Mean Tide Range (MTR) using data from Atlantic coast marshes. Application of this model at San Bruno Slough predicts a growth range for *S. alterniflora* that is consistent with the results of experimental transplants (Daehler & Strong 1996), and about three times *S. foliosa*'s range at the site (Callaway and Josselyn 1992; Josselyn *et al.* 1993). In contrast, in the North Bay, this model predicts that *S. alterniflora* would not grow any lower in the intertidal than *S. foliosa* does (Atwater and Hedel 1976). However, there are several reasons to be cautious about applying this model to the Estuary without further examination: (1) Daehler and Strong's (1996) validation of the MTR relationship for the Pacific Coast is based upon a single data point; (2) Pacific Coast tidal regimes (mixed semidiurnal) differ from those in the Atlantic; (3) McKee and Patrick (1988) note that *S. alterniflora*'s growth range varied substantially even within Atlantic marsh; (4) *S. foliosa*'s growth range in the Estuary varies greatly with salinity (Atwater and Hedel 1976; Atwater *et al.* 1979), suggesting that *S. alterniflora*'s may also; (5) different interpretations of MTR are possible, resulting in significantly different model outputs.

Surveys to-date have found *S. alterniflora* growing at 0.22-0.43 m below *S. foliosa* at San Bruno Slough and 0.06-0.09 m below at Alameda (estimated from figures in Callaway and Josselyn 1992; Josselyn *et al.* 1993). If *S. alterniflora* does extend the lower limit of intertidal vegetation by about 0.3 m, this would reduce the *vertical* range of unvegetated tidal flats by as much as 30-35% in the Central Bay, eliminating much of the upper part of existing tidal flats. This portion of tidal flats may be the most significant for avian foraging (G. Page, pers. comm.). Colonization by *S. alterniflora* may also cause greater sediment accretion, resulting in further cordgrass growth and loss of additional tidal flat area (Sayce 1988; Daehler and Strong 1996). Substantial amounts of tidal flat are clearly vulnerable to *S. alterniflora* invasion, but without more information about the species' relationship to controlling physical conditions, and the distribution of those conditions in the Estuary, more detailed and local predictions are not possible.

Spartina alterniflora also has the potential to invade existing tidal marshlands in the Estuary. It has been observed in established tidal marshes in the Central and South Bay (Callaway and Josselyn 1992; Josselyn *et al*. 1993; J. Albertson, pers. comm.; J. Alexander, pers. obs.) as well as on tidal flats. Low- and mid-elevation tidal marshes (Fig. 1), where *S. foliosa* is common, are particularly likely to be invaded by *S. alterniflora* or by hybrids between *S. foliosa* and *S. alterniflora* (Daehler and Strong 1997). Higher-elevation tidal marshes may also be affected, based on *S. alterniflora*'s distribution on the east coast (McKee and Patrick 1988). Tidal marsh restoration projects (potentially involving several tens of thousands of acres in the region) may be particularly vulnerable to invasion because they present an unvegetated, mid-intertidal surface (Alexander 1997).

The potential upstream range of *S. alterniflora* is probably best indicated by the upstream limit of the native cordgrass *S. foliosa*, which has varied in recent years from the mouth of the Carquinez Straits to Suisun Slough (B. Grewell, pers. comm.; J. Collins, pers. obs.). *Spartina foliosa*'s upstream limit is apparently set by competition with other, less salt-tolerant plants. Given that *S. alterniflora* is both faster-growing and more robust than *S. foliosa* (Josselyn *et al*. 1993; Callaway and Josselyn 1992), it may be able to compete more effectively with these other plants, and range further upstream.

Control Efforts: Washington State has a major *S. alterniflora* control program. Efforts in Willapa Bay began in 1975 with experimental herbicide applications using Atrizene, Amitrol T, and Tordon 10K. The USFWS used mowing, crushing, and herbicide in 1987, removed a small patch by digging in 1988, covered with black plastic in 1989, and applied the herbicide Rodeo in 1990. The Washington State Department of Natural Resources conducted a study of mowing and covering with black plastic in 1990, and worked with The Nature Conservancy in 1991 spraying Rodeo (Mumford *et al*. 1990). A coordinated multi-agency (USFWS, Washington Department of Fish and Wildlife, Department of Natural Resources) control program began in Willapa Bay in 1997 with early summer mowing and ground and aerial Rodeo application in late summer (Aberle 1993; K. Patten, pers. comm.; S. Jones, pers. comm.). *Spartina alterniflora* is also currently being controlled in Puget Sound with success (K. Patten, pers. comm.). In Humboldt Bay in northern California, *S. alterniflora* was eradicated in 1989 by mowing and covering with black plastic (Aberle 1993).

In the Estuary, the Alameda County Public Works Agency has been using Rodeo to control *S. alterniflora* in creeks along the Alameda shoreline since 1994, and has also been aerially spraying herbicide in the Alameda Flood Control Channel since 1995 (S. Jones, pers. comm.). In 1993 the SFB Refuge began trying to control *S. alterniflora*, first with mowing and covering with filter fabric, and since 1994 with Rodeo applications (J. Albertson, pers. comm.). Beginning in 1995, the East Bay Regional Park District (EBRPD) experimentally covered, burned, and hand-removed clones of *S. alterniflora* at Cogswell Marsh, and in winter of 1996-97 attempted winter mowing there as well. Since 1997, EBRPD control efforts have focused on Rodeo application alone (D. Smith, pers. comm.). Since 1993, Rodeo has been used by CalTrans to control *S. alterniflora* at San Bruno Slough (M. Taylor, pers. comm.). A regional, multi-agency coordination effort for *S. alterniflora* control is being developed between the SFB Refuge, EBRPD, and Alameda County (J. Albertson, pers. comm.; S. Jones, pers. comm.; D. Smith, pers. comm.).

Spartina densiflora **Brongniart (Dense-flowered cordgrass)**

General Information: Dense-flowered cordgrass is a perennial, salt-tolerant grass that grows in upper intertidal habitats near mean high water, among *Salicornia* or just below it on open mud (Daehler and Strong 1996; Kittelson 1993 from Daehler 1996). It is native to South America and was accidentally introduced to Humboldt Bay in the mid-nineteenth century, probably in the solid ballast of lumber ships returning from Chile (Mobberly 1956; Spicher and Josselyn 1985). *Spartina densiflora* is considered an invasive weed where it is found along the Mediterranean coast of Europe (Figuerra and Costellanos 1988 in H. T. Harvey 1993), and is on CalEPPC's Red Alert List.

Introduction and Spread: *Spartina densiflora* was transplanted from Humboldt Bay to Corte Madera Creek in 1976 as part of a restoration project at a time when it was thought by some to be an ecotype of the native *S. foliosa* (Spicher and Josselyn 1985; Callaway 1990; H.T. Harvey 1993; P. Faber, pers. comm.). By 1984, *S. densiflora* was also found in Muzzi Marsh and at Greenwood Cove in Richardson Bay, where it was planted for a condominium landscaping project (Spicher 1984; Spicher and Josselyn 1985; H. T. Harvey 1993). Both of these sites are in southeastern Marin County, within a 7 km radius of the original introduction site (Spicher 1984; Spicher and Josselyn 1985). This distribution did not change but the density of this species in these areas increased three fold in about ten years (H. T. Harvey 1993). EBRPD found *S. densiflora* on the north shore of Pt. Pinole Regional Park, Contra Costa County by 1996 (D. Smith, pers. comm.). In 1997 we found *S. densiflora* at some locations on Corte Madera Creek where it had not been reported in 1993, and in greater density at sites where it had been reported.

Current Distribution: *Spartina densiflora* is currently found in southeastern Marin County along the entire length of Corte Madera Creek, in Muzzi Marsh, and at Greenwood Cove in Richardson Bay; and in western Contra Costa County at Pt. Pinole Regional Park and at the mouth of Garrity Creek just east of the park (Figure 5).

Potential Distribution: In Humboldt Bay, *S. densiflora* occurs throughout the entire marsh but dominates middle elevations of undisturbed marshes (Eicher 1987 in H. T. Harvey 1993). At Creekside Park on Corte Madera Creek in San Francisco Bay, Spicher (1985 cited in H. T. Harvey 1993) found *S. densiflora* to range from 0.5 ft below to 1.0 ft above MHW, a narrower range than reported in Humboldt Bay. In Corte Madera Creek, H. T. Harvey (1993) found *S. densiflora*'s range to coincide generally with that of *Salicornia virginica*, with the greatest number of plants found in the lower *Salicornia* zone at the ecotone with *Spartina foliosa*. Plants also occurred in mid-marsh areas with *Salicornia* and *Distichlis spicata* (saltgrass); and occurred, sometimes in abundance, in otherwise barren areas among and above riprap and in rocky soils or soils mixed with concrete fill that were marginally marsh-like. In recent years we have observed large numbers of plants in disturbed, high marsh sites along the creek. At Pt. Pinole, scattered plants are found ranging from just below the *Salicornia* zone on mud or on sand at creek mouths, to mid-marsh locations among *Salicornia virginica*, to banks along sloughs hosting various saltmarsh plants.

Thus, in the regions where it is found within the Estuary, *Spartina densiflora* is capable of becoming established throughout the tidal range of existing *Salicornia* marsh to just above and below this range. At least initially, colonization may occur more densely within disturbed areas, in areas receiving sediment such as around culverts (H. T. Harvey 1993), and in the lower part of this range. However, its expansion within Humboldt Bay indicates that it is capable over time of establishing nearly solid homogenous stands within undisturbed *Salicornia* marsh and in the uplands transition zone (Spicher 1984).

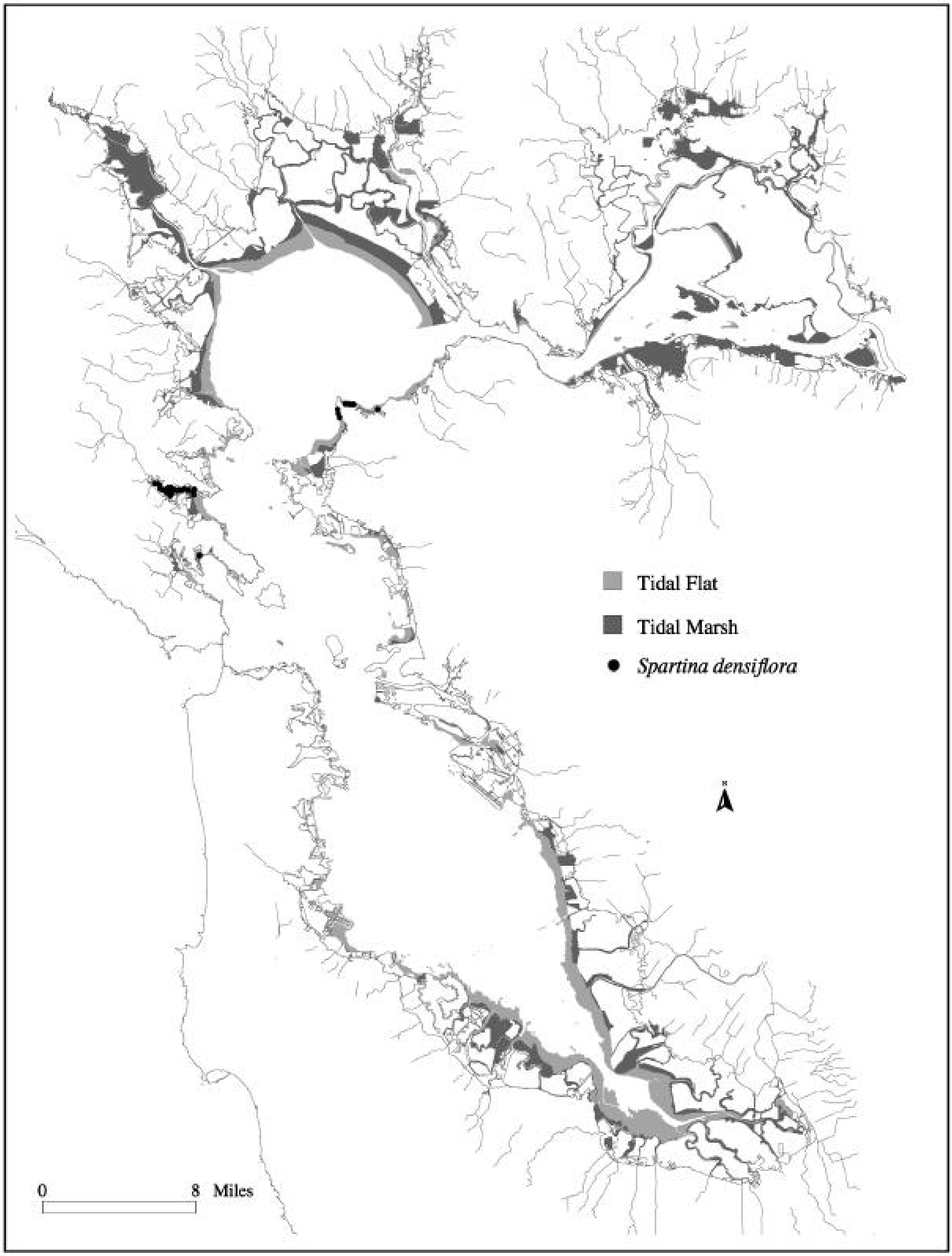

Figure 5. *Spartina densiflora*

Compiled by the SFEI, 1998 (Basemap: Bay Area EcoAtlas Version 1.50)

Although presently distributed only in San Pablo and Central Bays, sites in the South Bay are likely also suitable for colonization. *Spartina densiflora* has not been reported from open coastal waters or from freshwater habitats, but data is not available for a more precise assessment of its likely oceanward or upstream limits within the Estuary. Seed germination in greenhouse experiments was higher in freshwater and declined with increasing salinity (Kittelson 1993 in H. T. Harvey 1993), and like some other saltmarsh plants its upstream limit may be set by competition rather than by intolerance of freshwater conditions.

Spartina densiflora's recent establishment at Pt. Pinole roughly 15 km across the Bay and upstream from previous known sites demonstrates some significant capacity to disperse. Dispersal could occur through spread of seeds—it flowers and sets abundant seed in San Francisco Bay—or possibly through the spread of uprooted plants that can re-root (H. T. Harvey 1993).

Control Efforts: The EBRPD hand-pulled 70 clones of *S. densiflora* from Point Pinole in November 1996, and later sprayed with Rodeo or hand-pulled an additional 0.5 acres in October 1997 (D. Smith, pers. comm.). A pilot eradication project was planned for Creekside Park (H. T. Harvey 1993) but has never been implemented (P. Faber, pers. comm.).

Status of Potential Species of Concern

Arundo donax Linnaeus (Giant Reed)

General Information: *Arundo* is a tall perennial reed that is found at moist sites, such as ditches, streams, or seeps, at low elevations in cismontane and desert California (Munz and Keck 1959; Hickman 1993). It has long been thought native to Europe but it is likely that it is originally from India and was brought to Europe through the silk trade (T. Dudley, pers. comm.). It is on CalEPPC's A-1 List.

Introduction and Spread: Jepson (1951) reported *Arundo* "escaped along irrigation ditches" in central and southern California and it is now abundant in many Southern California watersheds, including the Santa Ana, Santa Margarita, Ventura, Santa Clara, San Diego, and San Luis Rey (Bell 1997; T. Dudley, pers. comm.). *Arundo* is reported as occasional on herbaceous banks in the Delta (Madrone Assoc. 1980; Herbold and Moyle 1989), and Atwater (1980) recorded it from the bank of an islet at Sand Mound Slough in the Delta.

Current Distribution: *Arundo* is primarily a freshwater species, but can tolerate brackish water and in the San Francisco Estuary is occasionally found within the reach of the tides (Figures 6 and 7). In the Delta, *Arundo* is present on the levees of Bacon Island, Bethel Tract, Bishop Tract, Lower Jones Tract, Medford Island, Orwood Tract, Palm Tract, Lower Roberts Island, Sherman Island, Smith Tract, Tyler Island, Victoria Island, Woodward Island, and Wright-Elmwood Tract in the Delta (CDFG 1994). A heavier infestation (~ 8 acres) was reported on the levees of East and West Union Island (CDFG 1994), but this amount may have diminished because of extensive riprapping (B. Grewell,

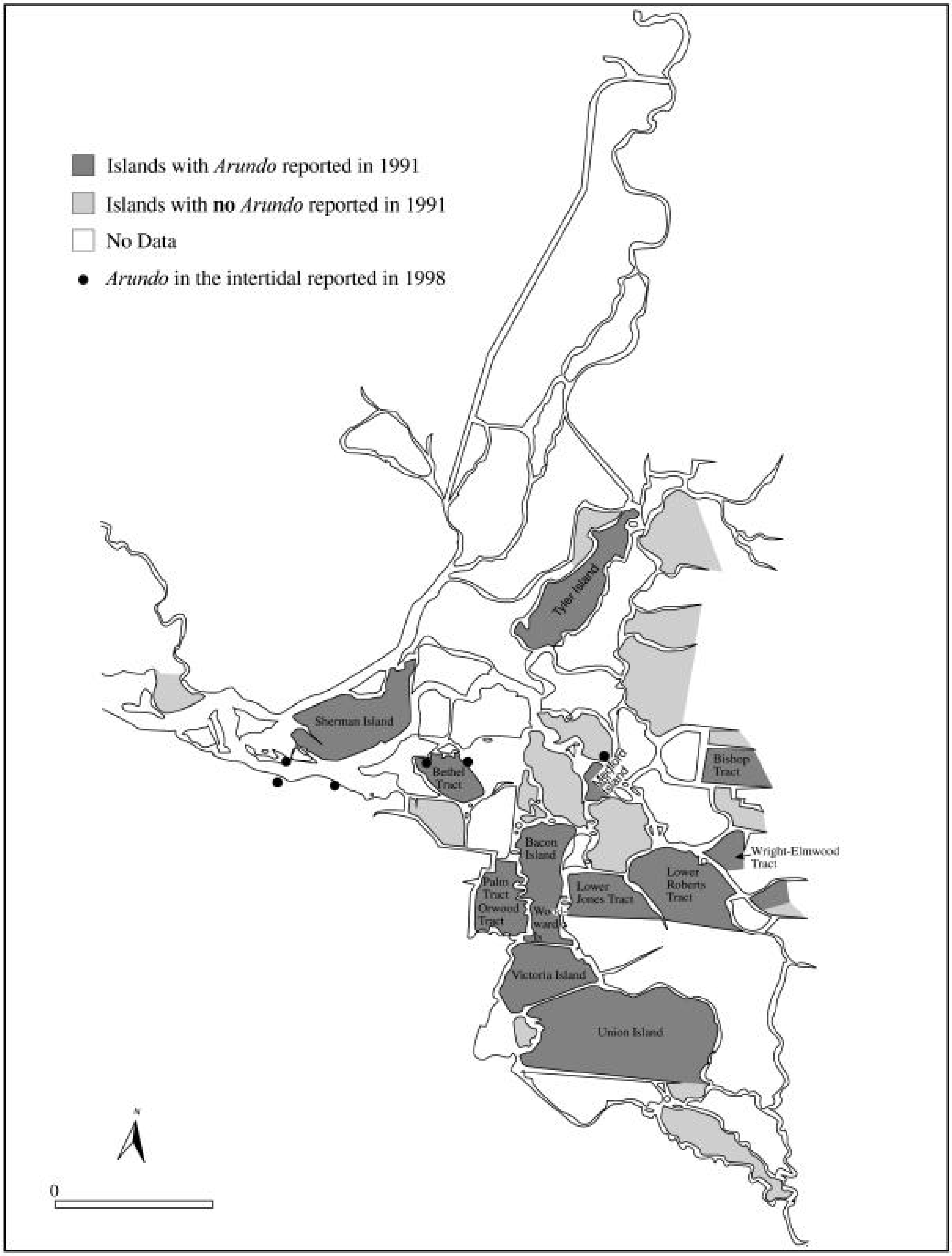

Figure 6. *Arundo donax* in the Sacramento-San Joaquin River Delta. Populations reported on Delta islands are from Delta Levee Assessments (CDFG 1994), and may include both the outboard and inboard sides of levees, not necessarily within the intertidal. Mapping of other intertidal sites was not comprehensive, and there are likely additional sites not shown here.

Compiled by SFEI, 1998 (Basemap: A. Cohen)

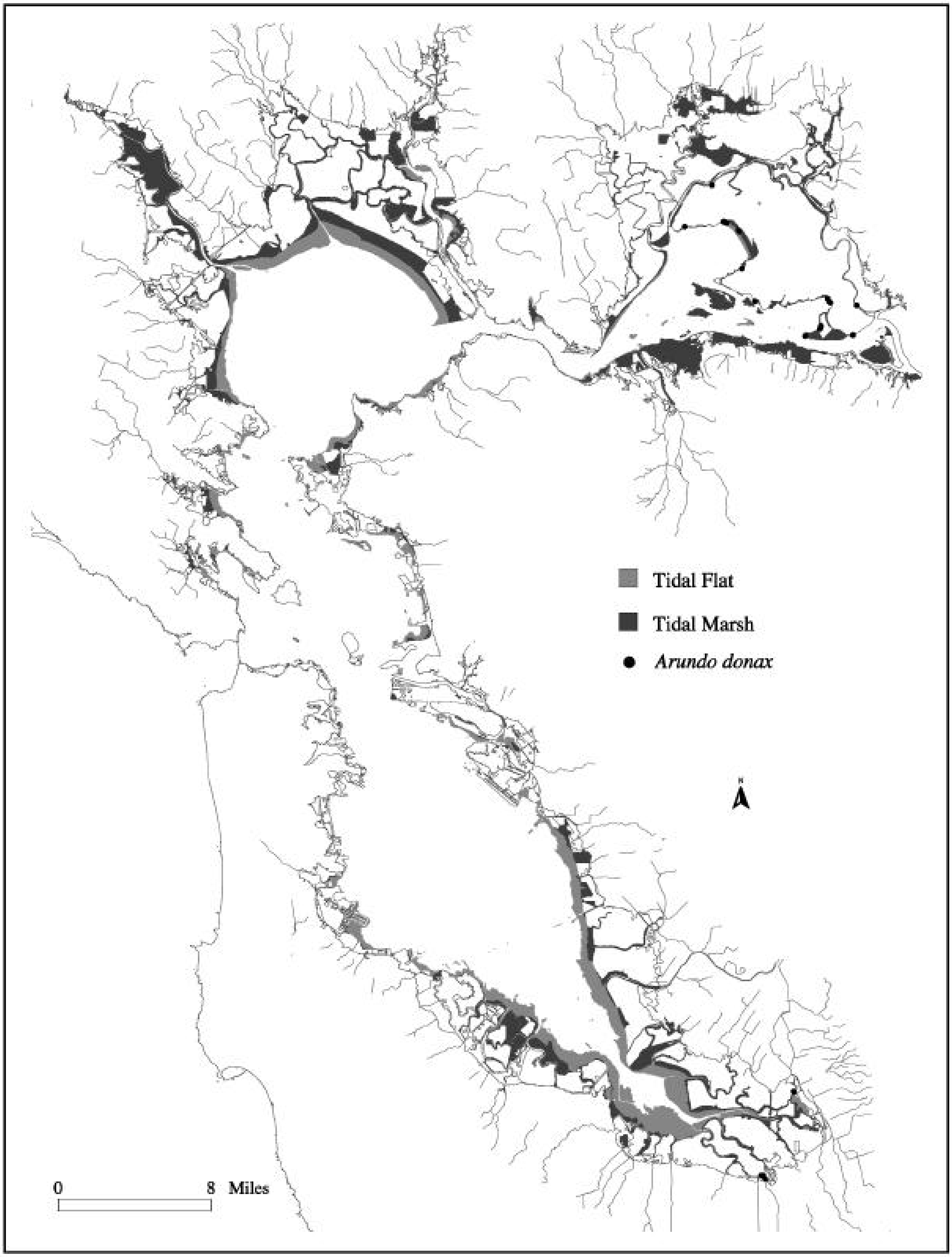

Figure 7. *Arundo donax*

Compiled by SFEI, 1998 (Basemap: Bay Area EcoAtlas Version 1.50)

pers. comm.). *Arundo* is also found in Venice Island (J. Trumbo, pers. comm.), West Island, and in some marshes along the Antioch shoreline (T. Dudley, pers. comm.).

In Suisun, *Arundo* is reported in some marshes outboard of Grizzly Island, in Honker Bay marshes, and in Montezuma Slough. In the South Bay, it is present in the upper reaches of Mud and Guadalupe Sloughs.

Potential Distribution: This species is likely to be limited to the freshwater and brackish marshes of the Delta and Suisun Bay and smaller areas at the mouths of creeks and artificial freshwater discharge sites, especially those of the southern tip of the South Bay where high volumes of treated effluent decrease salinity.

Control Efforts: Southern California watersheds have been the focus of most control efforts though some projects have begun near the Estuary in nontidal areas. These control efforts usually involve Rodeo application alone or in combination with cutting either before or after spraying (T. Dudley, pers. comm.). The Santa Clara Valley Water District has undertaken control projects in Permanente and Coyote Creeks, and the Sonoma Ecology Center has worked with CDFG in Sonoma Creek. Some work has been done in San Pablo and Wildcat Creeks as well (T. Dudley, pers. comm.). Since 1989, the Alameda Flood Control District has been spraying *Arundo* wherever it occurs in their jurisdiction (S. Jones, pers. comm.). Work also has been done by CDFG along Delta levees (T. Dudley, pers. comm.).

Salsola soda **Linnaeus (Glasswort)**

General Information: Native to southern Europe, *Salsola soda* is found on mudflats, in open areas and among pickleweed in salt marshes, and on berms, among riprap and in open areas at and above the high tide mark at scattered sites in San Francisco Bay (Hickman 1993; Cohen and Carlton 1995). *Salsola soda* in the Mediterranean flourishes in warm regions along the coast of South Italy to Africa (Carrago *et al*. 1993). On the Ukraine side of the Azov Sea, *Salsola soda* is found on regularly inundated sea shores, in transition zones to fore-dune stands, on the top or the landward sides of dunes, and in saltier sites (Dubyan *et al*. 1994). CalEPPC placed this species in its “Need More Information” category.

Introduction and Spread: *Salsola soda* was first collected in the Estuary in July 1968 at the west end of the Dumbarton Bridge in the South Bay (Thomas 1975). By the mid-1990s it had been found at several sites in the South Bay from Candlestick Park to the SFB Refuge, and on the Alameda shore; from Emeryville Marina to Hoffman Marsh, Richmond and at Richardson Bay in the Central Bay; and at Chevron Marsh, Richmond, at Pinole and at Tubbs Island in San Pablo Bay (Thomas 1975; Tamasi 1995; Cohen and Carlton 1995). It is also found in San Diego (A. Cohen, pers. obs.), and was reported one year from Bodega Bay (C. Daehler, pers. comm.). We know of no other records from North America.

Current Distribution: A large portion of marsh outboard of Mare Island in the North Bay is infested with *Salsola soda*, and it occurs in isolated patches elsewhere in the San Pablo Bay marshes (Figure 8). Small populations are found along the Contra Costa shoreline of the North Bay with a larger population at Pt. Pinole. Near the Petaluma River, a new invasion was recently sighted and removed (P. Baye, pers. comm.). Along the Marin shoreline, *Salsola soda* is found just north of Pt. San Pedro and just south of Corte Madera Creek. *Salsola soda* is scattered along the east shore of the Central Bay from Richmond to Berkeley and then again just north of the San Mateo Bridge in marsh managed by the Hayward Area Recreation District, and at Newark Slough. On the west shore of the Central Bay, it is found in sheltered areas near Hunter's Point, Candlestick Point, and San Bruno Slough. Further south, *Salsola soda* has been found in Redwood Creek and the Palo Alto Baylands.

Potential Distribution: Based upon its current distribution in the Estuary, and in other parts of the world, *Salsola soda* appears to be primarily a plant of saline soils, found at or in areas above the high tide mark, or in high marsh areas that are inundated only for short periods or are dry for a substantial part of the summer. In such areas it may be found among *Salicornia*, and may successfully compete with it. Its association with saline soils suggests that within the Estuary's tidal zone it may remain restricted to areas west of the Carquinez Strait.

Control Efforts: The only reported control effort has been the hand-pulling of a single clump near the Petaluma River in 1997 (P. Baye, pers. comm.).

Spartina anglica **C. E. Hubbard, 1968 (English cordgrass)**

General Information: *Spartina anglica* is a perennial grass species which grows in low marsh and mudflat. It arose in England by 1870 from a hybridization between the American *Spartina alterniflora* and the English *Spartina maritima* (Ferris *et al* 1997; Gray *et al* 1991; Raybould *et al* 1991a; Raybould *et al* 1991b). Through a combination of transplantings for marsh and mudflat reclamation purposes, natural dispersal, and vigorous clonal growth, this plant now occupies 25,000 acres of the British coast (Spicher and Josselyn 1985; Thompson 1991). *Spartina anglica* was introduced to other parts of the world, including northern Europe, Australia and New Zealand, and China, for erosion control projects and other purposes. In China it now occupies over 36,000 hectares, mainly derived from 21 plants introduced in 1963 (Chung 1990). This species is considered a "noxious weed" in Australia and New Zealand, and is on CalEPPC's Red Alert List.

Introduction and Spread: In 1961 the U. S. Department of Agriculture and Washington State University introduced what was thought to be *S. townsendii* (an infertile hybrid of *S. alterniflora* and *S. maritima*) into Puget Sound, Washington (Spicher and Josselyn 1985; Frenkel 1987). Ramets from these plants were introduced into San Francisco Bay at Creekside Park Marsh, Marin County, as part of a marsh restoration project in 1977. Botanists realized these plants were in fact *S. anglica* when they flowered and produced 20% viable seeds in 1983 (Spicher and Josselyn 1985; Callaway 1990; Cohen and Carlton 1995).

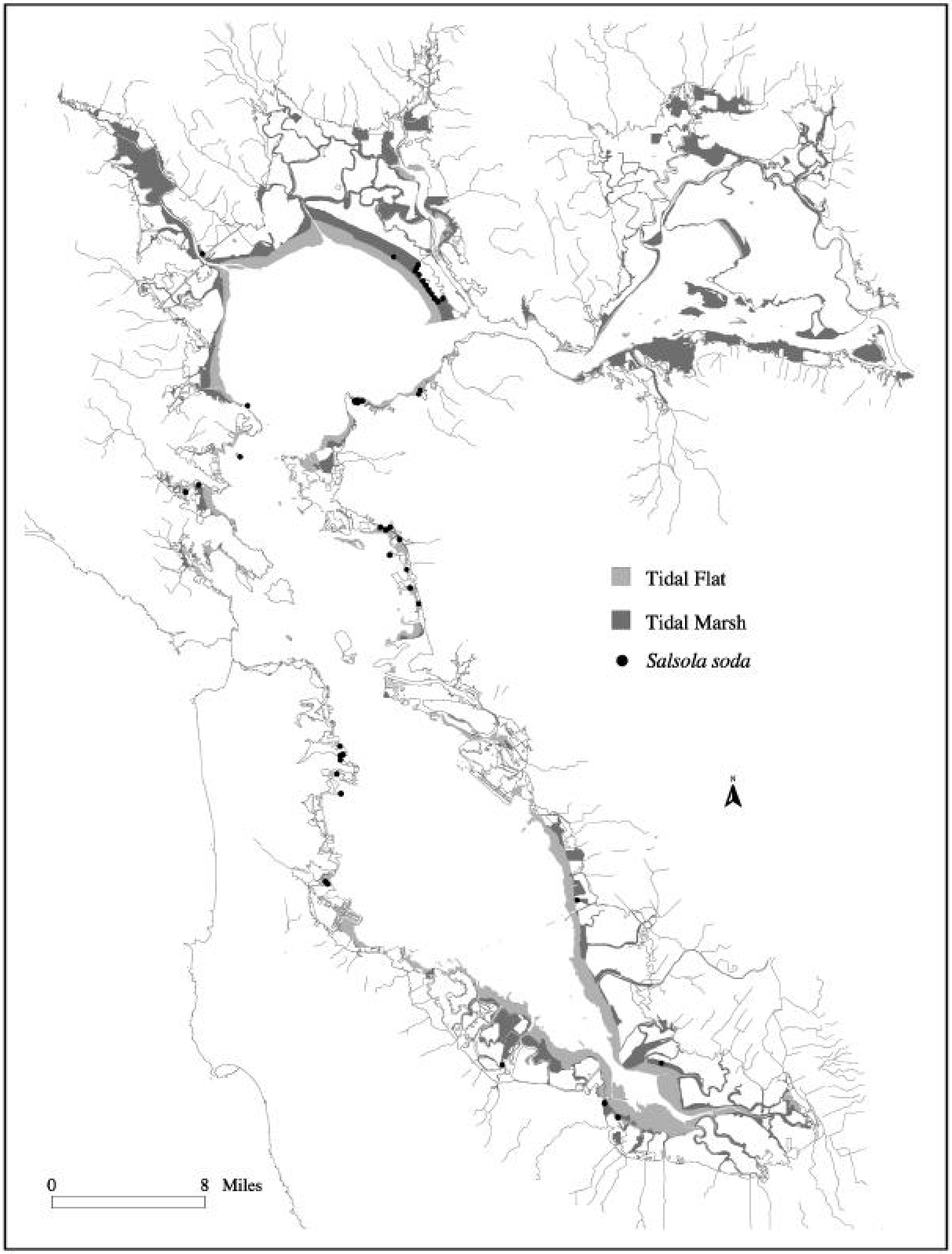

Figure 8. *Salsola soda*

Compiled by SFEI, 1998 (Basemap: Bay Area EcoAtlas Version 1.50)

Current Distribution: *Spartina anglica*'s presence in the Bay was recently confirmed near the observation platform at Creekside Marsh (D. Smith, pers. comm.; D. Spicher, pers. comm.; D. Strong, pers. comm.; M. Josselyn, pers. comm.; Figure 9).

Potential Distribution: Daehler and Strong (1996) suggest that *S. anglica*'s likely southern range limit on the Pacific Coast is at San Francisco Bay, based upon its greater success at high latitudes elsewhere in the world and its slow spread within the Bay to date, and that the plant is therefore not likely to act invasively or become a problem in the Bay (C. Daehler, pers. comm.). However, *S. anglica*'s establishment at lower latitude sites and at sites with warmer water surface temperatures relative to San Francisco Bay (Table 3) suggests that its range limit on the Pacific Coast may lie substantially further south. Further, Gray *et al*. (1991) noted that this plant's introduction into various British estuaries has been characterized by 20-40 years with little or no expansion followed by a sudden burst of population growth, so that its past performance in San Francisco Bay may not be a reliable indicator of its future invasive potential.

Table 3. Latitude Limits of *Spartina anglica* and Ocean Surface Temperatures in Four Regions Relative to the San Francisco Bay Region

Sites	Latitude	Surface Water Temperatures Summer	Surface Water Temperatures Winter
Europe			
Côtes-du-Nord, France to Aberdeen, Scotland	48-57.5°N	12.5-16.5°C	5.5-8°C
Australia			
Adelaide to Tamar River Estuary, Tasmania	34.5-41.5°S	14.5-22°C	11.5-14°C
New Zealand			
Auckland to Stewart Island	37-47°S	13-20°C	8-13.5°C
China			
Guangxi to Liaoning	21.5-41°N	24-28°C	0-17°C
Northeastern Pacific			
San Francisco Bay Region	38°N	14.5°C	11.5°C

Sources: Sources: Range data taken from Ranwell 1967, Chung 1983, Partridge 1987, Boston 1992 and Aberle 1993. Water temperatures estimated from charts of mean ocean surface temperatures for February and August in Sverdrup *et al.* 1942.

Where it has become established, *S. anglica* has been extremely successful at colonizing unvegetated tidal flats, and in places has extended its range into the adjacent native salt marsh communities (Gray *et al*. 1991). It has generally been limited to low tidal marsh and flats, but has been observed on sandy, gravel substrates in Puget Sound (Aberle 1993). In British salt marshes, *S. anglica* typically occupies previously bare tidal flats between spring and neap water (Gray *et al*. 1991). San Francisco Estuary tidal marshes already extend below the range of high waters to mean tide level or below, so *S. anglica* may face competition with other plants here. Potential range in the Estuary relative to tidal elevation could be estimated using the regression models developed by Gray (1992),

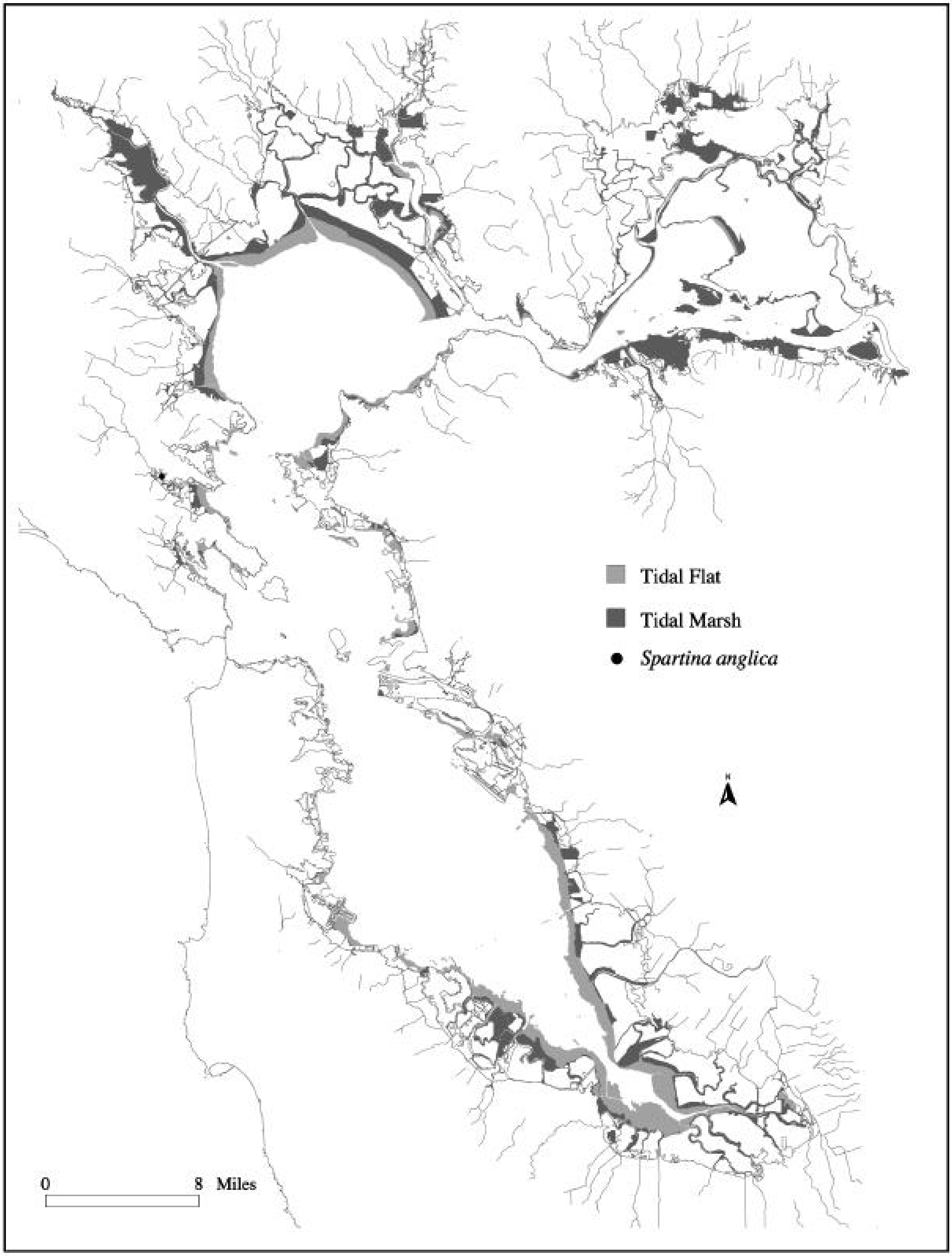

Figure 9. *Spartina anglica*

Compiled by SFEI, 1998 (Basemap: Bay Area EcoAtlas Version 1.50)

which related *S. anglica*'s elevational range to tidal range, fetch, estuary area and latitude using data from estuaries in southwest Britain. However, many of the caveats discussed above for McKee and Patrick's (1988) *Spartina alterniflora* model would apply, and conversions from the British datums would need to be applied.

Control Efforts: *Spartina anglica* control efforts have been undertaken in Southland, New Zealand, in 20 estuaries in the United Kingdom, and to a small extent in France (Mumford *et al*. 1990, Aberle 1993). In Port Susan Bay, Washington (Puget Sound), the Washington Department of Fish and Wildlife applied herbicide to a population of *S. anglica* in 1978 (Mumford *et al*. 1990). Local tribes mow *S. anglica* on their land in Puget Sound, while resource agencies continue to have success with herbicide (Rodeo) application there (K. Patten, pers. comm.).

Spartina patens Aiton (Saltmeadow cordgrass)

General Information: *Spartina patens* is a perennial grass that grows in high marsh. It is native to the eastern United States from Maine to Texas and reported rarely from inland marshes in New York and Michigan. *Spartina patens* was introduced to Cox Island, Siuslaw River, Oregon by 1939 (Frenkel and Boss 1988), Hood Canal, Washington by 1984 (Frenkel and Kunze 1984), and to China in 1977 (Chung 1990). The size of the Cox Island population increased exponentially from less than 90 m^2 in 1939 to more than 3000 m^2 in 1980 (Frenkel and Boss 1988). This species is on CalEPPC's Red Alert List.

Introduction and Spread: In San Francisco Bay, Munz (1968) listed *S. patens* as "reported from Southampton Bay in a marsh, northwest of Benicia, Solano County, *Mall*." Atwater *et al*. (1979) referred to "R. E. Mall's report of salt hay at Southampton Bay" but could not find it there or elsewhere in the estuary. In 1985 Spicher and Josselyn again found "an existing patch" of the plant in Southampton Marsh which "does not appear to have spread from its original location."

Current Distribution: A patch of *S. patens* a few meters in diameter is present on the eastern side of Southampton Marsh where it may be encroaching on a patch of *Cordylanthus mollis* sp. *mollis,* a state-listed rare plant (P. Baye, pers. comm.; Figure 10). At San Bruno Slough, a plant reported as *S. patens* (Josselyn *et al*. 1993) was identified solely on its leaf morphology, as it has not been observed in flower (M. Josselyn, pers. comm.).

Potential Distribution: *Spartina patens* is common at mid-to-high elevations under a range of salinity zones in tidal marshes of the coastal United States, occupying higher elevational positions with decreasing latitude (Frenkel and Boss 1988). In New England marshes, *S. patens* dominates the seaward edge of the high salt marsh, above *S. alterniflora*, which dominates the lower marsh (Bertness and Ellison 1987). In Louisiana, *S. patens* is a significant but not dominant component of salt marshes, but dominates brackish and intermediate (between brackish and fresh) tidal marshlands (Gosselink 1984; Brewer and Grace 1990). On Cox Island in Oregon, *S. patens* is invading the relatively open mid-elevation salt marsh community (*Deschampia caespitosa-Scirpus*

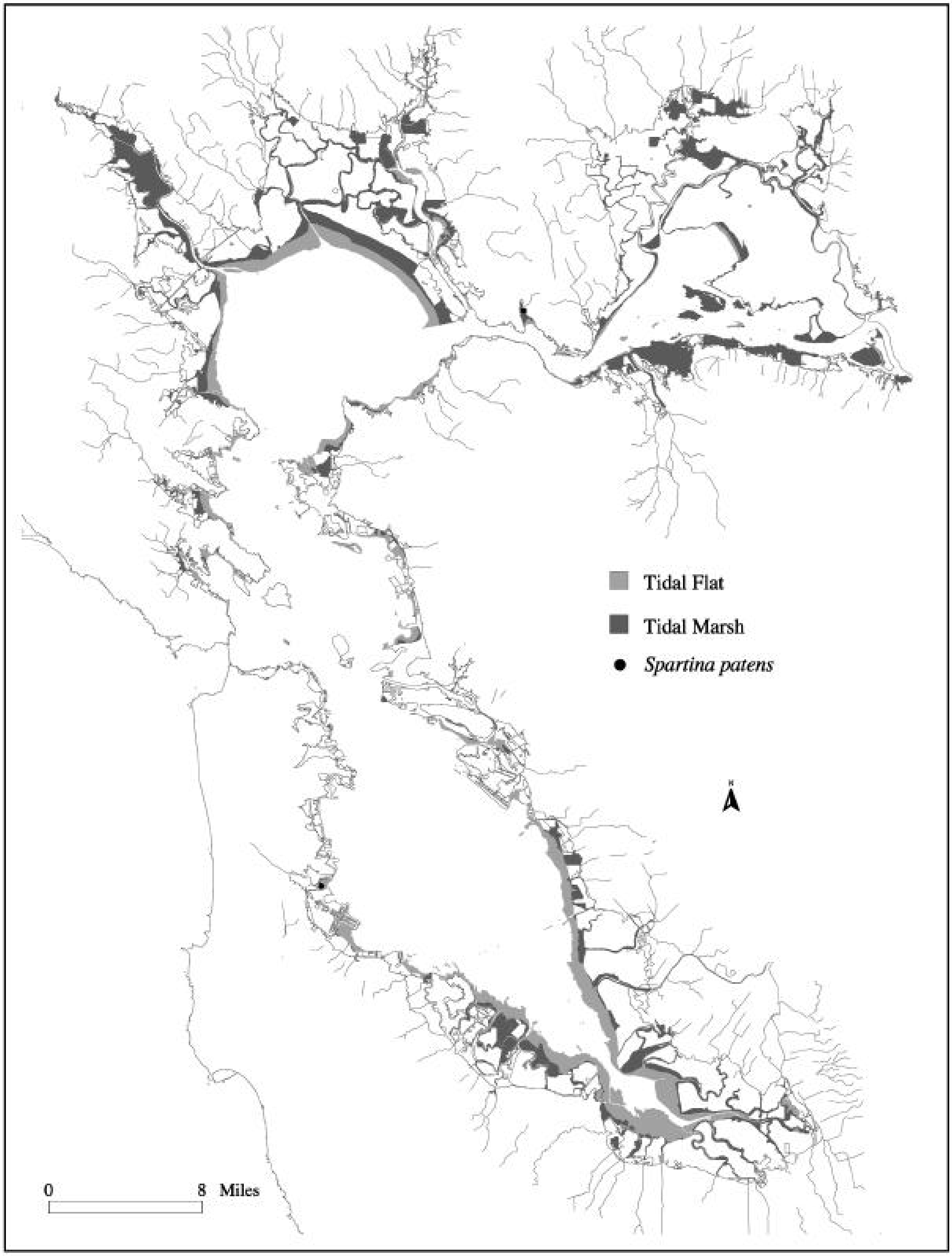

Figure 10. *Spartina patens*

Compiled by SFEI, 1998 (Basemap: Bay Area EcoAtlas Version 1.50)

maritimus, 7.7% bare ground), where its distribution ranges from 1.83 to 2.05 m above MLLW (Frenkel and Boss 1988).

In the Estuary at Southampton Bay, *S. patens* is located at the transition from high marsh to dredge spoils (P. Baye, pers. comm.), somewhat higher than its location at Siuslaw Estuary. While the population at Cox Island has grown exponentially for the past 50 years, at Southampton Bay *S. patens* has not spread appreciably (Spicher and Josselyn 1995; P. Baye, pers. comm.). Based upon physical parameters alone, though, *S. patens* could potentially occupy the mid-high elevational zone of marshes across a wide range of salinities in the Estuary, from nearly fresh to saline tidal marshes.

Control Efforts: Approaches taken at Cox Island, Oregon include burning, salting, covering with black plastic, and spraying with herbicide, though none of these methods has eradicated the *S. patens* population there (Aberle 1993). At Hood Canal, Washington, the Washington State Parks agency applies Rodeo to control *S. patens* (K. Patten, pers. comm.; Ebasco Environmental 1993). To our knowledge, there have been no efforts to control *S. patens* in the San Francisco Estuary.

Status of Watch List Species

***Carpobrotus edulis* Linnaeus N. E. Brown (Iceplant)**

Native to South Africa, *C. edulis* was introduced into the United States in the early 1900s for erosion control along railroad tracks and has been extensively planted along highways, on sand dunes and in high fire-risk areas. Jepson (1951) reported it escaped on the Los Angeles coast. Its fruits have been widely dispersed from planted areas by several native mammals, and it is now common and naturalized along much of the California and Mexican coasts, where it may compete with native species, including several threatened or endangered plants (Munz and Keck 1959; D'Antonio 1993; Hickman 1993; Albert 1995). CalEPPC placed this species on their A-1 List. It is common at the margins of the Estuary's salt marshes, with occasional plants extending below the level of the highest tides (A. Cohen, pers. obs.). At the muted tidal marsh at the Richmond Field Station, *Carpobrotus edulis* has invaded 10-15 feet at the upper marsh margin (R. Grossinger, pers. obs.). *Carpobrotus edulis* often forms monocultural stands, and may have a substantial impact on the high tidal marsh-upland ecotone community.

***Cortaderia jubata* (Andean Pampas Grass or Jubata Grass)**
***Cortaderia selloana* (Pampas Grass)**

Cortaderia species are native to South America and have been planted around the world. These species are now considered invasive in Australia (Harradine 1991) and New Zealand (Gadgil *et al*. 1990) as well as along the California coast (Costello 1986 in Harradine 1991), where C. jubata is the more invasive of the two (M. Rejmonek, pers. comm.). Both species are listed on CalEPPC's A-1 List. *Cortaderia* species are present in the San Francisco Bay region but are not commonly found within the reach of the tides. Populations are found at or just above the high tide line and could potentially move further towards the shore and impact the fresh, brackish, and salt marshes in the Estuary. Several plants have been observed on the brackish marsh plain near Rush Ranch in

Suisun, hundreds of feet from the upper marsh margin (J. Alexander, R. Grossinger, pers. obs.) and with the reach of the tides in Richmond (R. Grossinger, pers. obs.) Populations at the marsh fringe can strongly affect the character of the tidal marsh-upland ecotone and could also progress into the neighboring marshes.

***Iris pseudacorus* Linnaeus (Yellow Flag, Yellow Iris)**
A native of Europe, *Iris pseudacorus* was a popular garden flower that escaped from cultivation. The first populations reported in North America were from areas in New York in 1868 and 1886, from Massachusetts in 1889, and from Canada at Ontario in 1940 (Mills *et al.* 1993, 1995). It is now widespread east of the Rocky Mountains (Hickman 1993), and has been reported from Montana, Oregon and British Columbia (Raven and Thomas 1970). Apparently the first record of *Iris pseudacorus* in California is that of Mason (1957), who reported that it "has escaped in Merced County and is apparently moving down the watercourses." It has since been found in irrigation ditches and pond margins in the San Francisco Bay area, in the southern San Joaquin Valley, and in Sonoma County (Munz 1968; Hickman 1993). Raven observed it in the Delta in 1969 as "relatively small isolated clumps and local populations" at Sand Mound Slough, Rock Slough, Quimby Island and Mandeville Island (Raven and Thomas 1970). Atwater (1980) found it was the only common introduced plant on Delta islets, reporting it from the banks of 4 out of 6 islets surveyed in 1978-79. *Iris pseudacorus* has thus far received little attention in the Estuary, but some observations suggest that it may be impacting some rare native plants (B. Grewell, pers. comm.), and if so it may be a more significant candidate for control

***Lythrum salicaria* Linnaeus (Purple Loosestrife)**
Native to Europe, *Lythrum* is invasive worldwide. It was introduced to North America by the early 1880s and has spread throughout the northern United States and southern Canada. It can grow in monospecific stands, competes with cattails and other marsh plants, and has thereby degraded waterfowl habitat (Mills *et al*. 1993; Hight 1993). It is listed as a noxious weed in California (Hickman 1993) and is on CalEPPC's Red Alert List. *Lythrum* was reported by Munz (1968) in Nevada and Butte counties, but not mentioned by Munz and Keck (1959) or Mason (1957). It is now found in low elevation marshes, ponds, stream banks and ditches throughout much of California, including the Sacramento Valley and the Bay Area (Hickman 1993). Freshwater marshes in the Estuary are at risk of invasion.

Other Plants Considered

We compiled an initial list of introduced tidal marsh plants in the Estuary from published reports and personal communications, which we then modified based on survey responses. Based upon the survey, workshop, and additional research, the Key, Potential, and Watch List species were selected from this list. Those species not placed in one of the priority lists are given below. Some did not fall within the scope of this project, while others are found in the tidal marshes of the Estuary but were not chosen as priorities for a variety of reasons. The native or introduced status of two species, *P. australis* and *T. angustifolia*, is unclear. Some of these species may be of concern locally or in the future, as more information is obtained or as conditions change.

Ailanthus altissima
Apium graveolens
Atriplex semibaccata
Cardaria draba
Conium maculatum
Cotula coronopifolia
Egeria densa
Eichhornia crassipes
Foeniculum vulgare
Phragmites australis
Phyla nodiflora
Polypogon monspeliensis
Tamarisk species
Typha angustifolia
Washingtonia filifera

NEEDED RESEARCH

Six areas of research are recommended to address the problems of introduced species in the San Francisco Estuary:

(1) Region-wide field survey and mapping to produce more reliable maps of the distribution of introduced plants in the Estuary. We believe that incorporating these efforts into a larger Regional Wetlands Monitoring Program, as provided for in the Comprehensive Conservation and Management Plan for the Estuary (SFEP 1994), would be the most effective and assured method of long-term monitoring. Monitoring of introduced tidal marsh plants is needed to assess trends in abundance and dispersal, to assess potential impacts and threats to restoration efforts, and to design and guide effective control efforts and assess their effectiveness. To reliably distinguish some of the cordgrasses and their hybrids, such surveys will need to include expert taxonomic assistance, probably including molecular genetics work in the laboratory.

The workshop that we conducted as part of this project, which included assembling and mapping the current extent of expert knowledge on the distribution of these introduced marsh species, clearly demonstrated the need for such a field survey, and was strongly supported by the workshop participants.

(2) Research on the effect of physical factors, such as inundation period and water and soil chemistry, on the growth and reproduction of introduced tidal marsh plants relative to that of native marsh plants. Such knowledge will be essential to develop improved prediction of potential range, to assess potential impacts on native species, to design marsh restoration projects that will promote native rather than introduced species, and to develop habitat management approaches to controlling introduced marsh plants.

(3) Research on the impacts of introduced marsh plants on native plants and animals. Particularly needed is research on the impacts of introduced marsh plants on rare native plants in brackish and freshwater marsh; and the potential for elimination of native cordgrass by competition and hybridization with introduced cordgrasses.

(4) Research on the efficacy of potential methods of control for introduced marsh plants. One approach would be to set up pilot or small-scale control efforts as experimental tests of the effectiveness of different approaches.

(5) Research on the ecological side effects of potential methods of control, and monitoring of the ecological impacts of control efforts. Ideally, monitoring and research on ecological impacts should be a required component of any pilot or full-scale control effort. Monitoring and research on impacts should be managed by a separate entity from the organization managing the control effort (to avoid the obvious pressures that would otherwise exist to conclude that there are no significant impacts). Information on the ecological side effects of control methods is needed to design control projects that make maximal contributions to restoration.

(6) Research into the vectors for importing introduced marsh plants into the Estuary. Aquatic pest plants of various kinds may be intentionally or unintentionally transported as ornamental plants (commercially or privately), with aquaculture activities, with agricultural (rice) seed, with restoration activities, with dredging equipment, or by other means. A better understanding of the patterns and scale of transport of introduced plants, both along the coast and from other coasts or interior regions, is essential to developing programs to prevent the introductions of new pest plants.

DISCUSSION AND RECOMMENDATIONS

The results of the prioritization suggest that while a number of introduced tidal marsh plants are present in the Estuary, strong concern is currently focused on only a few of these. The three Key Species of Concern recommended by workshop participants—*Lepidium latifolium*, *Spartina alterniflora*, and *Spartina densiflora* —have been the object of control efforts in recent years (Table 2). But these efforts have been insufficient to eliminate populations on a regional or, in many cases, even on a local scale. These species should be the focus of research, monitoring, and control efforts. Four additional species—*Arundo donax, Salsola soda, Spartina anglica, and Spartina patens*—were considered Potential Species of Concern. These species may be of importance locally and should be monitored closely for increasing impacts.

In the San Francisco Estuary, the middle and lower regions of the intertidal zone are at risk of invasion from introduced *Spartina* species. These *Spartinas* are primarily colonizers of salt-to-brackish marsh. However, since the upstream limit of the native *Spartina foliosa* is probably set by competition, and since at least some of the introduced *Spartinas* appear to be much stronger competitors, they may be capable of invading considerably upstream of the native *Spartina*'s range. In the lower regions of freshwater tidal marsh, two plants occur whose status as native or introduced species is unclear: *Phragmites australis* (see below) and *Typha angustifolia*.

The upper portions of fully tidal marshes and the middle and upper portions of muted tidal marshes may be susceptible to invasions by a greater variety of plants. Species which may invade in these areas in salt, brackish or freshwater marshes include *Lepidium latifolium*, *Salsola soda*, *Arundo donax*, *Iris pseudacorus*, *Carpobrotus edulis*, *Cortaderia* species and *Lythrum salicaria* (which were included on the prioritized lists) as well as a variety of other introduced plants that may progressively invade marshes from the upland border.

Cotula coronopifolia (Brass buttons) is a widespread introduced plant in the Estuary, whose growth is promoted as waterfowl feed in diked brackish marshes. Its abundance and ubiquity suggest the possibility of impacts on native species. However, perhaps because of its long residency in the Estuary or its popularity as duck food, its potential negative effects on the environment have not received much attention, and workshop participants did not recommend it for control at this time. There is, however, a recognized need to study its impacts on native plants.

Phragmites australis (= *P. communis*) is described in the latest California flora as a native plant with a worldwide distribution (Allred 1993). However, in recent years *Phragmites* has been aggressively invading marshes in several areas in the eastern United States, which some researchers suspect may have resulted from the introduction of an exotic genotype. *Phragmites* has also recently become an aggressive weed in the diked and managed portions of Suisun Marsh, where the Suisun Resource Conservation District, Ducks Unlimited and local duck clubs have sprayed several thousand acres of *Phragmites* with herbicides since 1995 (Hewitson 1997). It would be of intrest to determine whether the aggressively-spreading populations of *Phragmites* in California represent an exotic genotype. If *Phragmites* were determined to be an introduction, this would probably increase the support for its control.

In addition to the consensus priorities recommended by the workshop participants, several additional concerns warrant discussion, mainly because they relate to the success or failure of future control efforts.

First, the distribution and behavior of introduced plants in the Estuary cannot be entirely predicted from their observed behavior in other parts of the world. Many organisms have successfully invaded habitats outside the limits of physical parameters that characterize their native range. In a few cases, introduced species have dominated habitats where we would have predicted that physical factors would have prevented their survival. These situations could be due to native range limits being set by biological or historical factors rather than physical factors, or to genetic change in the organism after introduction.

Second, we cannot assume that a plant that has been in the Estuary for some time and has not yet spread will not do so in the future. There are many examples of introduced organisms suddenly multiplying and spreading aggressively a long while after their initial introduction, a phenomenon well known to invasions biologists as "lag time" (Kowarik 1995; Crooks and Soulé 1996). Explanations that have been offered include exponential growth interpreted as a lag effect; a population growing beyond the stochastic effects that tend to limit small populations; dispersal out of a small, particularly-favorable habitat (i. e. an "invasion incubator;" Cohen et al. 1995); a change in the invaded environment; a change in dispersal vectors; or a genetic change in the introduced organism.

Third, control priorities should take into account the regional distribution of species relative to their potential to spread inside or outside of the Estuary. There are several introduced marsh plants within the Estuary that are not yet established at other sites in California or even over larger regions, so that removing them from the Estuary would eliminate a significant threat to other estuaries along the coast; and natural dispersal back into the Estuary would be unlikely.

Taken together, these concerns lead us to emphasize the control of introduced plants that currently have restricted distributions and are present in small numbers, regardless of what their past behavior suggests about their likelihood of spreading or having harmful impacts. We therefore make the following recommendations, in addition to those provided by the workshop participants:

- An immediate effort to determine if *Spartina anglica* is present in the Estuary, and to eradicate it if it is. *Spartina anglica* has been called the most aggressively invasive cordgrass in the world. It has been reported from only one site in the Estuary and in small numbers. If it is present in the Estuary, it should be possible to eradicate it quickly and cheaply, without causing any significant damage to other resources. Puget Sound is its only other known site in western North America, where the State of Washington is attempting to control it, so dispersal back into the Estuary would be unlikely.

- An immediate effort to eradicate *Spartina patens* from the Estuary. Its only other western North America sites are Puget Sound and the Siuslaw Estuary in Oregon, and at both sites it is the subject of control programs. It has been reported in the Estuary in small numbers from one or possibly two sites, so, like *S. anglica*, it should be possible to eradicate it quickly, cheaply, without harming other resources, and without much risk of reintroduction.

- A concerted effort to eradicate *Spartina densiflora* from the Estuary. This species has demonstrated its potential for aggressive spread in Humboldt Bay, and it has recently begun to spread more widely in the Estuary. It is still restricted to few sites and is probably eradicable with a reasonable effort. Its recent spread, however, suggests that if we wait much longer it could become a far more difficult and expensive problem. Humboldt Bay is its only other known site in western North America, and dispersal back into the Estuary seems unlikely.

- Initially focusing *Spartina alterniflora* control efforts on eliminating new populations within the Estuary before they become abundant. Although eradication of this increasingly widespread and fairly abundant species will at the very least be difficult, immediate control of outlying populations (such as in Richardson Bay) may prevent it from spreading further in the Estuary, and is the minimum immediate effort necessary if we are to ever have a chance of eradicating it. In addition, the methods and expertise developed by the *Spartina* control effort in Willapa Bay, Wahsington should be drawn on in developing a realistic plan for eradicating *S. alterniflora* from the Estuary.

- Consideration of a program to eradicate *Salsola soda* from the Estuary. Although fairly widespread in the Estuary, its numbers overall are low, though it appears to be spreading steadily and can be very abundant at some sites. It could become a threat to various rare and endangered plants in the upper parts of the Estuary's brackish tidal marshes. It is easily spotted and identified, and at most sites it could probably be eliminated by hand-pulling, perhaps by a coordinated, volunteer effort. No surveys have been done, but as far as we know the only other sites in North America where this plant has been observed are Bodega Harbor (a small population that apparently spread there from San Francisco Bay, and did not persist) and San Diego. Thus if it were eradicated from the Estuary, reintroduction would be unlikely.

- Coordinating control efforts for *Arundo donax* in the Estuary's watershed. Controlling *Arundo* within the Estuary is not possible without also controlling the numerous source populations in the Sacramento and San Joaquin watersheds and the local watersheds of the Bay Area.

There will be a need to maintain communication among experts in the field of introduced tidal marsh plants such that a consensus approach to responding to these problems is developed and adapted. Next steps towards successfully implementing the recommendations described here should be informed by this community of regional experts.

LITERATURE CITED

Aberle, B. L. 1993. The biology and control of introduced *Spartina* (cordgrass) worldwide and recommendations for its control in Washington. Unpubl. Master's thesis, Evergreen State College. 176 pp.

Albert, M. E. 1995. Portrait of an invader II: The ecology and management of *Carpobrotus edulis*. Pp. 4-6 *In* CalEPPC Newsletter, Spring 1995. California Exotic Pest Plant Council.

Alexander, J. 1997. The distribution of *Spartina alterniflora* in San Francisco Bay: A study of invasion and restoration. *In* Dudley, T., J. Reynolds, and M. Poteet (eds.), The science and policy of environmental impacts and recovery. Senior Research Seminar, Environmental Sciences Group Major, Univ. California, Berkeley.

Allred, K. W. 1993. *Phragmites*. P. 1282 *In* Hickman, J. C. (ed.), The Jepson Manual: Higher plants of California. University of California Press, Berkeley.

Atwater, B. F. 1980. Attempts to correlate late Quaternary climatic records between San Francisco Bay, the Sacramento-San Joaquin Delta, and the Mokelumne River, California. Ph. D. thesis, Univ. Delaware. 214 pp.

Atwater, B. F., S. G. Conard, J. N. Dowden, C. W. Hedel, R. L. MacDonald, and W. Savage. 1979. History, landforms and vegetation of the estuary's tidal marshes. Pp. 347-400 *In* Conomos, T. J. (ed.), San Francisco Bay: The Urbanized Estuary. Pacific Div/Amer. Assoc. Adv. Sci., San Francisco.

Atwater, B. F. and C. H. Hedel. 1976. Distribution of seed plants with respect to tide levels and water salinity in the natural tidal marshes of the northern San Francisco Bay Estuary, California. U. S. Geological Survey Report 76-389.

Bell, G. P. 1997. Ecology and management of *Arundo donax*, and approaches to riparian habitat restoration in Southern California. Pp. 103-113 *In* Brock, J. H., M. Wade, P. Pysek, and D. Green (eds.), Plant invasions: Studies from North America and Europe. Backhuys Publishers, Leiden, The Netherlands.

Bertness, M. D. and A. M. Ellison. 1987. Determinants of pattern in a New England salt marsh plant community. *Ecological Monographs* 57(2): 129-147.

Boston, K. G. 1992. The introduction of *Spartina townsendii* (s.l.) to Australia. Pp. 3-8 *In* Fraser-Quick, G. and A. Philips (eds.), The sea has weeds too! Proceedings of a conference on the problem of *Spartina*. Inverloch, Victoria, May 10-12, 1991.

Brewer, J. S. and J. B. Grace. 1990. Plant community structure in an oligohaline tidal marsh. *Vegetatio* 90: 93-107.

California Department of Fish and Game. 1994. Report of Findings, Sacramento-San Joaquin River Delta Levees Investigation pursuant to the Delta Flood Protection Act of 1988. Prepared for State of California, Department of Fish and Game, Region 2 by Harding Lawson Associates, Novato, CA.

California Exotic Pest Plant Council. 1996. Exotic pest plants of greatest ecological concern in California as of August 1996. CalEPPC newsletter, Sacramento, CA.

Callaway, J. C. 1990. The introduction of *Spartina alterniflora* in south San Francisco Bay. M. A. thesis, San Francisco State Univ. San Francisco, CA. 50 pp.

Callaway, J. C. and M. N. Josselyn. 1992. The introduction and spread of smooth cordgrass (*Spartina alterniflora*) in south San Francisco Bay. *Estuaries* 15(2): 218-226.

Carrago, L., G. Patrignani, P. Iacumin, and M. Orsenigo. 1993. Leaf morphology and isotope discrimination in members of the genus *Salsola*. II. Studies on *Salsola soda* L. *Caryologia* 46(4): 335-342.

Chung, C.-H. 1983. Geographical distribution of *Spartina anglica* C. E. Hubbard in China. *Bull. Mar. Sci.* 33(3): 753-758.

Chung, C. 1990. Twenty-five years of introduced *Spartina anglica* in China. Pp. 5-10 *In* Gray, A. J. and P. E. M. Benham (eds.), *Spartina anglica*: a research review. ITE Research Publication 2, Natural Environment Research Council, Institute of Terrestrial Ecology, London.

Cohen, A. C. and J. T. Carlton. 1995. Nonindigenous aquatic species in a United States estuary: A case study of the biological invasions of the San Francisco Bay and Delta. U. S. Fish and Wildlife Service and National Sea Grant Report No. PB96-166525. 246 pp.

Cohen, A. N., J. T. Carlton, and M. C. Fountain. 1995. Introduction, dispersal and potential impacts of the green crab *Carcinus maenas* in San Francisco Bay. *Marine Biology* 122: 225-237.

Conomos, T. J. 1979. Properties and circulation of San Francisco Bay waters. Pp. 47-84 *In* Conomos, T. J. (ed.), San Francisco Bay: the Urbanized Estuary. Pacific Division, Amer. Assoc. Advance. Sci., San Francisco, CA.

Costello, L. R. 1986. Control of ornamentals gone wild: Pampas grass, bamboo, English and Algerian ivy. Pp. 162-170 *In* Proceedings of the 38th California Weed conference.

Crooks, J. and M. E. Soulé. 1996. Lag times in population explosions of invasive species: causes and implications. Pp. 39-46 *In* Sandlund, O. T., P. J. Schei and Å. Viken (eds.), Proceedings of the Norway/UN Conference of Alien Species. Trondheim, 1-5 July 1996, Norwegian Ministry of Environment.

D'Antonio, C. M. 1993. Mechanisms controlling invasion of coastal plant communities by the alien succulent *Carpobrotus edulis*. *Ecology* 74(1): 83-95.

Daehler, C. and D. R. Strong. 1996. Status, prediction and prevention of introduced cordgrass *Spartina* spp. invasions in Pacific estuaries, USA. *Biological Conservation* 78: 51-58.

Daehler, C. and D. R. Strong. 1997. Reduced herbivore resistance in introduced smooth cordgrass (*Spartina alterniflora*) after a century of herbivore-free growth. *Oecologia* 110: 99-108.

Dubyan, D. V., Z. Neuhäuslová, and J. R. Seljag-Sosonko. 1994. Coastal vegetation of the 'Birjucij Island' spit in the Azov Sea, Ukraine. *Preslia* 66(2): 193-216.

Dudley, T. and B. Collins. 1995. Biological invasions in California wetlands: The impacts and control of non-indigenous species (NIS) in natural areas. Pacific Institute for Studies in Development, Environment, and Security, Oakland. 59 pp.

Ebasco Environmental 1993**.** Environmental Impact Statement for control of *Spartina alterniflora* in Willapa Bay. Unpubl. report, 204 pp.

Eicher, A. L. 1987. Salt marsh vascular plant distribution in relation to tidal elevation, Humboldt Bay, California. Unpubl. Masters thesis, Humboldt State University. Arcata, CA. 85 pp.

Ferris, C., R. A. King, and A. J. Gray. 1997. Molecular evidence for the maternal parentage in the hybrid origin of *Spartina anglica* C. E. Hubbard. *Molecular Ecology* 6: 185-187.

Figuerra, M. E. and E. M. Costellanos. 1988. Vertical structure of *Spartina maritima* and *Spartina densiflora* in Mediterranean marshes. Pp. 105-108 *In* Werger, M. J. *et al*. (eds.), Plant form and vegetation structure. SPB Academic Publishing. The Hague, Netherlands.

Frenkel, R. E. 1987. Introduction and spread of cordgrass *Spartina* into the Pacific Northwest. *Northwest Environmental Journal* 31: 152.

Frenkel, R. E. and L. M. Kunze. 1984. Introduction and spread of three *Spartina* species in the Pacific Northwest. Assoc. Am. Geographers, Ann. Meeting, Washington D. C. , April 22-25, 1984. Program Abstracts: 57.

Frenkel, R. E. and T. R. Boss. 1988. Introduction, establishment and spread of *Spartina patens* on Cox Island, Siuslaw Estuary, Oregon. *Wetlands* 8: 33-49.

Gadgil, R. L., P. G. Barton, P. J. Allen, and A. M. Sanderberg. 1990. Growth of pampas grass (*Cortaderia* spp.) in New Zealand *Pinus radiata* forests. *New Zealand Journal of Forestry Science* 20(2): 176-183.

Gosselink, J. G. 1984. The ecology of delta marshes of coastal Louisiana: A community profile. U. S. Fish and Wildlife Report FWS/OBS-84/09, 134 pp.

Gray, A. J. 1992. Saltmarsh plant ecology: zonation and succession revisited. Pp. 63-79 *In* Allen, J. R. L., and K. Pye (eds.), Saltmarshes: morphodynamics, conservation and engineering significance. Cambridge University Press, Cambridge.

Gray, A. J., D. F. Marshall, and A. F. Raybould. 1991. A century of evolution in *Spartina anglica*. *Advances in Ecological Research* 21: 1-62.

Grossinger, R. 1995. Historical evidence of freshwater effects on the plan form of tidal marshlands in the Golden Gate estuary. Unpubl. Master's thesis, University of California, Santa Cruz. Santa Cruz, CA. 130 pp.

Harradine, A. R. 1991. The impact of pampas grasses as weeds in southern Australia. *Plant Protection Quarterly* 6(3): 111-115.

Harvey, H. T. and Assoc. 1993. Aspects of the distribution, ecology, and evolution of dense-flowered cordgrass. Unpubl. report.

Harvey, H. T. and Assoc. 1997. Marsh plant associations of south San Francisco Bay: 1996 comparative study including Alviso Slough. Unpubl. report, 22 January 1997. 117 pp.

Harvey, H. T., H. L. Mason, R. Gill, and T. W. Wooster. 1977. The marshes of San Francisco Bay: their attributes and values. Report to the San Francisco Bay Conservation and development Commission, San Francisco, CA.

Herbold, B. and P. B. Moyle. 1989. The ecology of the Sacramento-San Joaquin Delta: A community profile. U. S. Fish and Wildlife Service Biol. Rep. 85(7.22). 106 pp.

Hewitson, S. 1997. *Phragmites* control program continues in the Suisun Marsh. *Valley Care* (Ducks Unlimited) June/July 1997: 4.

Hickman, J. C. (ed.). 1993. The Jepson manual: Higher plants of California. Univ. California Press, Berkeley. 1400 pp.

Hight, S. D. 1993. Control of the ornamental purple loosestrife (*Lythrum salicaria*) by exotic organisms. Pp 147-148 *In* McKnight, B. N. (ed.), Biological pollution: The control and impact of invasive exotic species. Indiana Academy of Sciences, Indianapolis, 261 pp.

Hughes, V. 1975. The relationship between the upper limit of coastal marshes and tidal datums. National Ocean Survey, Rockville, MD. 84 pp.

Jepson, W. L. 1951. A manual of the flowering plants of California. Univ. California Press, Berkeley. 1238 pp.

Josselyn, M., Larsson, B. and A. Fiorillo. 1993. An ecological comparison of an introduced marsh plant, *Spartina alterniflora*, with its native congener, *Spartina foliosa,* in San Francisco Bay. Romberg Tiburon Center, San Francisco State University, Tiburon. 47 pp.

Kowarick, I. 1995. Time lags in biological invasions with regard to the success and failure of alien species. Pp. 15-38 *In* Pysek, P., K. Prach, M. Rejmanek, and P. M. Wade (eds.), Plant invasions: General aspects and special problems. SPB Academic Publishing, Amsterdam.

Kittelson, P. M. 1993. Expansion of an introduced species of cordgrass, *Spartina densiflora*, in Humboldt Bay, CA. Unpubl. Master's thesis, Humboldt State University, Arcata, CA. 57 pp.

Madrone Assoc. 1977. The Natural Resources of Napa Marsh. Coastal Wetland Series #19, Calif. Dept. of Fish and Game, Sacramento.

Madrone Assoc. 1980. Sacramento/San Joaquin Delta Wildlife Habitat Protection and Restoration Plan. Report for Calif. Dept. of Fish and Game and U. S. Fish and Wildlife Service.

Mason, H. L. 1957. A flora of the marshes of California. Univ. California Press, Berkeley, 878 pp.

May, M. 1995. *Lepidium latifolium* L. in the San Francisco Estuary. Unpubl. report.

McKee, K. L. and W. H. Patrick, Jr. 1988. The relationship of smooth cordgrass (*Spartina alterniflora*) to tidal datums: A review. *Estuaries* 11(3): 143-151.

Miller, G. K., J. A. Young, and R. A. Evans. 1986. Germination of seeds of perennial pepperweed (*Lepidium latifolium*). *Weed Science* 34: 252-255.

Mills, E. L., Leach, J. H., Carlton, J. T. and C. L. Secor. 1993. Exotic species in the Great Lakes: a history of biotic crises and anthropogenic introductions. *Journal Great Lakes Res.* 19(1): 1-54.

Mills, C. E., Carlton, J. T, Chapman, J. W. and A. N. Cohen. 1995. Where have all the flowers gone? The disappearance of hydroids in San Francisco Bay. Poster, 9th Ann. Mtg., Soc. Conserv. Biol., Fort Collins CO, June 7-10, 1995.

Mobberly, D. G. 1956. Taxonomy and distribution of the genus *Spartina*. *Iowa State College J. Sci.* 30: 471-574.

Mooney, H. A., S. P. Hamburg, and J. A. Drake (eds.). 1986. The invasions of plants and animals into California. Pp 250-274 *In* Mooney, H. A. and J. A. Drake (eds.), Ecology of Biological Invasions of North America and Hawaii. Ecological Studies Vol. 58, Springer-Verlag, New York, 321 pp.

Muenscher, W. C. 1944. Aquatic Plants of the United States. Comstock Publishing Associates, Cornell Univ. Press, Ithaca. 374 pp.

Mumford, T. F. Jr., P. Peyton, J. R. Sayce, and S. Harbell, eds. *Spartina* Workshop Record. Seattle, Washington. November 14-15, 1990. 73 pp.

Munz, P. A. 1968. Supplement to a California Flora. Univ. California Press, Berkeley, 224 pp.

Munz, P. A and D. D. Keck. 1959. A California Flora. Univ. California Press, Berkeley, 1681 pp.

Partridge, T. R. 1987. *Spartina* in New Zealand. *New Zealand Journal of Botany* 25: 567-576.

Ranwell, D. S. 1967. World resources of *Spartina townsendii* and economic us of *Spartina* marshland. *Journal of Applied Ecology* 4: 239-256.

Ratchford, S. G. 1995. Changes in the density and size of newly settled clams in Willapa Bay, WA, due to the invasion of smooth cordgrass, *Spartina alterniflora* Loisel. Unpubl. Master's thesis, Univ. Washington.

Raven, P. H. and J. H. Thomas. 1970. *Iris pseudacorus* in western North America. *Madroño* 20: 390-391.

Raybould, A. F., A. J. Gray, M. J. Lawrence, and D. F. Marshall. 1991a. The evolution of *Spartina anglica* C. E. Hubbard (Graminae): origin and genetic variability. *Biological Journal of the Linnean Society* 43(2): 111-126.

Raybould, A. F., A. J. Gray, M. J. Lawrence, and D. F. Marshall. 1991b. The evolution of *Spartina anglica* C. E. Hubbard (Graminae): genetic variation and status of the parental species in Britain. *Biological Journal of the Linnean Society* 44(4): 369-380.

Robbins, W. W., M. K. Bellue, and W. S. Ball. 1941. Weeds of California. California Department of Agriculture, Sacramento, California.

San Francisco Estuary Institute. 1998a. Bay Area EcoAtlas Narrative Documentation Version 1.50. Manuscript in progress. (see *www.sfei.org*).

San Francisco Estuary Institute. 1998b. Draft spatial analysis of the baylands ecosystem. Report to the Bay Area Wetlands Ecosystem Goals Project, 22 January 1998.

San Francisco Estuary Project. 1994. Comprehensive conservation and management plan. U. S. Environmental Protection Agency and Association of Bay Area Governments, Oakland, CA. 236 pp.

Sayce, K. 1988. Introduced Cordgrass, *Spartina alterniflora* Loisel. in Saltmarshes and Tidelands of Willapa Bay, Washington. U. S. Fish and Wildlife Service, 70 pp.

Spicher, D. P. 1984. The ecology of a caespitose cordgrass (*Spartina* sp.) introduced to San Francisco Bay. Unpubl. Master's thesis, San Francisco State University. San Francisco, CA. 82 pp.

Spicher, D. 1985. Distribution and dispersal potential of *Spartina densiflora* in San Francisco Bay. Unpubl. report.

Spicher, D. and M. Josselyn. 1985. *Spartina* (Gramineae) in northern California: Distribution and taxonomic notes. *Madroño* 32(3): 158-167.

Strong, D. R. and C. Daehler. 1995. Alien cordgrass in Pacific estuaries. *In* Proceedings California Exotic Pest Plant Council Symposium '95. J. Lovich, J. Randall, and M. Kelly, eds.

Sverdrup, H. U., M. W. Johnson, and R. H. Fleming. 1942. The oceans: their physics, chemistry and general biology. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Tamasi, J. 1995. Distribution of the introduced plant, *Salsola soda*, in San Francisco Bay. Pages 3-19 in: Sloan, D., Christensen, M. and D. Kelso (eds.), Environmental Issues: From a Local to a Global Perspective. Environmental Sciences Group Major, Univ. California, Berkeley, 330 pp.

Thomas, J. H. 1975. *Salsola soda* L. (Chenopodiaceae) in central California. *Madroño* 23(2): 95.

Thompson, J. D. 1991. The biology of an invasive plant – what makes *Spartina anglica* so successful. *BioScience* 41: 393-401.

Trumbo, J. 1994. Perennial pepperweed: A threat to wildland areas. *California Exotic Pest Plant Council News* 2(3): 4-5.

Young, J. A., D. E. Palmquist, and S. O. Wotring. 1997. The invasive nature of *Lepidium latifolium*: A review. Pp. 59-68 *in* Plant invasions: Studies from North America and Europe. Brock, J. H., M. Wade, P. Pysek, and D. Green, eds. Backhuys Publishers, Leiden, The Netherlands.

Young, J. A. and C. E. Turner. 1995. *Lepidium latifolium* L. in California. *California Exotic Pest Plant News* Winter 1995: 4-5.

Personal Communication

Joy Albertson, Don Edwards San Francisco Bay National Wildlife Refuge

Peter Baye, U. S. Fish and Wildlife Service

Curt Daehler, University of Hawaii

Tom Dudley, University of California, Berkeley

Phyllis Faber, California Native Plant Society

Brenda Grewell, Department of Water Resources

Paul Jones, U. S. Environmental Protection Agency

Stephen Jones, Alameda County Flood Control District

Michael Josselyn, San Francisco State University

Paul Kelly, California Department of Fish and Game

Karl Malamud-Roam, Contra Costa Co. Mosquito and Vector Control District

Gary Page, Point Reyes Bird Observatory

Kim Patten, Washington State University

Steve Schoenig, California Department of Food and Agriculture

Debra Smith, East Bay Regional Park District

Doug Spicher, Wetland Research Associates

Don Strong, University of California, Davis

Mark Taylor, East Bay Regional Park District

Jean Takekawa, U. S. Fish and Wildlife Service

Joel Trumbo, California Department of Fish and Game

APPENDIX 1. Form Employed in Survey.

APPENDIX 2. List of Survey Recipients and Workshop Participants.

Survey of Introduced Tidal Marsh Plants in the San Francisco Estuary

In Preparation for a Regional Workshop in Fall 1997

San Francisco Estuary Institute
September 1997

In response to growing concerns about the potential impacts of a range of introduced tidal marsh plants in the San Francisco Estuary, the San Francisco Estuary Institute (SFEI) is compiling information to help local, state, and federal agencies prioritize control efforts. This effort is funded by Category III of CALFED. As part of this project, SFEI will be producing maps of the current distribution of key introduced plants within the Estuary; assembling data about ecological and economic effects, and control methods; and holding a regional workshop.

You have been suggested as having expertise on one or more introduced tidal marsh plants in the Estuary. We would appreciate your help in identifying key introduced species and general areas of known populations, and in assessing priorities for control. This brief survey is intended to help integrate basic knowledge and concerns of the community of expertise on introduced marsh plants in the Estuary, as a first step towards developing shared priorities and goals for control. We will present the results of our research, including this survey, at a workshop in late 1997.

Please return competed surveys to SFEI by **September 10**. Comments and questions about this survey can be emailed to Robin Grossinger at *robin@sfei.org*.

Return completed survey to:
San Francisco Estuary Institute **Attn: Robin Grossinger** **1325 S. 46th Street** **Richmond, CA 94804**

***Phone*: (510) 231-5742**
***Fax*: (510) 231-9414**

Please use this map as a guide when answering Question 1.

QUESTION 1: Abundance

The table below lists introduced plant species reportedly appearing in **tidal marsh** in the San Francisco Estuary.

Abundance:

For each of the subregions listed in the table, please estimate the abundance of each species **within tidal marsh** with one, and only one, of the following rankings. (Note: this does not include aquatic non-marsh plants, seasonal wetlands not subject to the tides, or plants growing above the normal reach of the tides.) The subregions are defined in the map on the preceding page. Please base these estimates on your own direct knowledge, rather than on published reports or other accounts, and fill as many cells as possible. We have listed 17 species and 5 subregions; however, we expect that most people will focus on a few species and/or areas. If we've missed any species that you think should be included, please add them on the blank lines.

N = not present R = rare C = common A = abundant
P = present, but don't know enough to estimate abundance
***Blank* = don't know enough to provide an answer**

Priority of Control:

In the last column of the table, please categorize each species in terms of your judgment of the priority of controlling the species, relative to controlling other introduced species, using the following rankings:

H = highest priority M = middle priority L = lowest priority

Assign one rank to each species listed based upon your knowledge. We're asking you to take an Estuary-wide perspective, using your best judgment as a biologist or resource manager, excluding as much as possible immediate agency or individual focus. In assigning these ranks, consider such factors as existing and potential environmental and economic impacts or benefits, the potential for successful eradication or control, the economic and environmental costs of control efforts, and any other concerns that you feel are relevant. The relative importance of these concerns will be queried on the next page.

Abundance **Priority**

Plant Name	Delta	Suisun	North Bay	Central Bay	South Bay	
Arundo donax (giant reed)						
Atriplex semibaccata (Australian saltbush)						
Cardaria draba (white-top, hoary cress)						
Carpobrotus edulis (iceplant)						
Carpobrotus conicesia (iceplant)						
Cortaderia jubata (pampas grass)						
Cortaderia selloana (pampas grass)						
Cotula coronopifolia (brass buttons)						
Iris pseudacorus						
Lepidium latifolium (perennial pepperweed)						
Lythrum salicaria (purple loosestrife)						
Phyla nodiflora (mat grass)						
Salsola soda						
Spartina alterniflora (smooth cordgrass)						
Spartina anglica (English cordgrass)						
Spartina densiflora (dense-flowered cordgrass)						
Spartina patens (salt meadow cordgrass)						

QUESTION 2: Prioritization Concerns

As a starting point in our prioritization process, SFEI will be evaluating the concerns listed below. For the questions about control, base your answers on the control method you think is most appropriate. While some of the species listed also affect terrestrial systems, focus your responses on their estuarine effects. Please assign a rank to each species for the following categories:

H = high M = moderate L = low *Blank* = don't have enough information to answer

Plant Name							**Potential Cost of Control**		
***Arundo donax** (giant reed)*									
***Atriplex semibaccata** (Australian saltbush)*									
***Cardaria draba** (white-top, hoary cress)*									
***Carpobrotus edulis** (iceplant)*									
***Carpobrotus conicesia** (iceplant)*									
***Cortaderia jubata** (pampas grass)*									
***Cortaderia selloana** (pampas grass)*									
***Cotula coronopifolia** (brass buttons)*									
Iris pseudacorus									
***Lepidium latifolium** (perennial pepperweed)*									
***Lythrum salicaria** (purple loosetrife)*									
***Phyla nodiflora** (mat grass)*									
Salsola soda									
***Spartina alterniflora** (smooth cordgrass)*									
***Spartina anglica** (English cordgrass)*									
***Spartina densiflora** (dense-flowered cordgrass)*									
***Spartina patens** (salt meadow cordgrass)*									

<u>Workshop:</u> SFEI will be holding a workshop in November to present the results of this survey and to discuss approaches to prioritizing regional introduced tidal marsh plant control efforts. The tentative dates of **November 13 and/or 14** have been set for this workshop.

Would you be interested in participating in such a workshop? If so, what type of workshop do you feel would be most useful to your work?
1 day: whole day presentations 1 day: half day presentations, half day discussion
1 day: whole day workshops 2 days: one day presentations, one day workshops

At the workshop, would you be willing to participate in a group exercise mapping the distribution of some of these species on SFEI's base map of the Estuary? YES NO

Would you like to receive a copy of the final report for this project? YES NO

Personal information: Name ____

Agency ____

Mailing address ____

(if different from ____

mailing label)____

Phone ____

Fax ____

E-mail address ____

Preferred method of correspondence: Phone Fax E-mail Mail

This survey has been sent to the following people, who will also be invited to the regional workshop. Are there additional people who should receive this survey and the workshop invitation? Please write their names and contact information below.

David Ainley
Joy Albertson
Pete Alexander
Greg Archbald
Vic Baracosa
Bob Batha
Peter Baye
Dennis Becker
Dennis Beebe
Fred Botti
Pat Boursier
Andree Breaux
Robert Brenton
Nancy Brownfield
Mike Casazza
Steve Chappell
David Chipping
Bob Coates
Gretchen Coffman
Howard Cogswell
Tom Cooper
Roger Crawford
Carla D'Antonio
Melanie Denninger
Joe Didonato
Charlie Dill
Tom Dudley
Ron Duke
Barbara Ertter
Jules Evens
Phyllis Faber
Erin Fernandez
Peggy Fiedler
Steve Foreman
Steve Granholm
Ruth Gravanis
Brenda Grewell
Jeff Haltiner
Janet Hanson
Elaine Harding-Smith
Susan Hatfield
Bruce Herbold
Diana Hickson
Kathy Hieb
Tom Hoffman
Glen Holstein
Mark Hoshovsky
Ann Howland
Mark Jennings
Mike Johnson
Paul Jones
Steve Jones
Michael Josselyn
Paul Kelly
William Kier
Margaret Kolar
Brita Larssen
Robert Leidy
William Lidicker
Wes Maffei
Karl Malamud-Roam
Michael May
Brad Olson
Gary Page
Lorraine Parsons
Mike Pitcairn
Ruth Pratt
Nigel Quinn
Betsy Radtke
John Randall
Fritz Reid
Marcel Rejmanek
Eliska Rejmankova
Mike Rigney
Howard Shellhammer
Jake Sigg
Debra Smith
Doug Spicher
Don Strong
Jean Struthers
Jim Swanson
Bob Tasto
Mark Taylor
Laureen Thompson
Lynn Trulio
Joel Trumbo
Michael Vasey
Betty Warne
Peter Warner
Lisa Wayne
Frank Wernette
Carl Wilcox
Ted Winfield
Glen Wylie
Tom Yocum
John Zentner

Additional contacts:____

____

Please notify us if you or your agency can contribute any data, reports, or management plans that may be of use to this mapping and prioritization project.

Thank you very much for your help.

Appendix 2. List of Survey Recipients and Workshop Participants

(a) *Workshop attendees who did not receive a survey*
(b) *Workshop attendees who received a survey*

Patrick Abers, California Department of Food and Agriculture (a)
David Ainley, H.T. Harvey and Associates
Joy Albertson, Don Edwards San Francisco Bay National Wildlife Refuge
Pete Alexander, East Bay Regional Park District (b)
Greg Archbald, Golden Gate National Park Association
Debra Ayres, University of California, Davis (a)
Vic Baracosa, Solano Co. Mosquito Abatement District
Bob Batha, Bay Conservation and Development Commission
Peter Baye, U. S. Fish and Wildlife Service (b)
Dennis Becker, California Department of Fish and Game
Dennis Beebe, Solano Co. Mosquito Abatement District
Fred Botti, California Department of Fish and Game
Pat Boursier, H. T. Harvey and Associates
Andree Breaux, Regional Water Quality Control Board (b)
Robert Brenton
Nancy Brownfield, East Bay Regional Park District (b)
Roger Byrne, University of California, Berkeley (a)
Mike Casazza, U. S. Geological Survey
Steve Chappell, Suisun Resource Conservation District (b)
David Chipping, California Native Plant Society
Bob Coates, Phillip Williams and Associates
Howard Cogswell, Eco-Aire Photos
Tom Cooper, Marin-Sonoma Mosquito Abatement District
Roger Crawford, San Francisco State University
Carla D'Antonio, University of California, Berkeley
Melanie Denninger, California Coastal Conservancy
Kristen Dessange, Hayward State University (a)
Joe Didonato, East Bay Regional Park District (b)
Charlie Dill, Marin-Sonoma Mosquito Abatement District
Tom Dudley, Univeristy of California, Berkeley (b)
Ron Duke, H. T. Harvey and Associates
Barbara Ertter, University of California, Berkeley
Jules Evens, Avocat Research
Phyllis Faber, California Native Plant Society (b)
Dave Feliz, California Department of Fish and Game (a)
Erin Fernandez, Don Edwards San Francisco Bay National Wildlife Refuge
Peggy Fiedler, University of California, Jepson Herbarium
Steve Foreman, Resource Management
Steve Granholm, LSA Associates, Inc.
Ruth Gravanis, California Native Plant Society (b)
Brenda Grewell, Department of Water Resources (b)
Jeff Haltiner, Phillip Williams and Associates
Janet Hanson, San Francisco Bay Bird Observatory
Elaine Harding-Smith, University of California, Santa Cruz
Susan Hatfield, U. S. Environmental Protection Agency
Bruce Herbold, U. S. Environmental Protection Agency
Diana Hickson, California Department of Fish and Game
Kathy Hieb, California Department of Fish and Game
Glen Holstein, Zentner and Zentner (b)
Mark Hoshovsky, California Department of Fish and Game

Ann Howald, California Exotic Pest Plant Council
Mark Jennings
Mike Johnson, University of California, Davis
Paul Jones, U. S. Environmental Protection Agency (b)
Stephen Jones, Alameda County Public Works Agency (b)
Michael Josselyn, San Francisco State Univeristy
Paul Kelly, California Department of Fish and Game
William Kier, William Kier and Associates
Marge Kolar, Don Edwards San Francisco Bay National Wildlife Refuge
Brita Larsson, San Francisco State University (b)
Teresa LeBlanc, California Department of Fish and Game (a)
Robert Leidy, U. S. Environmental Protection Agency
William Lidicker, University of California, Berkeley
Wes Maffei, Alameda Co. Mosquito Abatement District
Frankie Malamud-Roam, University of California, Berkeley (a)
Karl Malamud-Roam, Contra Costa County Mosquito and Vector Control District
Michael May, San Francisco Estuary Institute
Brad Olson, East Bay Regional Park District
Gary Page, Point Reyes Bird Observatory
Lorraine Parsons, Wetland Research Associates
Mike Pitcairn, California Department of Fish and Game
Ruth Pratt, U. S. Fish and Wildlife Service
Nigel Quinn, U. S. Bureau of Reclamation
Betsy Radtke, San Pablo Bay National Wildlife Refuge
John Randall, The Nature Conservancy
Gale Rankin, Santa Clara Valley Water District (a)
Fritz Reid, Ducks Unlimited
Marcel Rejmanek, University of California, Davis (b)
Eliska Rejmankova, University of California, Davis
Steve Schoenig, California Department of Food and Agriculture (a)
Howard Shellhammer, San Jose State University
Jake Sigg, California Native Plant Society (b)
Debra Smith, East Bay Regional Plant District (b)
Doug Spicher, Wetland Research Associates
Don Strong, University of California, Davis (b)
Jean Struthers, California Native Plant Society
Jim Swanson, California Department of Fish and Game
Bob Tasto, California Department of Fish and Game
Mark Taylor, East Bay Regional Park District
Laureen Thompson, California Department of Fish and Game
Huy Tran, Hayward State University (a)
Lynn Trulio, San Jose State University
Joel Trumbo, California Department of Fish and Game
Luisa Valiela, U. S. Environmental Protection Agency (a)
Louise Vicencio, San Pablo Bay National Wildlife Refuge (a)
Betty Warne, U. S. Fish and Wildlife Service
Frank Wernette, California Department of Fish and Game
Carl Wilcox, California Department of Fish and Game
Ted Winfield, Entrex, Inc.
Glen Wylie, U. S. Geological Survey
Tom Yocum, U. S. Environmental Protection Agency
Katy Zavemba, California Native Plant Society (a)
John Zentner, Zentner and Zentner