

San Francisco Bay Habitat Index Indicator Analysis and Evaluation

Developing an Index of Habitat Recovery for San Francisco Bay

ABSTRACT:

Wetland, mudflat and riparian habitats throughout the Bay have been eliminated or reduced in quality by significant land conversion since European colonization. Many threatened and endangered species and commercial and recreational fish and shellfish species depend on these habitats. Because the re-establishment of natural physical processes and associated vegetation is the first step in the restoration of full ecosystem function, increases in the aerial extent of these habitats can be seen as an initial sign of ecosystem recovery. The San Francisco Bay Habitat Index estimates the extent of habitat types essential to wetland, tidal flat and riparian associated species in the San Francisco Bay Region. It also provides a measure of habitat restoration, which is a mission and/or mandate of numerous federal and state agencies. The index is based on information from studies of bayland historical conditions, recent aerial photography (SFEI EcoAtlas v.1.5), and estimates of restored habitat from restoration project databases.

INTRODUCTION:

The San Francisco Bay estuary, the interface between the Pacific Ocean and California's largest watershed, is surrounded by a mosaic of aquatic associated habitats, including tidal and non-tidal wetlands, tidal mudflats and riparian corridors that are habitats to a myriad of species. These habitats once contiguous, have been severely fragmented, reduced, and degraded since European colonization (Goals Project 1999). Across the nation, coastal wetlands and submersed habitats including mudflats, are being destroyed by erosion, dredge and fill, impoundments (levees), excessive sedimentation, toxic pollutants, and eutrophication. In the Bay region the most significant reductions in these habitats occurred in the late 1800's when farmers began diking and draining the tidal marshes in the 1850s, encouraged in part by the federal Arkansas Act of 1850 and by subsequent state legislation, the Green Act of 1868. Development in the bayland margins severely affected tidal and non-tidal wetlands and tidal flats by infill, land conversion, and isolating remnants from natural freshwater flows and tidal marsh inundation. Meanwhile, riparian vegetation was also eliminated for housing, firewood and land conversion. In the Bayland margins and further up the watershed, these areas were converted to urban and agriculture uses and in many instances, streams diverted or eliminated completely. The result has been to reduce the amount of habitat available, isolate habitats leading to a reduction in habitat quality, and a reconfiguration of the habitats to include more freshwater and highly saline habitats including non-tidal diked marshes and salt ponds (Figure 1).

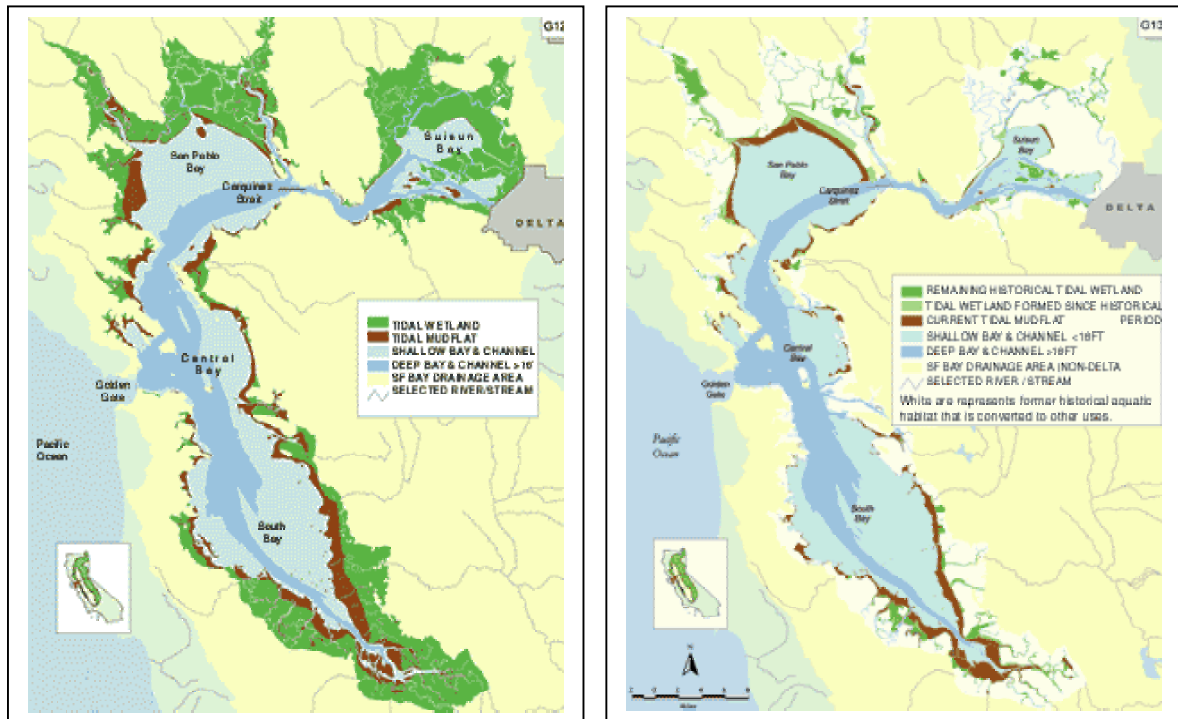


Figure 1: These maps illustrate the changes in tidal marsh and mudflat habitats from the mid-1800s to today. Source: The Bay Institute. 1998. From the *Sierra to the Sea: The Ecological History of the San Francisco Bay-Delta Watershed*. Calculations for these maps were based on SFEI's EcoAtlas Version 1.5.

Wetlands, tidal mudflats and riparian habitats are highly productive systems; providing a rich resource for a variety of flora and fauna. Changes in habitat quality and configuration affect the species that inhabit these areas, favoring some species at the expense of others. Many rare species that once inhabited these areas are extinct; others are nearly so, and many fish and wildlife that depend on more naturally occurring habitats continue to be impacted (see Shellfish, Bird and Fish indexes). These habitats also provide a broad array of economic and social benefits. They support education, recreation, a large industry of sport fishing and hunting (see Fishable index), and provide an important aesthetic resource for bay area residents. These relationships are complex and vital to ecosystem health. Figure 2 illustrates in a general way, how the Habitat Extent Index is related to other key ecosystem attributes represented in the Bay Institute's Ecological Scorecard and emphasizes the importance of these bay region habitats in supporting both biological and human uses.

The large scale historic loss of these habitats throughout the San Francisco Estuary has prompted major restoration initiatives including the Goals Project, CALFED, the San Francisco Joint Venture, and the San Pablo Bay Watershed Framework Plan (Goals Project 1999; CALFED 2000; Steere and Schaefer 2001; Camp Dresser and McGee and the Bay Institute 2001). Most of these initiatives emphasize tidal marsh

restoration in extensive diked areas that were formerly tidal wetlands. State, federal and local agencies have proposed restoration of between 13,000 and 26,000 hectares of tidal marsh in San Francisco Bay (Goals Project 1999; Steere and Schaefer 2001; CALFED 2000). Because the re-establishment of natural physical processes is the first step in the restoration of full ecosystem function, increases in the extent of habitat, even in their initial stages of “restoration” can be viewed as an initial sign of ecosystem recovery, provided that these advances are not negated by sea level rise (Orr et. al. 2003). Because restoration typically requires large investments and there are trade-offs between the types and locations of habitat to be restored, it is essential to develop a means to measure progress over time. Potential uses for habitat extent and condition indicators include a means to inform policy makers of habitat condition and trends in restoration, indicate risks to fish and wildlife, integrate habitat information with restoration and management plans, and measure performance towards environmental sustainability.

The San Francisco Bay Habitat Index estimates the extent and distribution of “historically present” habitat types (tidal marsh, tidal flat, seasonal wetlands, and riparian habitats) deemed essential to aquatic ecosystem health in the San Francisco Bay watershed. It also provides baseline estimates of two man-made habitat types (diked non-tidal marsh and salt ponds and lagoons) that provide value to many forms of biota, whose conversion and/or enhancement is planned. These habitats are contiguous: mudflat grades into tidal marsh and upland into seasonal marshes as the elevation and exposure to inundation dictates. Despite this gradation, the habitat extent index measures discreet habitat types, in order to provide managers with a better understanding of losses and a means of tracking enhancement and restoration over time (see Table 1).

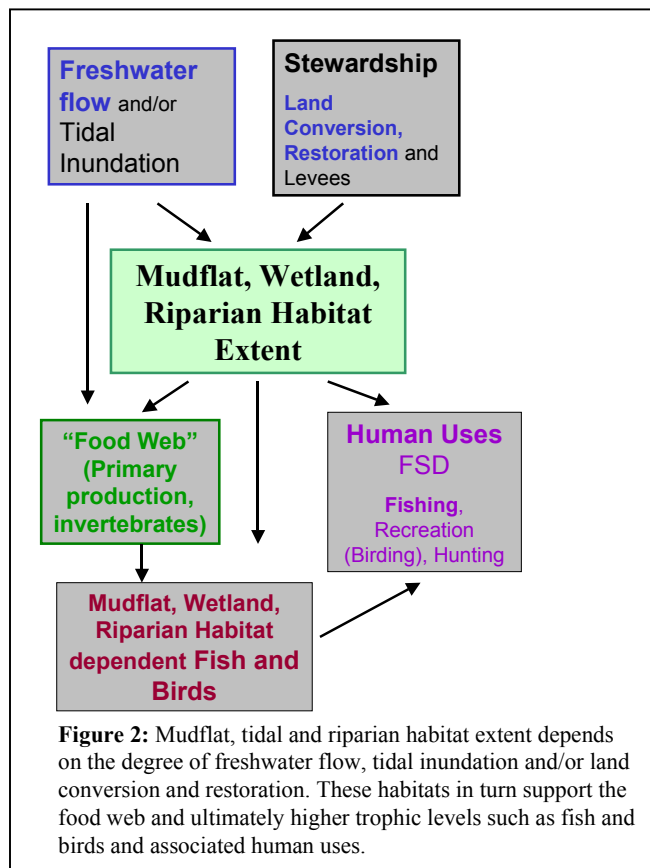


Table 1: Habitat Definitions

Tidal wetlands – Vegetated wetland that is inundated by tides. It extends from the lowest extent of vascular vegetation to the maximum height of the tides and can vary in salinity, from saline, brackish to freshwater. Tidal marshes include tidal channels or sloughs and sometimes marsh pans, natural ponds that only fill with water during very high tides.

Tidal Flat habitat – Habitat along the lowest tide level to the mean tide level that supports less than 10 percent emergent vegetation cover. It includes mostly mudflat, and some sand flats and shell flats.

Seasonal wetland habitat – Wetlands that are not tidally inundated, and usually seasonal. They include moist grasslands and vernal pools. Today, these grasslands still exist in the Bay area, although their botanical makeup differs from historic conditions.

Riparian habitat – Habitat bordering creeks, rivers, lakes, or other bodies of water. Plant species, soil types, and topography are distinctive when compared to the surrounding, drier upland area.

Non-tidal diked wetlands* – Areas of historic tidal marshes that have been isolated from tidal influences by dikes or levees, but which maintain wetland features.

Salt ponds* – Large persistent hypersaline ponds that are intermittently flooded with Bay water. There are extensive complexes of these man-made ponds in the North and the South bays that are slated for restoration to tidal marsh.

It should be emphasized that the Habitat Index does not directly measure many of the characteristics or stressors that affect wetland and tidal marsh quality. Though the index represents an initial step in measuring habitat recovery in the Bay region since measurements were made in 1998 (Goals 1999); additional detail on habitat quality is one method to improve this index. Currently there are ongoing pilot studies that may lead to methods that can be used regionally to evaluate wetland habitat quality (Collins et. al 2003; Breaux et. al. 2003). There is also a large west coast research consortium, the Pacific Estuarine Ecological Indicators Research Consortium (<http://www.bml.ucdavis.edu/peeir>) investigating indicators of wetland health that is slated to yield practical measures of condition.

METHODS, DATA SOURCES AND CALCULATIONS

The development of a habitat extent index requires knowledge of past and present land cover conditions, and a means of measuring changes in these conditions over time. Land cover change is a direct measure of quantitative habitat loss or gain. Five years is the

recommended frequency of change detection for most regions, but shorter periods may be necessary in regions undergoing rapid economic development or affected by catastrophic events (NOAA 1995). Documentation of the loss or gain of these habitats is needed to conserve and effectively manage these resources.

Though the development of a habitat extent index appears simple in concept, this concept was not possible without the advent of several state and federal supported mapping efforts. Consistent definitions and regional jurisdictions are needed to create a repeatable process. In the bay region, until the National Wetlands Inventory and the Bayland Habitat Goals process (1999) were initiated, there were no efforts to periodically measure land cover change in the same way, on a periodic basis.

The National Wetlands Inventory of the U.S. Fish and Wildlife Service was initiated by the Emergency Wetland Resources Act of 1986 which directs the Service to map the wetlands of the United States (NWI, Accessed 2003). This national mapping effort does not contain the detail or is updated frequently enough to track changes in habitats due to restoration. Currently there are efforts to update and refine these maps; however, this process is in its initial planning stages (Potter, personal communication). In San Francisco Bay, in light of significant reductions in bayland¹ habitats, there has been considerable attention placed on documenting and restoring these habitats, resulting in an impressive cooperative effort to establish a science based process and document outlining habitat goals for the region (Goals Project 1999). The EcoAtlas, a regional GIS (Geographic Information System), was established to support the Goals process and is managed by the San Francisco Estuary Institute (SFEI) (Grosinger, 2001). The EcoAtlas, provides a map and calculations of habitat types and is an essential foundation for the Bayland Habitat Goals document. The proposed Habitat Index would not be possible without these resources, which represent the work of more than 200 local volunteers - experts that helped define and execute the Habitat Goals process and contributed to the EcoAtlas (Goals Project 1999.) The EcoAtlas catalogues a range of habitats as small as 0.03 acres over about fifteen hundred square miles (Grossinger 2001). These products were essential for developing historic and 1998 condition habitat baselines for the San Francisco Bay Habitat index. Despite these efforts, habitats in local San Francisco Bay watersheds are not well mapped. The EcoAtlas and the Habitat Goals process includes only bayland margin habitats and does not include estimates of essential riparian habitat in the upper watershed. Furthermore, the EcoAtlas is in danger of becoming another snapshot approach without additional funding to update the GIS.

Methodology: For each habitat type, we developed a list of historic and recent acreage estimates from existing documents (i.e.; Goals 1999; Steere and Schaefer 2001). Several local restoration project databases were accessed to update the habitat acreage estimates (Appendix 2). We also compared the updated figures to large-scale regional planning and restoration goals. The process for calculating current habitat extent is shown in the box below. The determination of current habitat acreage and its evaluation relative to historic conditions relies on the availability of three distinct estimates of habitat extent:

¹ Bayland – term used by practitioners and in the Habitat Goals process to refer to habitats along the Bay including tidal flat, marsh as well as other man modified habitats in diked areas.

pre-European historic extent (HE), most recent current estimates from remote sensing imagery or aerial photography (RE), and additional acreage calculations added due to restoration project completion (RPE) after 1998.

Historic habitat extent: *Tidal wetlands, mudflats, non-tidal wetlands (grasslands and seasonal wetlands)*: Historic estimates of habitat extent prior to European habitation were derived from the Bay area EcoAtlas (SFEI 1998, see www.sfei.org). These estimates are based on a composite of hundreds of historic accounts integrated by SFEI to represent historic conditions (circa 1800) in the Estuary. Major data sources included the U.S. Coast Survey Hydrographic and Topographic sheets, other early federal maps, Mexican land-grant surveys, city and county surveys, and explorer's journals.

Recent historic conditions (circa 1998): The most recent estimates of habitat extent for each of the habitats were derived from the Bay area EcoAtlas (SFEI 1998; Sierra to the Sea 1998; Goals Project 1999). The results of this work was published in 1998; and were obtained by updating imagery from remote sensing images of 1994-95 with significant input from local experts (www.sfei.org).

Restoration project analysis: TBI evaluated and calculated restored acres from numerous restoration project databases that are updated with varying degrees of frequency (Table B-2 below). This process is essential as remote sensing is not performed on a regular basis and it is also important to track restoration progress. There is currently no way to ensure that all projects are evaluated and added to this estimate; however, by evaluating multiple sources of information (databases and interviewing restoration ecologists), we can more reliably "capture" most restoration projects in our estimate. In addition to our previous analysis (TBI poster, October, 2002), a more recent independent survey by Wetlands and Water Resources (<http://www.swampting.org>) was consulted to update previous estimates and provide additional information about projects. The maps and spreadsheets provided by Wetlands and Water Resources (WWR) for the North, South and Central Bay sub-regions were particularly helpful for the calculation of wetland indicators as they offered a means to calculate trends in wetland restoration over time and a means to look at whether wetland restoration projects are tidal, muted or seasonal. We consulted the Wetland Projects Tracker database (<http://www.wrmp.org/projectsintro.html>), which has made the lists generated by Wetlands and Water Resources available through a useful query based system. We also checked project designations and verified the status of ongoing projects by consulting with restoration practitioners, particularly for recently completed projects.

Projects were counted as additional restored acres only if the database consulted or a restoration practitioner deemed the project as "on the ground" and completed in terms of anthropogenic manipulation since the beginning of 1999. This period was used as a starting point in order to update the habitat acreage figures in the Goals report. We acknowledge that "project completion" does not necessarily indicate full restoration; however it provides a good estimate of restoration progress. In addition, the Central and South Bay region data provided by WWR provided information on whether the projects

were considered recovery (restoration), enhancement, creation or mitigation projects² (see definitions below). These designations were utilized to classify the North Bay and Suisun Bay projects (mapping of Suisun projects is not yet available) to obtain more reliable estimates of restoration progress. Mitigation projects were only counted in our restoration estimates if they were deemed to account for new habitat since the 1998 Habitat Goals estimates. Projects that were created in areas where wetlands did not naturally occur were not counted. Only – projects in the area fell into this category and were generally of minimal acreage. Examples include the Sunnyvale Baylands Park project freshwater wetlands of 1.6 acres. The final lists of projects completed in 1998 estimate can be found below (Appendix 1.)

Box 1: Habitat Extent Calculations

For each habitat type the following definitions and calculations were applied.

HE = *Historic habitat extent*

98E= *Most recent estimate of habitat extent from aerial surveys, remote sensing updated with information from practitioners in 1998*

RPE = *Total Restoration project acres restored after 1998 (from restoration project analysis)*

RT = *Restoration targets (Habitat Goals, Joint Venture)*

Restoration Projects can be further broken down into project types: Restoration (R), Enhancement (E), Creation (C) and Mitigation (M). Restoration projects are added to the current extent estimates only if they represent new habitat added after 1998. In other words they must be restoration projects that are not mitigation for current losses.

These values enable at least two types of calculations:

Current percent of Historic habitat = $(98E+RPE) / HE \times 100$

Percent of Desired Restoration Goals = $(98E+RPE) / RT \times 100$

Note: The overall score is the average of habitat types included in the index.

² *Restoration:* re-creating wetland conditions on lands without such conditions immediately prior to the project (restoration). *Enhancement:* improving existing degraded or limited wetland conditions
Creation: wetlands created in areas where they did not exist historically.
Mitigation: wetlands created to compensate for wetlands lost in the region.

Geographic specificity: The San Francisco Bay is a large and diverse region, characterized by wide geographic variation in environmental conditions (e.g., salinity) and corresponding variations in habitat and variability in political jurisdictions. Therefore, for analyses of the indicators, the Bay region was subdivided into four sub-regions: Suisun Bay, San Pablo Bay, Central and South Bay. However, each indicator was ultimately evaluated and scored for the entire Bay region.

EVALUATING AND GRADING:

For each habitat extent indicator, upper and lower reference conditions, corresponding to "excellent" and "very poor" ecological conditions were established. Reference conditions were based on historic data, and evaluated using information on stakeholder supported restoration goals. The range of the indicator results between the upper and lower reference conditions was subdivided into five categories, corresponding to letter grades A through F. Each letter grade also corresponded to a "grade point", ranging from 0 (no habitat remaining) to 100% of the historic habitat as calculated by the Goals Project (circa 1800). The upper reference condition was set at 70% which was considered a liberal estimate for the A grade. The restoration goal for tidal marsh, at 100,000 acres for the bay region or 52% of historic habitat extent was also used as a guide to set the break point between the B and C range at 50%. Other breakpoints are illustrated in the table below.

The San Francisco Bay Habitat Index was calculated as the average Percent Historic Extent of the collective component habitat type indicators (i.e., mudflat, tidal wetlands, seasonal, wetlands and riparian habitat extent). Table 2 below summarizes the breakpoints for evaluating ecological condition and assigning grades. A restoration rate was calculated to provide a trend for the tidal marsh extent indicator to evaluate progress during the past 5 years in goals set forth in the Habitat Goals, Joint Venture and CALFED planning documents.

Table 2: Evaluation Criteria for the Habitat type indicators in the Habitat Index

Reference condition	% Historic Habitat Extent	Rationale for reference conditions	Ecological condition	Grade point	Grade
Upper	70+	The percent of historic habitat extent (est. from Goals report ~1800) was calculated. For grading, the A-B break point was set at 70%, of historic extent. The restoration goal for tidal marsh extent was used as a guide to set the B-C breakpoint at 50%. Each subsequent grade increment was set at 20% lower than the grade above.	Excellent	4	A
	50-70		Good	3	B
	30-50		Fair	2	C
	10-30		Poor	1	D
Lower	0-10		Very poor	0	F

INDICATOR ANALYSIS

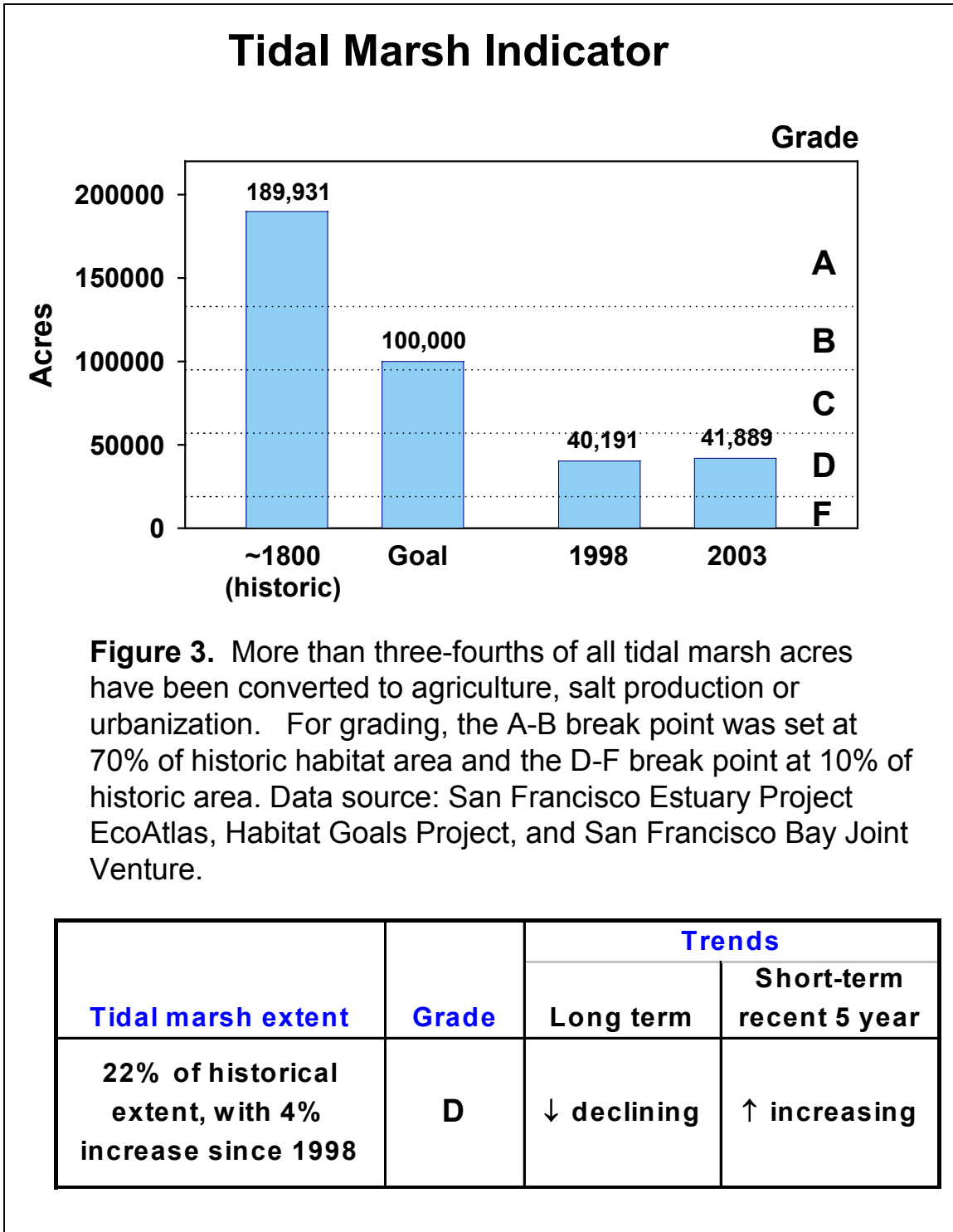
1. Tidal Wetlands Indicator

Tidal wetlands provide critical habitat for fishes, shellfish, waterfowl, shorebirds, wading birds and several mammals. Wetlands support many threatened and endangered species including the secretive clapper rail, the salt marsh harvest mouse, and juvenile winter run Chinook salmon. Nearly all of the shorebirds that migrate along the Pacific flyway use tidal wetlands in the Bay region at some time during their migration and the area is frequented by a large number of migratory waterfowl, nearly one fourth of those in California during some years (Goals Project 1999). The importance of this habitat type is underscored by significant resources being spent on large-scale tidal wetland restoration planning efforts (i.e., North and South Bay Salt Pond restoration).

Methods and Calculations:

The tidal wetlands indicator was calculated according to the above description (see methods, data sources and calculations). The status of restoration projects is not readily ascertained. Projects listed in project databases range from being concepts, in the planning stages, or in various stages of completion. Some restoration databases list projects as completed; however, "Completed projects" may range from wetlands that are fully tidal with the beginnings of emergent vegetation to recently completed projects that are graded and open to tidal inundation but are still lacking vegetation. Projects or portions of projects in the latter category could be defined as mudflats; however, information is not always readily available to evaluate whether some projects might be better classified as mudflat. We performed interviews with several practitioners and have circulated the restoration projects list (see below). We endeavored to include only those projects that were well on the road to full tidal restoration; however, there may be some cases where a more thorough and detailed analysis would remove some of these projects from this list. Projects considered muted tidal, managed marsh, or enhanced were not included in the final list. For example, in the Central and South Bays, this analysis does not include the Bayside Business Park Phase 2 project as it was considered a managed marsh. Citation, Triangle marsh, and Hayward Shoreline Enhancement project were not included as they were enhancement projects. It should also be noted that this estimate presumes that all restoration projects completed during or prior to 1998 were included in the Habitat Goals Project 1999 report acreage estimates.

Results:



Key Findings

Over the last 150 years tidal marshes decreased in area by nearly 79%, from 190,000 to 40,200 acres. Most of the decline occurred prior to 1950.

Estimates from the Bayland Habitat Goals project (1999) indicated a decline from 190,000 to 40,200 acres, to 21% of the extent present in the early 1800's. Most of this decline occurred in the late 1800's to early 1900's and prior to 1950. (EcoAtlas 1.5 and Goals Project, 1999). The land lost was reclaimed for different purposes. In Suisun and the North Bay, much of the land was diked and drained to allow livestock grazing and later agriculture and salt production. In the South Bay, much of the converted land was reclaimed for salt production.

Much of the remaining tidal marsh is degraded. Less than 3% of the original wetland area is in relatively pristine condition (Goals 1999).

Remaining tidal wetland habitat has changed in its character. Many of the remaining tidal wetlands are fragmented and cut-off from uplands and freshwater inputs. Tidal channels and pannes, important to freshwater fish and waterfowl, were once more prevalent in tidal marsh systems, and especially dense in salt marshes (Grossinger 1995).

The greatest losses in tidal marsh habitat acres occurred in the North and South Bays; however, these are areas with the greatest restoration potential. The Central Bay area lost a higher percentage of its tidal marsh habitat.

Calculations of tidal marsh loss (Goals 1999; estimate for 1998) indicate that the greatest losses in tidal marsh habitat acres occurred in the North and South Bays with losses at 39,000 and 47,000 acres respectively (calculated from estimates in Steere, J.T. and N. Schaefer 2001; Goals Project 1999). In the Central Bay, losses were fewer in actual acreage values (12,000 acres); however because the Central bay wetlands are a narrow strip along the margins of the bay, this represents nearly 92% of Central Bay's original tidal marshes.

The North Bay and Suisun Bay regions have more undeveloped diked tidal wetlands than Central and South Bays and are areas where the greatest number of acres are slated for tidal marsh restoration. Though diked wetlands in the North and South Bays offer significant restoration potential; much of this land has been subsided due to aerobic decomposition and the dewatering of the peaty marshes once the land was exposed for farming. Careful planning and evaluation of sites, is necessary to achieve the goals set forth in the planning documents.

Between 1998 and 2003, tidal marsh habitat increased by 1700 acres, more than 4% over the existing amount, to nearly 42,000 acres. The amount and quality of restored habitat needs to be better monitored and reported, however.

This represents an increase of 385.6 acres in the Central and South Bays, 1313 acres in the North Bay and no acres in Suisun Bay (See Appendix 1 for a list of projects). Project tracking in Suisun bay is not well developed and there are large institutional and private land holdings in Suisun Bay that have slowed restoration. This is a generous estimate of progress as many of these projects though considered “complete” or “on-the-ground” are only beginning to show signs of restoration. The review of the databases, which are not consistent in format or updated regularly was a painstaking process despite the paucity of new projects. If a reliable index of habitat change and tracking of restoration progress is to be achieved, it is essential to improve restoration project tracking in the future.

If the current 5-year trend holds, it will take nearly 200 years to achieve the 50 to 100 year targets set for Bay tidal marsh restoration by the Baylands Habitat Goals Project.

The Habitat Goals process (Goals Project 1999) and the San Francisco Joint Venture (Steere et. al. 2002) are the most comprehensive data driven efforts to establish goals for tidal marsh restoration. The Joint Venture 20-year goals were largely derived from the Habitat Goals which were proposed as long-term goals (an approximately 75 year time-frame was estimated in the Joint Venture as the projected time for completing the Habitat goals). We estimated the yearly regional restoration rate required to achieve the Joint Venture goals and the Bayland Habitat Goals assuming a 75-year goal. Restoration rates of 1600 acres per year are required to achieve the Habitat Goals in 75 years. If the current 5-year trend holds, it will take nearly 200 years to achieve the 50 to 100 year targets set for Bay tidal marsh restoration by the Habitat Goals Project. Restoration of up to 23,000 acres of salt ponds to tidal marsh could significantly accelerate progress.

Restoration of up to 23,000 acres of salt ponds to tidal marsh could significantly accelerate progress toward restoration goals.

Wetland acquisitions since 1997 total 40,000 acres, and at least two-thirds of these acres are slated for restoration in the next 30 years (Appendix x). The recent acquisition of South Bay salt ponds, following similar efforts in the North Bay, created a unique opportunity to restore up to 23,000 acres of tidal marsh around the Bay. For information on the North and South Bay restoration planning efforts see the following websites: <http://www.napa-sonoma-marsh.org> and <http://www.southbayrestoration.org>.

2. Tidal Mudflats Indicator:

The tidal mudflat indicator measures the extent of tidal flat in the Bay region, predominantly tidal mudflats. The extensive shallow-water mudflats located along the edge of San Francisco Bay are largely unvegetated except for algae, but are nevertheless highly productive and biologically rich habitats. Tidal action, currents, and variations in salinity make mudflat communities susceptible to rapid change, so they are usually dominated by colonizer species that develop quickly, mature rapidly, and have high reproductive rates. Invertebrates such as clams, worms, mussels, shrimps and crabs occur in large numbers. Tidal mudflats are also important foraging, nursery and rearing habitat for many estuarine and marine fish species and provide an essential feeding and staging area for hundreds of thousands of shorebirds (e.g., sandpipers and plovers) of the Pacific Flyway, a bird migration corridor that stretches along the Pacific coast between Alaska and South America. In addition, harbor seals haul out on mudflats and marsh plains on Lower Tubbs Island for resting during low tides.

Mudflat habitats are highly dynamic and this dynamic nature, can be observed in the changes observed in their area and distribution (see Jaffe et. al. 2000). The Baylands habitat goals process and the California Bay-Delta Authority do not call for increases in tidal mudflat; however, there is increasing recognition that these areas should be tracked due to the importance of mudflat dynamics as a source of sediment for the restoration of subsided tidal marshes, their importance to shorebirds, and their role as transition states in tidal marsh restoration.

Methods and Calculations:

The tidal flat indicator measures the extent of mudflat habitat in the Bay as calculated from the EcoAtlas Version 1.5. The EcoAtlas measured tidal flat habitat as the area between the MLLW estimates (NOAA, 1990 bathymetric surveys) and the vegetated or hardened shoreline via aerial photography (NWI). New estimates of mudflat are not available; though agencies and research organizations have requested that NOAA perform new bathymetric surveys (Collins, Williams, Shoelhammer, 2003 pers. comm.). In addition, restoration project databases currently are not set up to calculate additions of mudflat due to restoration. Generally tidal wetland projects, in their early phases represent transitional mudflat habitat; however, because they are targeted for tidal restoration, they are considered tidal wetland habitat. The next iteration of this index will require updated measures of mudflat extent and a more detailed evaluation of restoration projects to quantify the amount of each tidal marsh projects that is still largely unvegetated.

Results:

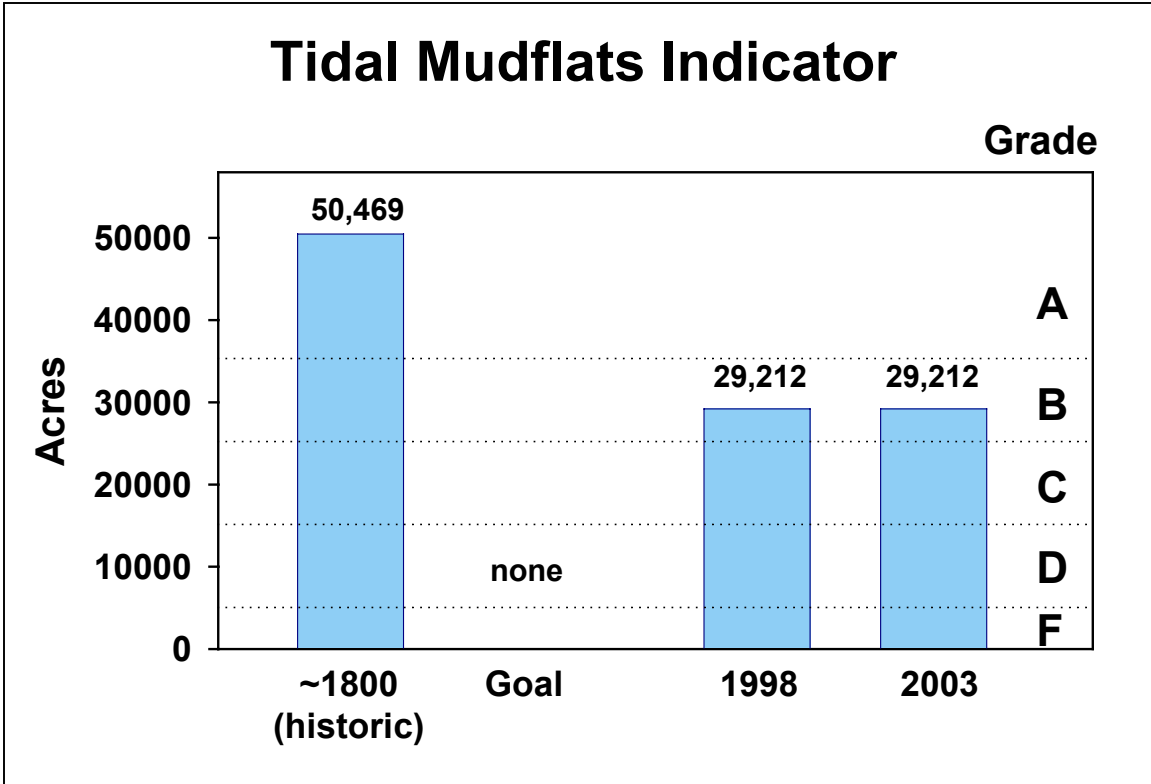


Figure 4. Tidal mudflats are highly dynamic but until recently, they have not been lost to the same degree as other habitat types. For grading, the A-B break point was set at 70% of historic habitat area and the D-F break point at 10% of historic area. Data source: San Francisco Estuary Project EcoAtlas, Habitat Goals Project.

Tidal mudflat	Grade	Trends	
		Long term	Short-term recent 5 year
58% of historical extent, no information on change since 1998	B	↓ declining	unknown

Key Findings:

By 1998, tidal flats had declined by 42% from 50,469 acres to 29,212 acres, This represents 57.9% of the historical extent estimated to be present in 1800. (EcoAtlas Goals Project, 1999).

The greatest loss of tidal mudflats was in ?. Today, the largest remnant mudflats are found in the South Bay, the most important area for shorebirds in the estuary. Suisun Bay, where freshwater allows vegetation to grow in the intertidal zone, has the least amount of mudflat habitat.

San Pablo Bay mudflats, however, actually expanded in area in the late nineteenth century, after sediments from hydraulic mining and land conversion far upstream were deposited along the Bay's shores.

In San Pablo Bay from 1856 (the earliest detailed hydrographic survey) until the late 1800s, tidal mudflat area grew in response to the great influx of hydraulic mining debris. Later, as the influx of mining debris declined, mudflats eroded rapidly. Mudflat area stabilized in the early to mid-1900s and later re-eroded at a rate of about 90 acres per year from 1951 to 1983. This latest episode of erosion could be a result of dam building and water project operations on the Sacramento and San Joaquin Rivers, which reduce sediment supplies. (Jaffe et al. 2000).

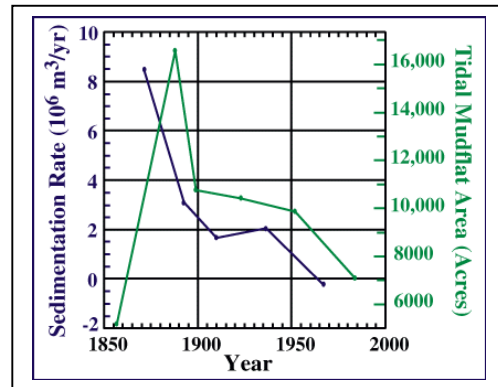


Figure 4a: Mudflat Habitat area versus the Sediment rate in San Pablo Bay. From: Jaffe, Smith & Zink. Accessed 2003. <http://sfbay.wr.usgs.gov/access/sanpablobay/bathy/mudflat.html>

While mudflats are no longer being filled, their extent is likely to continue shrinking due to the absence of new sediments from upstream (now captured behind major Central Valley reservoirs) and to long-term sea level rise as a result of climate change.

Sediment supply will continue to be a problem as dams limit sediment influx from the Sacramento and San Joaquin Rivers and tributaries (Jaffe 1999). Sediment shortages are likely to become more severe given the massive tidal restoration projects planned in the Delta, upstream of the Bay. Even local tidal marsh restoration may severely affect sediment dynamics and mudflat distribution and size. (Jaffe, 2001 ; Siegel, 200x; Williams, 2002)

Sediment should be valued by maximizing the reuse of minimally contaminated dredge materials within the tidal zone of the estuary system – particularly for wetland restoration.

The introduction of the invasive saltmarsh cordgrass *Spartina alterniflora* may result in infilling and conversion of mudflat to tidal wetland if the spread of this alien species is not controlled.

Exotic species modify and in some cases threaten the very existence of mudflats. In San Francisco Bay, the introduced Atlantic salt-marsh cordgrass, *Spartina alterniflora* may lead to the rapid infill of mudflats and ultimate conversion of these areas to high marsh if measures aren't taken to control its spread.

It is essential and past time for funding improved bathymetry and mudflat habitat extent measurements to evaluate the status of sediment in San Francisco Bay and the potential for restoration of tidal marsh in the region.

More current and frequent bathymetric surveys are needed to increase our understanding how changes in the bay (filling, levees, restoration) affect mudflat dynamics, distribution and the possible affects on tidal marsh restoration efforts (Collins, Shellhammer, Williams, 2003, personal communication).

3. Seasonal Wetlands Indicator

Moist grasslands and vernal pools naturally occur in upland areas along the Bay's margins that are not subject to tidal influence, especially those with clay soils, which are ponded for long periods with water during winter and spring. Clay slows the downward movement of surface water, so these areas tend to be saturated for relatively long periods. A number of rare plant and animal species are associated with these seasonal wetlands including goldfields, tadpole shrimp, fairy shrimp, and California tiger salamander. This indicator measures the spatial extent of seasonal wetlands around San Francisco Bay.

Methods and Calculations:

The seasonal wetland extent indicator measures the amount of naturally occurring moist grasslands and vernal pools in the Bay region using the EcoAtlas Version 1.5. (See Goals 1999, Appendix A-7).

Results:

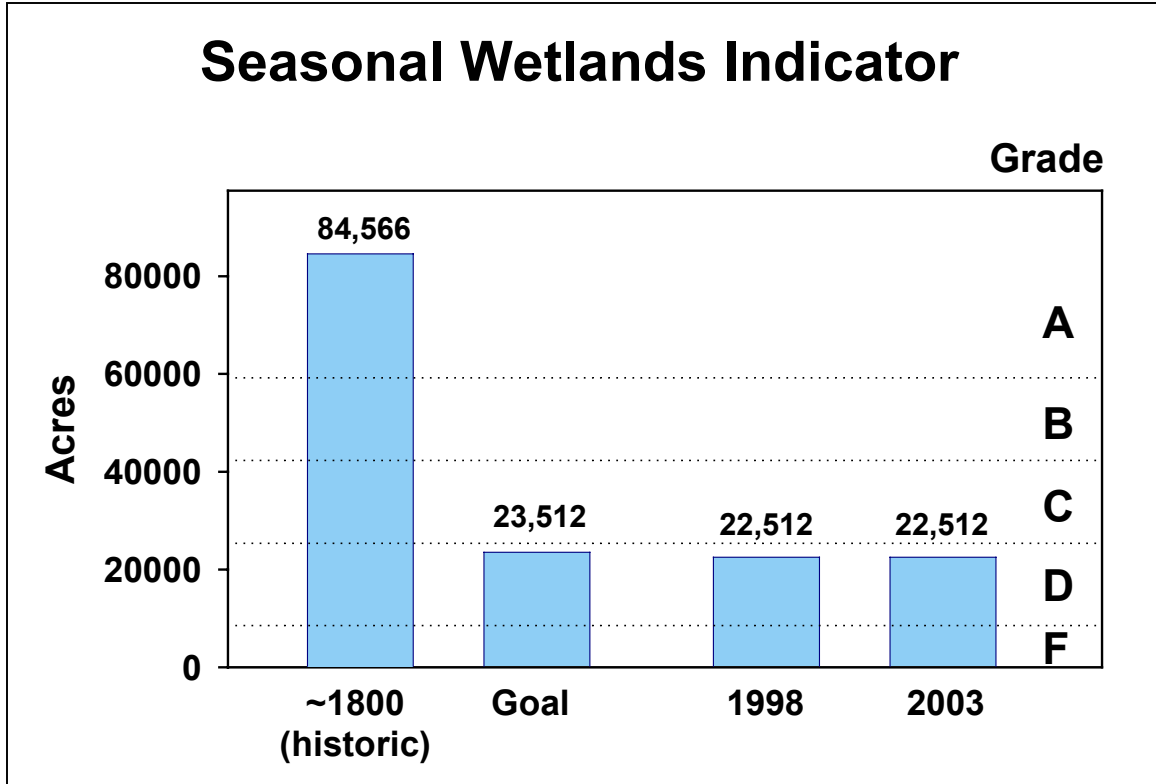


Figure 5. Over one fourth of the historical seasonal wetlands have been lost; however, reliable estimates for restoration of these areas was not available. For grading, the A-B break point was set at 70% of historic habitat area and the D-F break point at 10% of historic area. Data source: San Francisco Estuary Project EcoAtlas, Habitat Goals Project, and San Francisco Bay Joint Venture.

Seasonal Wetland	Grade	Trends	
		Long term	Short-term recent 5 year
27% of historical, no information on change since 1998	D	↓ declining	unknown

Key findings:

By 1998, grassland and associated wetlands had declined by nearly 75%.

The Habitat Goals indicate a decline from 84,557 acres to 25,512 acres, 26.6% of the extent present in the early 1800's (EcoAtlas in Goals, 1999). Historically, large areas of grasslands with vernal pools occurred near Suisun Marsh, along Sonoma Creek and in the Warm Springs area of the South Bay.

The San Francisco Bay Joint Venture calls for increasing seasonal wetlands by 1000 acres, but progress toward reaching this goal is not well documented.

4. Riparian (River corridor) Indicator

River corridor (riparian) habitats border the edges of rivers and streams. The complexity of the habitat created by the layering of trees, shrubs, herbs and aquatic vegetation promotes high species diversity. Here fish, birds and other wildlife find shade, shelter, and a rich array of food resources. In the bay area, natural riparian habitats tended to be long and narrow because the natural rivers and streams were entrenched within steep canyons and valleys (Goals 1999). Today, there are only a few remaining examples of riparian forests that extend from the upper reaches of local watersheds all the way to the Bay. Riparian habitats vary among different parts of the bay. Near the Bay, riparian habitat is dominated by willow groves, while upstream areas above the tidal zone are characterized by sycamore, cottonwood, ash, bay laurel, or box elder. This indicator measures the spatial extent of riparian habitats around San Francisco Bay.

Methods and Calculations:

The riparian extent indicator measures the amount of naturally occurring moist grasslands and vernal pools in the Bay region EcoAtlas Version 1.5. (See Goals 1999, Appendix A-7).

Key findings

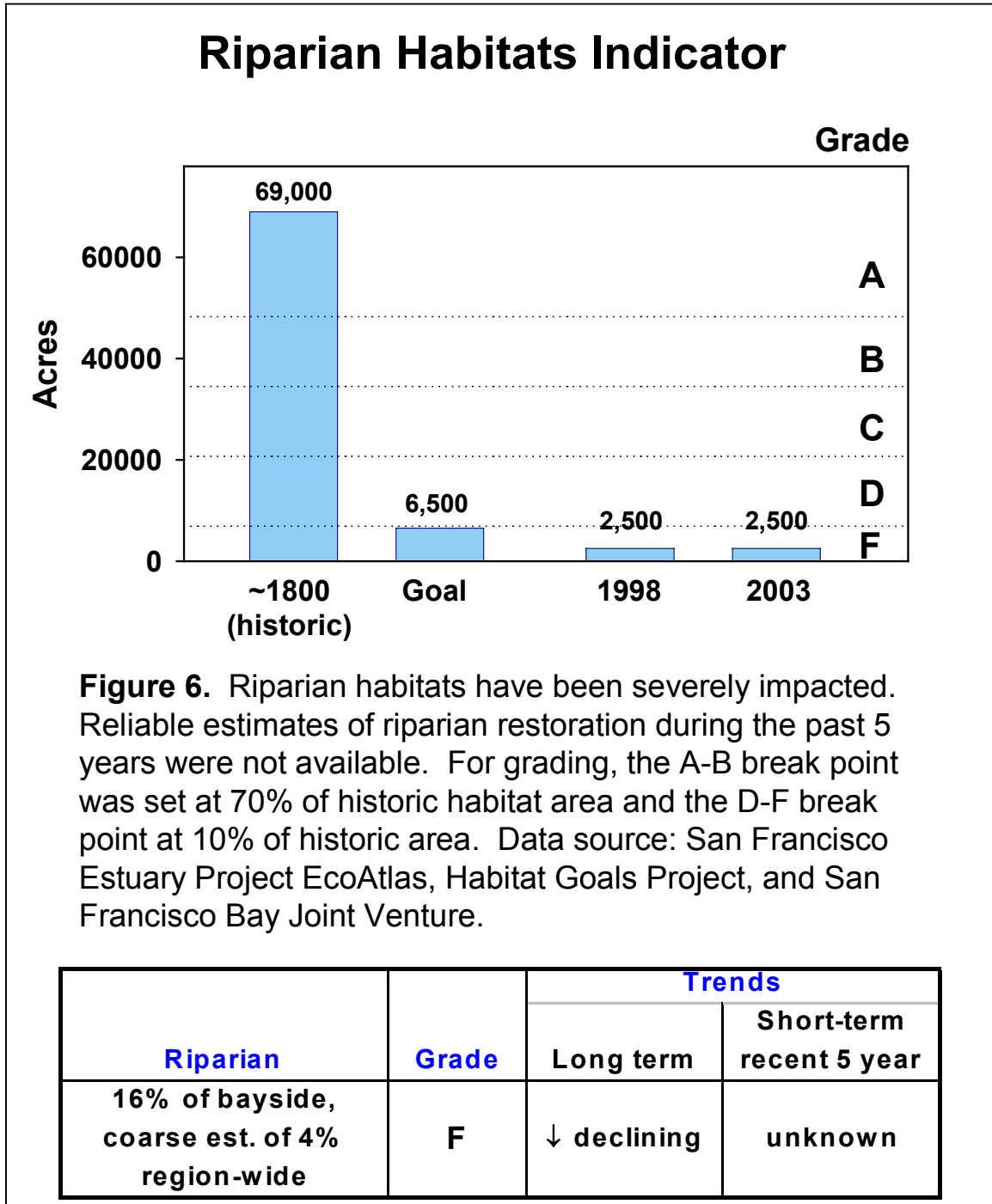
By 1998, riparian habitat had decreased by over 84% along the Bay margins, and 96% throughout the entire Bay region's watershed, from nearly 70,000 acres 150 years ago to just 2,500 acres today.

Much of the remnant riparian habitat remaining in the bay area is believed to be highly degraded in quality.

Current aerial imagery is not up-to-date, nor are restoration databases adequately designed to track riparian habitat extent.

Estimates of condition will depend on improving measurements of riparian habitat in the future. Additional research is being proposed by San Francisco Estuary Institute, The

Results:



5. Non-tidal diked wetlands habitat:

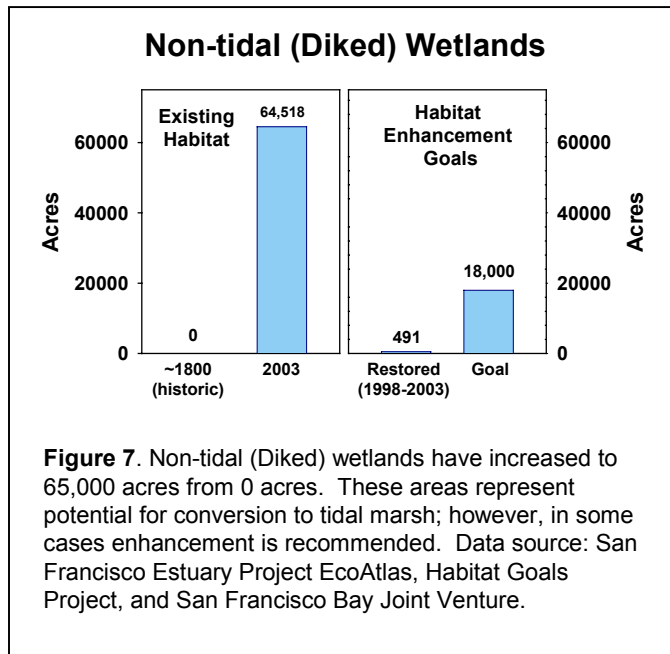
Some of the Bay’s tidal marshes that were diked for agriculture still function as wetlands, even though they are no longer open to tidal action. These diked non-tidal wetlands, including managed wetlands, serve to some extent as a replacement for the natural freshwater and seasonal wetlands that have largely disappeared. Nearly 80% of these areas are duck clubs or state reserves, managed primarily for waterfowl. Fresher water is delivered through tide gates, and artificial channels distribute it to support wetland forage plants and other species.

Though diked wetlands are man-modified habitats, these areas retain many features important to wildlife and are recognized as valuable resources. The plant communities of diked wetlands vary greatly from site to site but can resemble those of natural tidal marshes or freshwater marsh or seasonally wet grasslands. The Habitat goals call for enhancing non-tidal diked marsh areas in the North Bay Subregion (17000 acres) and converting diked wetlands to tidal marsh in other areas. The Joint Venture goal is to enhance 12000 acres in the next twenty-five years and “restore” 6000 acres, as seasonal marsh.

Non-tidal wetlands are mentioned in the 2003 Bay Index to recognize their importance, but are not graded as an indicator. The fact that these habitats were not present during the pre-European settlement period and the discrepancy in the goals between the two projects (Baylands Habitat Goals and the Joint Venture project) leads us to call for furthering efforts toward unifying diked wetland enhancement goals and improving the tracking of enhancement projects.

Methods and Calculations:

The non-tidal marsh indicator measures the extent of non-tidal habitat in the Bay as calculated from the EcoAtlas Version 1.5. A measure of progress in diked wetland enhancement was made difficult because many restoration projects were labeled as completed non-tidal marsh projects; but these projects include both diked wetlands and seasonal marshes. If tidal marsh enhancement is to be included in the next iteration of this index, it will require improved measures of restoration projects divided by appropriate descriptors for non-tidal habitat to ensure that “natural” seasonal wetlands (e.g.; moist grassland, vernal pools) are not included in this estimate as enhancement occurs.



Key findings

Non-tidal (diked) wetlands now account for nearly 65,000 acres of the Bay's existing wetlands.

The almost 500 acres of diked wetland enhancement projects undertaken in the Bay region over the last 5 years represents nearly 3% of the 17,000 acre target for enhancing this habitat type identified by the Baylands Habitat Goals and the San Francisco Bay Joint Venture. *At the current rate, it will take 185 years to meet the 50-75 year target.*

6. Salt Pond Habitat

Small areas of salt ponds—hypersaline water bodies periodically flooded with less salty water—naturally occurred within the tidal salt marsh zone. However, almost of all the Bay's current salt ponds are large artificial areas created to evaporate salt for commercial production. These artificial salt ponds have entirely displaced natural salt ponds and the acreage is much increased. Ponds support a highly productive environment for salt-tolerant algae, bacteria and invertebrates, and provide important habitat for shorebirds, waterfowl, and other species that formerly utilized the seasonal wetlands, sloughs and mudflats of the Bay and the seasonal wetlands of the Central Valley.

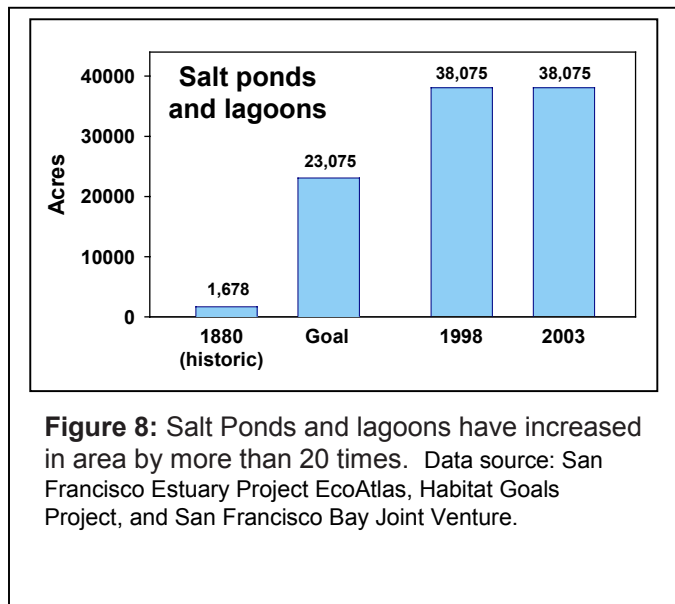


Figure 8: Salt Ponds and lagoons have increased in area by more than 20 times. Data source: San Francisco Estuary Project EcoAtlas, Habitat Goals Project, and San Francisco Bay Joint Venture.

The recent acquisition of South Bay salt ponds, following similar efforts in the North Bay, creates a unique opportunity to restore up to 23,000 acres of tidal marsh around the Bay. Because many species rely on the ponds as replacement areas for lost and degraded habitat, restoration plans for the Bay call for preserving some, though not all, ponds. The ecological benefits of restoring salt ponds to tidal action must be evaluated against the loss of benefits currently provided by salt pond habitat.

Methods and Calculations:

In the 2003 Bay Index, salt pond habitat is not graded as an indicator, since its extent is not expected to grow and will in fact diminish somewhat as a significant portion of the ponds is reconverted to tidal wetlands. However, this habitat type is included to

acknowledge its importance for bird populations in the existing Bay environment. As the Index is updated to reflect changes in the Bay environment, we intend to describe and evaluate the status and trends of salt ponds within the habitat mosaic of the Bay.

Key findings:

By 1998, salt ponds had increased by over twenty fold. The Habitat Goals estimated an increase from 1594 acres to 34,455 acres, representing over 200% of the extent present in the early 1800's (EcoAtlas in Goals, 1999).

7. Habitat Index

The San Francisco Bay Habitat Index aggregates the results of the tidal marsh, tidal mudflat, seasonal wetland, and riparian habitat indicators. Each indicator is graded separately based on the percent of historic area and then the grades are aggregated to calculate the score illustrated on the right side of the graph (Figure). The indicators illustrate that riparian habitat extent is the most reduced; though current estimates are coarse. Tidal marsh is the second most impacted habitat type, in terms of historic percent loss.

Table 3 shows the grades of each of the Indicators for the Habitat Index. The Index grade and the score are derived from the "grade point average" of the component indicators.

Table 3. Results, grades and grade points for the four indicators used to calculate the Food Web Index for 2001.			
Indicator	2001 Result	Grade	Grade point
Tidal wetland	22 percent of historical extent remaining, with 4 % increase from existing habitat in 1998.	D	1 (out of 4)
Tidal mudflat	58% of historical extent	B	3 (out of 4)
Seasonal Wetland	27% of historical extent	D	1 (out of 4)
Riparian	16% bayside, 4% regional left according to coarse estimates.	F	0 (out of 4)
Non-tidal diked wetland	Not graded	-	-
Salt ponds	Not graded.	-	-
Index Grade Point Average		F	1.25 (D+)
Food Web Index Score =			32 (out of 100)

Bay Habitat Index

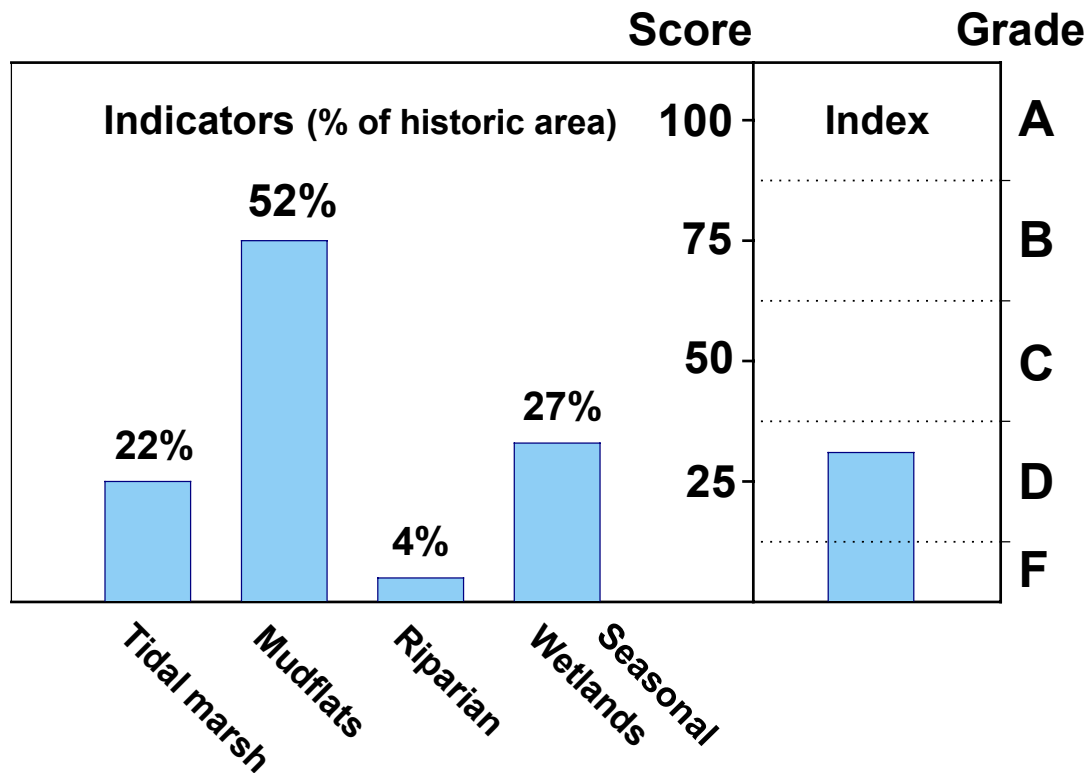


Figure 9: The Habitat Index aggregates the results of the tidal marsh, tidal mudflat, seasonal wetland, and riparian habitat indicators. Each indicator is graded separately based on the percent of historic area and then the grades are aggregated to calculate the score illustrated on the right side of the graph.

ECOLOGICAL AND MANAGEMENT IMPLICATIONS:

Much of the Bay shoreline—and areas significantly inland from the water—now familiar to Bay Area residents was once tidal marsh, mudflat, and tidal inlet. Over 150 years of land conversion has radically rearranged the Bay's appearance, and shrunk the Bay's total area by a third. The primary purposes for converting tidal wetlands in the early years were to create new agricultural lands and to construct salt evaporation ponds, especially in the South Bay and San Pablo Bay. As the Bay region urbanized, new residential areas, transportation projects, industrial and military facilities and landfills displaced shoreline habitats everywhere at an increasing rate. It was not until the formation of the Bay Conservation and Development Commission in the 1960s that the rate of filling decreased.

The Bay's habitats are not only threatened by development. Decreased freshwater inflow to the Bay from upstream diversion has changed the distribution and composition of salt and brackish water marshes, and decreased sediment loads prevent the rejuvenation of eroding wetlands and mudflats. In addition, wetland vegetation takes up toxic substances from polluted agricultural, industrial and urban runoff, remobilized sediments, and other sources, reducing the amounts of these contaminants that flow into the Bay but facilitating harmful accumulation of toxics in the tissues of wildlife species that feed in the marshes. And the forecast rise in sea levels could drown existing habitat on the Bay's margins, with endangered plants and animals unable to shift to adjacent higher elevation areas that have been urbanized or otherwise altered.

Today, nearly 80 percent of the Bay's original tidal wetland and riparian habitat has been destroyed. But the tide is slowly beginning to turn. Thanks to acquisitions for state and federal wildlife refuges, efforts by the San Francisco Bay Joint Venture and other initiatives, and the recent acquisition of the Cargill salt ponds by the state, about 40,000 acres are slated for restoration. And plans to reverse the trend further are ambitious: the multi-agency San Francisco Bay Habitat Goals Project has set a target of restoring 100,000 acres of tidal wetland habitat around the Bay. The goals may be ambitious, but the pace of restoration is slow. The Goals Project envisions meeting its tidal wetland restoration target in 50 to 100 years, but at the current rate it will take nearly 200 years. Most importantly, effective habitat restoration cannot be accomplished in baby steps by acquiring small, disconnected parcels of land. Only large areas of habitat provide adequate refugia from human disturbance, connectivity between different habitat types, and sufficient scale to test different restoration methods. Reliable long-term funding is essential: recent acquisitions have relied heavily on public bond financing, a situation that may not be sustainable given the state of today's economy. Fortunately, the acquisition of salt ponds around the Bay over the past few years affords the opportunity to restore tidal marshes at a faster rate and on a larger scale—while still preserving important salt pond habitat.

Protection for some critical habitat types has not matched the overall progress in elevating habitat restoration to the resource management agenda. Of all the Bay's remnant habitats, riparian corridors are the most endangered. But functional stream

corridors provide ecological benefits disproportionate to their size, and restoring stream channel habitat represents a smart ecological and financial investment.

DATA GAPS AND RECOMMENDATIONS:

This analysis is the first attempt to develop a habitat index for the bay region and provides a technique that can be improved upon over time. The analysis uncovered specific issues regarding remote sensing data availability, inconsistencies in restoration project tracking, and the need for consistent goals and indicators. The lessons learned will facilitate improvements in data gathering and the start of a process that ensures consistency in recording restoration progress over time.

As noted above, significant progress had been made in garnering support for tidal marsh restoration. The Habitat Goals Process (www.sfei.org), the San Francisco Joint Venture (<http://www.sfbayjv.org/>) and the San Pablo Bay Restoration Framework (www.bay.org), are efforts that have provided significant momentum for restoration; by documenting habitat losses and calling for the need for restoration. The Wetlands Restoration Program (www.sfwetlands.ca.gov) is slowly becoming an established entity that will support restoration through design review and monitoring efforts. However the record of our progress still remains a laborious effort that needs revamping by establishing a reliable database that is frequently updated.

Our research uncovered at least seven separate database efforts to track restoration projects – often with inconsistent methods for classifying habitat both in terms of habitat type and level of restoration. A coordinated system is needed for tracking projects, defining "restoration" and habitat types consistently across projects, and consolidating existing database management efforts. The database structure should be tied closely to a geographic information system that includes interpretation of historic and recent remote sensing imagery. The structure should be developed to facilitate the development of habitat extent indicators. For example, database development needs to be coupled with the development of consistent terms, so that projects can be "counted" in a consistent fashion. We have proposed certain terms that reflect the habitat type, restoration phase, and whether they are mitigation projects; but project managers need to be clear about these terms in order to adequately enter projects into a database. A significant effort that included habitat mapping was completed in the North, Central and South Bays by Wetlands and Water Resources Group (www.swampthing.org) and has been adapted for internet access through the Wetland Tracker project (www.sfei.org). With some relatively slight modifications, this project has the potential to link effectively with a habitat indicators effort. A new project tracking database proposed by the Joint Venture and Ducks Unlimited may also support this effort. These projects should also be designed to upload and download data to the statewide, Natural Resources Projects Inventory (www.ice.ucdavis.edu), a well developed and recently state mandated projects database developed at the U.C. Davis. Without a comprehensive attempt to maintain one database that links to others in a consistent way, an analysis of this type will continue to be fraught with uncertainty.

As noted above, the current index reflects habitat extent and does not attempt to rate wetland quality. We believe that the evaluation of wetland quality is some ways off in terms of scientific agreement on what constitutes quality and practicality, so it is essential to begin with the quantification of habitat extent. Until recently, monitoring of wetlands in the Bay has been generally infrequent and sporadic at best. It is important to develop methods to better ascertain wetland quality in the bay and to have these methods link to statewide and national efforts. This would not only improve the proposed regional level index, but also to supply agencies and other funding entities with a decision-making tool to better evaluate where to place precious financial resources. There are several pilot projects that are beginning this process, but sustained support is needed. The Pacific Estuarine Ecological Research Program (PEEIR) is developing new tools to evaluate wetlands on the west coast and two of the test sites are located in the Bay region. Rapid assessment programs are also being developed and tested (Collins, personal communication, Breaux and Martindale, 2003). In addition a tidal marsh wetlands monitoring program funded by the CALFED Bay-Delta Authority is slated to begin in 2004. Despite its scope, with the inclusion of a wide array of parameters, this program will include only six sites in the Bay-Delta across the bay for the next 2 years. These programs represent significant advances over current levels of monitoring; however, as pilot scale efforts that are short term, there is no guarantee that more detailed and ongoing assessments of wetland health will be forthcoming.

Unlike in other regions, the measurement and protection for some critical habitat types has not matched the overall progress made in tidal marsh restoration. Riparian habitats and seasonal marshes have suffered significant losses and are not receiving as much local attention. This analysis clearly indicates that riparian corridors are one of the most endangered habitats in the Bay. Restoration of riparian habitat should be a high priority for resource managers, because functional stream corridors provide ecological benefits disproportionate to their size. More accurate estimates of riparian habitat extent and quality should be developed because estimates of riparian habitat are extremely coarse to date. Proposed research by the Oakland Museum, San Francisco Estuary Project, The Resources Agency and The Bay Institute may remedy this situation in the future; however, most of these efforts will take several years to accomplish.

Mudflat habitat, though not as impaired in terms of extent, is also vitally important as habitat to a wide range of invertebrates and shellfish, shorebirds and waterfowl that rely on the area for the rich array of food resources that are exposed on a daily basis. Implicit in the proposed restoration of tidal wetland habitat, is the need for high quality sediment sources, especially local supplies. It is critical for managers and practitioners who are planning large-scale tidal wetland restoration projects in the region to gain a better understanding of sediment resources and the erosional processes that affect mudflat extent and sediment supplies. Funding for improved bathymetry and mudflat habitat extent measurements is also essential.

Appendix 1: Tidal Marsh Project List

Appendix 2: Restoration Databases

Name of data source	Organization	WWW URL and/or contact person	Region
NRPI-- Natural Resource Projects Inventory	California Biodiversity Council and the UC Davis Information Center for the Environment (ICE)	endeavor.des.ucdavis.edu/nrpi/	All
TERA -- Tracking Ecosystem Restoration Activities	U.S. Department of the Interior, Bureau of Reclamation	www.tera.mp.usbr.gov/projects_activities/index.htm	All
CWIS -- California Wetlands Information System	California Resources Agency	ceres.ca.gov/wetlands/tracking/table_tracking_one.html	All
SFBJV -- The San Francisco Bay Joint Venture	SFBJV Management Board consists of 27 agencies and private organizations	www.sfbayjv.org	Bay
SF Estuary Project CCMP (Workbook-Appendix A)	The Association of Bay Area Governments (ABAG)	Kathryn Ankrum at CCMP http://www.abag.ca.gov/bayarea/sfep/reports/ccmp/index.html	Bay and Delta
(WIP) Wetland Inventory of Projects	Regional Water Quality Control Board, San Francisco Bay Region.	Andree Breaux at SF BAY RWQCB	Bay
NRCS Inventory	Natural Resource Conservation Service	Alan Forkey	All
CALFED Look-Back Exercise and Databases	CALFED Ecosystem Restoration Program	Terry Mills, CALFED	All

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