ENVIRONMENTAL SENSITIVITY INDEX: SAN FRANCISCO BAY

INTRODUCTION

Environmental Sensitivity Index (ESI) maps have been developed for San Francisco Bay, California. The ESI maps include information for three main components: shoreline and wetland habitats; sensitive biological resources; and human-use resources. Background information, as well as the methods of data collection and presentation, are summarized in the following sections.

SHORELINE HABITAT MAPPING

The intertidal shoreline habitats of San Francisco Bay were originally mapped during overflights conducted in January 1986. In February 1997, the linear shoreline classification was updated onto 1:24,000 U.S. Geological Survey (USGS) topographic maps by an experienced coastal geologist using 1:24,000 natural color vertical aerial photography produced by the National Oceanic and Atmospheric Administration (NOAA), National Ocean Service, National Geodetic Survey, in August 1996. Maps for bayland habitats provided by the San Francisco Estuary Institute (SFEI) were also consulted during the shoreline classification. A series of overflights were conducted 4-6 March 1997 to verify the shoreline classification, using fixed-wing aircraft, flying at elevations of 500-1,000 feet and slow air speed. Air support was provided by the California Department of Fish and Game (CDFG). In conjunction with the linear shoreline classification, digital baylands habitat data developed by SFEI were used to delineate and classify polygonal habitats including marsh types, tidal flats, and other features such as salt ponds.

Prediction of the behavior and persistence of oil on intertidal habitats is based on an understanding of the dynamics of the coastal environments, not just the substrate type and grain size. The sensitivity of a particular intertidal habitat is an integration of the following factors:

1) Shoreline type (substrate, grain size, tidal elevation, origin)
2) Exposure to wave and tidal energy
3) Biological productivity and sensitivity
4) Ease of cleanup

All of these factors are used to determine the relative sensitivity of intertidal habitats. Key to the sensitivity ranking is an understanding of the relationships between: physical processes, substrate, shoreline type, product type, fate and effect, and sediment transport patterns. The intensity of energy expended upon a shoreline by wave action, tidal currents, and river currents directly affects the persistence of stranded oil. The need for shoreline cleanup activities is determined, in part, by the slowness of natural processes in removal of oil stranded on the shoreline.

These concepts have been used in the development of the ESI, which ranks shoreline environments as to their relative sensitivity to oil spills, potential biological injury, and ease of cleanup. Generally speaking, areas exposed to high levels of physical energy, such as wave action and tidal currents, and low biological activity rank low on the scale, whereas sheltered areas with associated high biological activity have the highest ranking. A comprehensive shoreline habitat ranking system has been developed for the entire United States. The shoreline habitats delineated in San Francisco Bay are listed below in order of increasing sensitivity to spilled oil.

1A) Exposed Rocky Shores
1B) Exposed, Solid Man-made Structures
2A) Exposed Wave-cut Platforms in Bedrock
3A) Fine-to Medium-grained Sand Beaches
3B) Scarps and Steep Slopes in Sand
4) Coarse-grained Sand Beaches
5) Mixed Sand and Gravel Beaches
6A) Gravel Beaches
6B) Riprap
7) Exposed Tidal Flats
8A) Sheltered Rocky Shores
8B) Sheltered, Solid Man-made Structures
8C) Sheltered Riprap
9A) Sheltered Tidal Flats
9B) Vegetated Low Riverine Banks
10A) Salt- and Brackish-water Marshes

Each of the shoreline habitats are described on pages 10-16, in terms of their physical description, predicted oil behavior, and response considerations.

In addition to the ESI habitat classification, certain bayland habitat types are also depicted on the maps, because they provide additional information important for spill planning and response purposes. SFEI bayland habitat types depicted on the ESI maps include:

- Tidal Marshes
- Muted Tidal Marshes
- Managed Marshes
- Diked Marshes
- Salt Ponds

Tidal marshes on the ESI maps include low tidal marshes, mid-tidal marshes, and high tidal marshes. Tidal marshes include areas under full tidal influence (between mean low-low water [MLLW] and the maximum extent of the tides) with at least 10 percent cover of emergent vascular vegetation (excluding submersed aquatic vegetation). Tidal marshes were considered part of the ESI = 10A category (salt to brackish marshes), even though some tidal marshes might also include tidal freshwater marshes. Tidal marshes are often the marsh type most vulnerable to water-borne spills in tidal waters. Marshes in general (all types) are usually the habitat type most sensitive to oil impacts.

Muted tidal marshes are marshes that are intertidal in elevation and subject to regular tidal action. However, tidal influence occurs to a lesser extent than for tidal marshes due to natural or man-made tidal controls or restrictions. Muted tidal marshes were also considered part of the ESI = 10A category (salt to brackish marshes), even though some muted tidal marshes might be better described as tidal freshwater marshes. Muted tidal marshes are typically less vulnerable to water-borne spills than fully tidal marshes, however, they are more vulnerable to spills than managed or diked marshes.

Managed marshes are diked habitats where surface waters are controlled or managed for the support of natural plant and wildlife communities. In some cases, these marshes may be managed to support a specific resource such as waterfowl or shorebirds (e.g., hunt clubs and some wildlife refuges). Though diked, managed marshes may be actively flooded by tidal waters during controlled management activities, typically on a seasonal basis. Managed marshes were not included as part of the ESI classification, since they are not considered an intertidal habitat type. Managed marshes in general are less vulnerable to spills than tidal and muted tidal marshes; however, managed marshes can still be vulnerable to water-borne spills when they are being flooded by tidal waters for management purposes. During spill incidents, resource managers should be notified so that managed marshes are not flooded with contaminated waters. It should also be recognized that the highly abundant and mobile wildlife resources often associated with managed marshes (such as birds) may use adjacent tidal habitats for feeding or other activities, where they are at greater risk from spills.

Diked marshes are leveed wetland habitats that are not (or are no longer) actively managed. Hyper-saline to brackish conditions often persist in such areas because the ground surface is poorly drained and water exchange is lacking. Diked marshes were not included as part of the ESI classification since they are not an intertidal habitat type. Compared to the other marsh types, diked marshes are the least vulnerable to water-borne spills, as they are not typically flooded or under tidal influence. However, seasonally abundant mobile wildlife resources associated with diked marshes could be at risk during spills if they move to adjacent tidal habitats for feeding or other purposes. Diked marshes were also depicted on the maps to help spill responders distinguish them from tidally connected and managed marshes.

Salt ponds are non-tidal habitats that are managed for salt production. Salt ponds can range in salinity from less than 60 parts per thousand (ppt) to more than 120 ppt depending on their location and their particular use in the salt production process. Salt ponds may usually be flooded, but can also be drained for periods. Salt ponds were not included as part of the ESI classification, since they are not considered an intertidal habitat type. However, salt ponds could still be vulnerable to water-borne spills when they are flooded by tidal waters for management purposes. Salt pond habitats (pond levees, small islands, shallow standing water, etc.) are also heavily utilized by a variety of wildlife resources, particularly shorebirds, wading birds, waterfowl, gulls, and terns, including nesting species and a few endangered species. During spill incidents, salt pond managers should be notified so that ponds are not actively flooded with contaminated waters. It should also be recognized that the abundant mobile wildlife resources associated with salt ponds often use adjacent tidal habitats for feeding and other activities, where they are at greater risk from spills.

One additional and important point to consider for the various wetland and other bayland habitat types of the study area is that due to current and future restoration efforts, many formerly tidal areas have been or will be converted back to tidal influence. For instance, diked marshes, salt ponds, farmed or grazed baylands, etc. may be converted to tidal marshes, muted tidal marshes, etc. in the near future. The maps presented in this atlas do not and will not reflect all these changes. For the most up to date information, the

SFEI EcoAtlas Project (telephone number: 510/231-9539), local resource managers should be consulted.

SENSITIVE BIOLOGICAL RESOURCES

Biological information presented in this atlas was collected and compiled with the assistance of biologists and resource managers from the California Department of Fish and Game and other state and federal agencies, organizations, and groups. Information collected and depicted on the maps denotes the key biological resources that are most likely at risk in the event of an oil spill. Seven major categories of biological resources are included in this atlas: marine mammals, terrestrial mammals, birds, reptiles/amphibians, fish, invertebrates, and habitats/rare plants.

Spatial distribution of the species on the maps is represented by polygons, points, and lines as appropriate. Associated with each of these representations is an icon depicting the types of species or habitat types that are present. Species have been divided into groups and subgroups, based on their behavior, morphology, taxonomic classification, and spill vulnerability and sensitivity. The icons below reflect this grouping scheme. The groups are color coded, and the subgroups are represented by different icons:

MARINE MAMMALS

Seals/Sea Lions

TERRESTRIAL MAMMALS

Small Mammals

BIRDS

Alcids

Diving Birds

Gulls and Terns

Passerine Birds

Raptors

Shorebirds

Wading Birds

Waterfowl

FISH

Fish

REPTILES/AMPHIBIANS

Amphibians

Turtles

INVERTEBRATES

Bivalves

Crabs

Insects

Shrimp

HABITATS

Eelgrass/Algae

Rare Plants

The polygon or point color and pattern are generally the same for all the species in each major group (e.g., birds are green), and match the icon colors. Also associated with each biological polygon or point feature on the map is a resources at risk identification number (RAR#), located under each icon or group of icons. The RAR# references a table on the reverse side of the map with a complete list of species associated with the polygon, point, or line as well as the state and federal protected status (T&E), concentration, seasonality, and life-history information for each species.

There are some species that are found throughout specific geographical areas or habitat types on certain maps. Displaying the polygons for these species would cover large areas or would obscure the shoreline, ESI classification, or other biological features, making the maps very difficult to read. Thus, species which occur over the majority of certain geographic areas or habitats are often identified in a small box on the maps which states that they are "Present in ..." (e.g., "Present in San Pablo Bay" or "Present on Tidal Flats"). This approach informs the user of the presence of these species, while maintaining readability of the map. In all instances, data for species listed as "Present in ...." exist as polygons in the digital spatial data layers. The use of this strategy is implemented on a map per map basis, depending on the location, size, and number of polygons present on each map.

MARINE MAMMALS

Marine mammals depicted in the San Francisco Bay atlas include harbor seals and California sea lions. Seal areas shown on the maps represent major haul-out sites and pupping areas. Certain harbor seal feeding concentrations are also shown on the maps. A few California sea lion haul-outs also occur in the Bay area, and these are depicted on the maps also (note that sea lions do not pup in the Bay). Seal and sea lion haul-outs and other locations were compiled from several recent surveys and reports, using USGS topographic maps and NOAA nautical charts for spatial referencing. Seal and sea lion locations were augmented and carefully refined based on the opinion of local resource managers and expert biologists. In addition to haul-outs and pupping areas shown on the maps, harbor seals and California sea lions are distributed throughout the estuarine waters of the bay, and may even venture up some of the rivers. Harbor seal feeding concentrations are often located in waters adjacent to the major haul-out sites, but occur in other areas as well. Feeding concentrations depicted on the maps are limited to a few sites that are not directly adjacent to haul-out locations. Though not considered threatened or endangered species, it should be noted that harbor seals and California sea lions are legally protected by the Marine Mammal Protection Act.

Harbor seal and California sea lion locations are displayed on the maps as polygons with a brown horizontal hatch pattern. In cases where multiple resource types occupy the same polygon (such as seabirds and marine mammals), a black-hatched multi-group pattern is used rather than a brown hatched polygon. A brown icon with a seal silhouette is used to indicate the presence of marine mammals, and is associated with all polygons containing seals or sea lions. The RAR# under the icon references a table on the reverse side of the map. In this table, the first column gives the species name. The next column provides an estimate of the concentration of the species at the site. Concentration for harbor seals is usually represented as a number value indicating the highest number of seals documented at each haul-out or pupping site during recent surveys. Sea lion haul-outs are represented as descriptive concentrations, such as "high," "medium," or "low". Descriptive concentrations are based on the opinion of local resource managers or experts concerning relative concentrations within the study area.

The species seasonality is shown in the next twelve columns, representing the months of the year. If the species is present at that location in a particular month, an "X" is placed in the month column. The final columns list the time periods for sensitive life-history activities, such as pupping and molting for harbor seals. Pupping refers to the time-period when pups are born. Molting refers to the time-period when seals haul-out to shed.

TERRESTRIAL MAMMALS

Terrestrial mammals depicted in this atlas emphasize rare and endangered small mammals that are closely associated with wetland habitats of the Bay, such as the salt-marsh harvest mouse, San Pablo vole, Suisun ornate shrew, and salt-marsh wandering shrew. In addition, areas with highly abundant populations of semi-aquatic fur-bearing mammals, such as the northern river otter, are also shown on the maps. For species closely associated with wetland habitats (such as tidal marshes), expert sources were used in conjunction with the SFEI bayland habitat maps and digital data to identify and delineate specific locations for each species. River otter distributions are based on expert opinion, and are depicted mainly in aquatic habitats such as in or along certain rivers and sloughs. Polygons and point data from CDFG's Natural Diversity Data Base (NDDB) were also used to depict occurrences of rare and endangered small mammal species. To avoid redundancy on the final maps, resource locations generated from expert sources and the SFEI habitat data took precedence over the NDDB data. NDDB records were used in assisting resource experts during data development and review, and were valuable in filling in additional resource locations not indicated by expert sources.

Terrestrial mammals are displayed on the maps as polygons with a brown vertical hatch pattern, or as point occurrences indicated by a small brown dot. In cases where multiple resource types occupy the same polygon (such as birds and mammals), a black-hatched multi-group pattern is used rather than a brown hatched polygon. A brown icon with a small mammal silhouette is used to indicate the presence of terrestrial mammals, and is associated with all polygons or point features containing these resources. The RAR# under the icon references a table on the reverse side of the map. On this table, the first column contains the species common name. The second column indicates whether the species is listed as threatened (T) or endangered (E) on either the state (S) and/or federal (F) lists. The next column provides the concentration of each species at the site. Concentrations for terrestrial mammals are indicated using descriptive terms such as "present," "potential," "very high," "high," "medium," "low," etc. "Present" is used for endangered or rare species that were known to occur at a site, where more detailed concentration information was not appropriate or not available. "Potential" is used for rare or endangered species that are likely or suspected to occur at a site. The "high," "medium," and "low" categories are used whenever possible, and represent the opinion of local resource managers or experts on relative concentrations in the study area. Finally, the species seasonality is shown in the next twelve columns representing the months of the year. If the species is present at that location in a particular month, an "X" is placed in the month column.

BIRDS

Birds in this atlas are divided into several species subgroups based on taxonomy, morphology, behavior, and oil spill vulnerability and sensitivity. The species table lists all the birds included on the maps, sorted by subgroup. These species are included either because of their likelihood of direct or indirect impact by an oil spill or similar incident, their general rarity or imperilment, or their special protection status as threatened or endangered.

Migratory or wintering concentration areas, nesting sites and colonies, and protected species are especially emphasized.

For birds closely associated with wetland habitats, tidal flats, salt ponds, storage/treatment ponds, etc., expert and published sources were used in conjunction with the SFEI bayland habitat data and USGS topographic maps to identify and delineate specific locations for each species or assemblage of birds. California clapper rails, black rails, several passerine species, shorebirds, wading birds, waterfowl, certain raptors, etc. were mapped in this manner. Other species, many of them associated with certain open water habitats (e.g., diving ducks, grebes, common murres, etc.), linear shoreline segments, bridges (e.g., peregrine falcon), breakwaters, etc. were mapped by resource experts using USGS topographic maps and NOAA nautical charts as reference materials. Specific nesting colonies and nesting sites for seabirds (gulls, terns, diving birds, etc.) were mapped using published sources and USGS topographic maps. Most wading bird nesting colonies for the northern section of the study area (Yerba Buena Island northward) are mapped as points using latitude and longitude coordinates provided by resource experts, rather than polygons. Wading bird colonies in other areas are depicted as polygons. Polygons and point data from CDFG's NDDB are also used to depict occurrences of rare and endangered bird species. To avoid redundancy on the final maps, resource locations generated from expert or published sources (in conjunction with the SFEI habitat data and/or USGS topographic maps) took precedence over the NDDB data. NDDB records were used in assisting resource experts during data development and review, and were valuable in filling in additional resource locations not indicated by expert or published sources.

At the request of local resource managers and experts, several species of shorebirds and waterfowl have been grouped into functional categories based on their behavior and habitat utilization. These categories, or groupings, will be used on the maps and data pages to simplify the graphical and tabular presentation. The species listed in each category (Table 1) represent the most commonly occurring species in the San Francisco Bay region. It is not meant to be an inclusive list of all shorebird and waterfowl species ever observed in the study area. It should also be noted that category names represent the general habitat or behavior of the group and exceptions do occur. For instance: "Salt Pond" shorebirds occur primarily in salt ponds, but will also be found in shallow water mudflat habitats in ponded, muted tidal or managed marshes throughout the bay area; dabbling ducks occur primarily in shallow ponds of all marsh habitats but can also be found occasionally in shallow nearshore open bay waters. Likewise, not all species within each group behave the same or utilize the exact same habitat; some may prefer different habitats or vegetation types, different water depths, sand versus mud bottoms, etc.

TABLE 1. Shorebird and waterfowl assemblages.

Assemblage	Species
Tidal Flat Shorebirds	Black-bellied plover, Black turnstone, Dunlin, Greater yellowlegs, Least sandpiper, Lesser yellowlegs, Long-billed curlew, Marbled godwit, Red knot, Ruddy turnstone, Sanderling, Semipalmated plover, Western sandpiper, Whimbrel, Willet
Salt Pond Shorebirds	American avocet, Black-necked stilt, Killdeer, Red-necked phalarope, Western snowy plover, Various other shorebirds depending on location
Dabbling Ducks	American wigeon, Blue-winged teal, Cinnamon teal, Gadwall, Green-winged teal, Mallard, Northern pintail, Northern shoveler
Diving Ducks	Barrow's goldeneye, Bufflehead, Canvasback, Common goldeneye, Greater scaup, Lesser scaup, Red-breasted merganser, Redhead, Ruddy duck, Surf scoter, White-winged scoter

In addition to the use of shorebird and waterfowl assemblages, a limited number of species of special interest were also listed separately on the maps and data tables, as requested by resource managers and expert sources. Species which were nesting in an area, threatened or endangered species, and unique species of special management or spill response concern were listed separately on the maps and data tables (Table 2).

TABLE 2. Supplemental shorebird and waterfowl species.

Shorebirds	Waterfowl
Western snowy plover (endangered, nesting)	Canvasback (declining species, unique habitat association)
Red-necked phalarope (unique habitat association)	Ruddy duck (unique habitat association and behavior)
Black oystercatcher (nesting, unique habitat association)	Northern pintail (declining species)

TABLE 2. Continued.

Shorebirds	Waterfowl
American avocet (nesting)	Greater white-fronted goose (unique to delta and Suisun marsh region)
Black-necked stilt (nesting)	Canada goose (unique to delta and Suisun marsh region)
Killdeer (nesting)	Snow goose (unique to delta and Suisun marsh region)
	Tundra swan (unique to delta and Suisun marsh region)

Birds are shown on the maps as polygons with a green hatch pattern. Certain nesting data and some NDDB occurrences are shown as point locations using a green-colored dot. In cases where multiple resource types occupy the same polygon (such as birds and mammals), a black-hatched multi-group pattern is used rather than a green hatched polygon. A green icon (or icons) with the appropriate subgroup silhouette(s) is used to indicate the presence of different bird types (shorebirds, waterfowl, raptors, etc.). The appropriate icons are associated with all polygons or point features containing birds. The RAR# under the icon or icon set references a table on the reverse side of the map. In this table, the first column gives the species name(s). The second column indicates whether each species is listed as threatened (T) or endangered (E) on either the state (S) and/or federal (F) lists. The next column provides an estimate of the concentration of each species at the site. Concentration is indicated as "present," "potential," "very high," "high," "medium," or "low," or as a numerical value representing the number of nests (for nesting records), or the number of individuals (for non-nesting records) occurring at a site. "Present" is used for endangered or rare species that were known to occur at a site, where more detailed concentration information is not appropriate or not available. "Potential" is used for rare or endangered species that were likely or suspected to occur at a site, or that were expected to re-occupy a site in the very near future, based on expert information (e.g., potential return of least tern nesting following predator control at a site). The "very high," "high," "medium," and "low" categories or numerical values are used whenever possible. Descriptive concentration values represent the opinion of local resource managers or experts, based on relative concentrations in the study area. Numerical concentration values are based on the maximum number of birds recorded during recent surveys. Numerical concentrations at any particular site may fluctuate seasonally and annually based on local or regional conditions, or other factors. Species seasonality is shown in the next twelve columns representing the months of the year. If the species is present at that location in a particular month, an "X" is placed in the month column. The last columns denote the nesting time-period for each species, if nesting occurs in the particular area or site in question. Nesting refers to the entire nesting period, while laying, hatching, and fledging are discrete subsets of the nesting time period. For many species there is a temporal shift in seasonality and reproduction along with spatial changes in location. Temporal information included in the tables is specific to the one polygon or point that it references.

REPTILES/AMPHIBIANS

Reptiles and amphibians depicted in the San Francisco Bay atlas are limited to rare and endangered species including Western pond turtle, California red-legged frog, and California tiger salamander. These species are only shown when they occur near estuarine shorelines or habitats, or when they are located near potential staging or access sites (where spill-related disturbance would be possible). In most cases, these species were mapped from published and expert sources, using USGS topographic maps and/or SFEI baylands habitat data for spatial referencing. Polygons from CDFG's NDDB records were also used to depict some occurrences of these species. To avoid redundancy on the final maps, resource locations generated from expert and published sources took precedence over NDDB records. NDDB records were used to assist data development and review, and were also valuable in filling in additional resource locations not indicated by published or expert sources.

Reptile and amphibian locations or occurrences are depicted as polygons with a red hatch pattern. In cases where multiple resource types occupy the same polygon (such as reptiles and birds), a black-hatched multi-group pattern is used rather than a red hatch polygon. A red icon with a turtle or amphibian silhouette is used to indicate the presence of these species, and is associated with all polygons containing them. The number under the icon references a table on the reverse side of the map. In the tables, the first column gives the species name. The second column denotes whether the species has been designated as endangered (E) or threatened (T) on either the state (S) and/or federal (F) lists. The next column provides an estimate of the concentration of the species at a site. Concentration is indicated as "present" where more detailed concentration information was not appropriate or not available. "High," "medium," or

"low" concentrations are used whenever possible. The species seasonality is shown in the next twelve columns, representing the months of the year. If the species is present at that location in a particular month, an "X" is placed in the month column. For turtles and amphibians, the life-history columns indicate nesting, hatching, juvenile, and adult time-periods. For turtles, nesting refers to the time when adults construct nests and deposit eggs. Hatching refers to the time when young turtles are hatching and emerging from the nests. For amphibians, nesting refers to the general time when adults are breeding and laying eggs.

FISH

Fish species depicted for San Francisco Bay include selected marine, estuarine, anadromous, and freshwater species. Species of commercial, recreational, ecological, and/or conservation interest are emphasized. Fish (and invertebrates such as bay shrimp and crabs) are mapped as multi-species assemblages to the greatest extent possible. For different regions of the Bay area, assemblages are broken into two major categories: shoals, shallow creeks, and sloughs (< or = 20 feet below MLLW) versus deeper channels (>20 foot depths). Polygons for "shallows" versus "channels" were developed from digital data provided by SFEI. Often, the same species, but different life stages, were associated with adjacent "shallows" and "channels." Regional fish and invertebrate distributions were provided mainly by fisheries scientists with the CDFG Bay-Delta Division. Sacramento River-run chinook salmon distributions were depicted with the added assistance of USFWS biologists. Estuarine salinity zone distribution and seasonality data compiled by NOAA's Biogeographic Characterization Branch and Estuarine Living Marine Resources program were also consulted. It should be noted that fish (and invertebrate) resource distributions depicted on the maps may be more widespread in some locations than would actually occur in any given year, due to inter-annual variation in river discharge and salinity. During dry years, distributions for several species may shift towards the upstream or upper estuary portions of the areas depicted on the maps, the opposite being true during wet years.

In addition to the multi-species assemblages depicted on the maps, specific concentration areas or other key habitats for a few individual species are mapped separately. For instance, Pacific herring spawning locations are mapped for Central San Francisco Bay based on: expert sources; rock, gravel, and man-made shoreline types (ESI = 1A, 1B, 5, 6A, 6B, 8A, 8B, 8C); eelgrass and *Gracilaria* (algae) distributions; and nearshore structures depicted on USGS topographic maps and NOAA nautical charts.

The lower sections (mouths) of known anadromous rainbow trout (steelhead) and chinook salmon (non-Sacramento R.) spawning streams were also mapped based on published sources, information provided by local resource managers, and USGS topographic maps. National Marine Fisheries Service (NMFS) and U.S. Forest Service (USFS) personnel were consulted to confirm the locations of existing anadromous salmonid runs in the estuary. In a few cases, the names and/or locations of streams reported to have steelhead or chinook runs could not be identified using the USGS topographic maps, or were located just outside of the study area. Therefore, existing salmonid streams in the Bay area reported by Leidy (1997) or local resource managers are listed below (Table 3). Historic runs were not mapped as a part of this project, even though they might potentially hold salmonid runs in the future. It should also be recognized that steelhead and chinook juveniles and adults can be found migrating or feeding throughout the estuarine and riverine waters of the study area, not just in the spawning streams identified.

TABLE 3. Anadromous salmonid streams in the Bay area.

Stream Name	Species
Arroya Corte Madera Del Presidio Creek	steelhead
Corte Madera Creek	steelhead
Miller Creek	steelhead
Novato Creek	steelhead
Petaluma River (and some tribs.)	steelhead
Sonoma Creek (and tribs.)	steelhead, chinook
Napa River (and tribs.)	steelhead, chinook
Green Valley Creek	steelhead
Suisun Creek (and tribs.)	steelhead
Sacramento-San Joaquin Rivers and Tribs.	steelhead, chinook
Walnut Creek	steelhead, chinook
Pinole River	steelhead
San Pablo Creek	steelhead
Tolay Creek	steelhead

TABLE 3. Continued.

Stream Name	Species
Wildcat Creek	steelhead
San Leandro Creek	steelhead
San Lorenzo Creek	steelhead
Alameda Creek	steelhead
Coyote Creek	steelhead, chinook
Guadelupe River	steelhead, chinook
Saratoga Creek	steelhead
Redwood Creek	steelhead
Permanente Creek	steelhead
San Francisquito Creek	steelhead

Polygons and point data from CDFG's NDDB records and California State Lands Commission (SLC) datasets were also used to depict locations for certain fish species. To avoid redundancy on the final maps, resource locations generated from expert and published sources, SFEI data, and USGS topographic maps took precedence over the NDDB and SLC data. NDDB records as well as fisheries coverages provided by SLC were used in assisting resource experts during data development and review. These records were valuable in filling in additional resource locations for rare and endangered species not indicated by expert and published sources.

Fish are mainly shown on the maps as polygons with a blue hatch pattern. Some NDDB occurrences are shown as point locations using a blue-colored dot. Anadromous salmonid streams that were too small to be depicted as polygons are shown as linear features using a bright blue color readily distinguishable from the light blue color and black outline used for general hydrographic features. In cases where multiple resource types occupy the same polygon (such as fish and invertebrates), a black-hatched multi-group pattern is used rather than a blue hatched polygon. A blue icon with a fish silhouette is used to indicate the presence of fish. This icon is associated with all polygons or point features containing fish.

The RAR# under the icon or icon group references a table on the reverse side of the map. In this table, the first column gives the species name. The second column denotes whether the species has been designated endangered (E) or threatened (T) on either the state (S) and/or federal (F) lists. Fish concentrations are listed as "high," "medium," "low," or "rare" in most cases, based on expert opinion. Some records for rare and endangered species may also contain "present" in the concentration field, where more detailed concentration descriptions are not appropriate or not available. Seasonality is represented with an "X" indicating a species presence in any particular month. The last columns indicate time-periods for various life-history stages or activities (spawning [parturition for sharks and rays], eggs, larvae, juveniles, and adults). For the several anadromous species (sturgeon, shad, striped bass, longfin smelt, steelhead, chinook), spawning is only indicated for locations where actual spawning is known to occur. Where the beginning of spawning runs are indicated (e.g., steelhead trout), but actual spawning activity takes place upstream of the mapped distribution or study area (or specific spawning stretches of streams were not known), the adult time-period is used, but not the spawning category. For many species there may be spatial and temporal shifts in seasonality and life-history time-periods depending on location. Temporal information included in the tables can be specific to the one polygon or site that it references.

INVERTEBRATES

Invertebrate species depicted for San Francisco Bay mainly include bay shrimp (*Crangon* spp.) and crabs (*Cancer* spp.) of commercial, recreational, or ecological importance. Japanese little-neck clam harvest sites are also depicted in a few areas. Certain rare and endangered species, including tadpole shrimp and several insects are also included in the atlas. Rare and endangered species are shown only when they occur near estuarine shorelines or habitats, or when they are located near potential staging or access sites (where spill-related disturbance would be possible). Estuarine bay shrimp and crabs (and fish species) are mapped as multi-species assemblages to the greatest extent possible. For different regions of the Bay area, assemblages are divided into two major categories: (1) shoals, shallow creeks, and sloughs (< or = 20 feet below MLLW) and (2) deeper channels (>20 foot depths). Polygons for "shallows" versus "channels" were developed from digital data provided by SFEI. Often, the same species, but different life stages, were associated with adjacent "shallows" and channels." Bay shrimp, crab, and fish distributions were provided mainly by fisheries scientists with the CDFG Bay-Delta Division. Estuarine salinity zone distribution and seasonality data compiled by NOAA's Biogeographic Characterization Branch and Estuarine Living Marine Resources program were also consulted. It should be noted that bay shrimp, crab, and fish resource distributions depicted on the maps may be

more widespread in some locations than would actually occur in any given year, due to inter-annual variation in river discharge and salinity. During dry years, distributions for several species may shift towards the upstream or upper estuary portions of the areas depicted on the maps, the opposite being true during wet years.

In addition to the multi-species assemblages depicted on the maps, special concentration areas or other key habitats for a few individual species are mapped separately. For instance, Pacific rock crab and Red rock crab concentration areas are mapped based on expert sources, ESI shoreline types, and nearshore structures depicted on USGS topographic maps and NOAA nautical charts. Rock crabs are shown in certain portions of the Bay where rock or riprap shorelines predominated (ESI = 1A, 6B, 8A, 8C).

Expert sources, and polygons and point data from CDFG's NDDB records, were used to depict locations for rare and endangered invertebrates. NDDB records were used by resource experts during data development and review, and were valuable in filling in resource locations for rare and endangered species not indicated by expert sources.

Invertebrates are shown on the maps as polygons with an orange hatch pattern. Some NDDB occurrences are shown as point locations using an orange-colored dot. In cases where multiple resource types occupy the same polygon (such as fish and invertebrates), a black-hatched multi-group pattern is used rather than an orange hatched polygon. An orange icon with the appropriate invertebrate silhouette is used to indicate the presence of these resources. An orange icon(s) is associated with all polygons or point features containing invertebrates.

The RAR# under the icon or icon group references a table on the reverse side of the map. In this table, the first column gives the species name. The second column denotes whether the species has been designated endangered (E) or threatened (T) on either the state (S) and/or federal (F) lists. Concentration is listed as "high," "medium," or "low" in most cases, based on expert opinion. Some records for rare and endangered species may also contain "present" in the concentration field, where more detailed concentration descriptions are not appropriate or not available. Seasonality is represented with an "X" indicating a species presence in any particular month. The last columns indicate time-periods for various life-history stages or activities (spawning, eggs, larvae, juveniles, and adults). For many species there may be temporal shifts in seasonality and life-history time-periods, depending on location. Temporal information included in the tables is specific to the one polygon or site that it references.

HABITATS / RARE PLANTS

Submersed habitats depicted in San Francisco Bay include eelgrass beds and *Gracilaria* (algae) beds. Eelgrass beds were mapped initially using digital data provided by SLC (after Echeverria and Rutten, 1989). Additional eelgrass beds were depicted using a wide variety of published sources, reports, and expert information. *Gracilaria* beds were mapped using expert opinion for limited portions of the Central Bay region, mainly areas associated with Pacific herring spawning activity. Additional *Gracilaria* beds may be present in other portions of the study area.

Individual plant species depicted on the maps include a wide variety of rare or endangered wetland and upland species. Certain wetland species are emphasized, although other species are included if they occur near estuarine shorelines or habitats, or if they are located near potential staging or access sites (where spill-related disturbance would be possible).

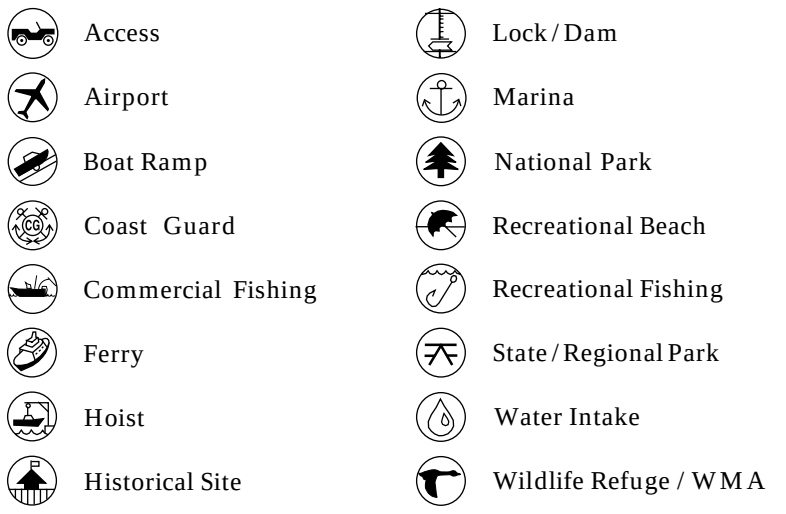
Mason's lilaeopsis is one species particularly emphasized. This species was mapped using digital point records provided by SFEI. Because the exact locations of individual Mason's lilaeopsis occurrences shift somewhat rapidly over time, SFEI records were used in conjunction with the ESI shoreline classification to develop polygons that represent areas where Mason's lilaeopsis is most likely to occur. Actual locations for this species will not cover the entire area indicated, but will occur at several discreet (though emphemeral) locations within the polygons. Additional records for Mason's lilaeopsis from other sources were also retained in some instances.

Other rare plant species emphasized in the atlas included: Suisun marsh aster, Alkali milk-vetch, Suisun thistle, Point Reyes bird's-beak, Soft bird's-beak, Delta tule pea, and California sea-blite. Rare plants were mainly mapped using expert and published sources in conjunction with SFEI baylands habitat data, USGS topographic maps, and polygons and point data from CDFG's NDDB records. USFWS and other experts were particularly helpful in locating certain key species. To avoid redundancy on the final maps, resource locations generated from experts, SFEI digital data, or published sources took precedence over the NDDB data. NDDB records were used in assisting resource experts during data development and review, and were valuable in filling in additional resource locations not indicated by other sources.

Submersed habitats and rare plants are depicted as polygons shaded with a purple hatch pattern. Some NDDB occurrences for rare plants are depicted as points using a purple-colored dot. In cases where multiple resource types occupy the same polygon (such as eelgrass and fish, or terrestrial mammals and rare plants), a black-hatched multi-group pattern is used rather than a purple hatched polygon. A purple icon with the appropriate silhouette is used to indicate the presence of submersed habitats or plants, and is associated with all polygons or point features containing these resources. The RAR# under the icon references a table on the reverse side of the map. In this table, the first column gives the species name. The next column provides an estimate of the concentration of the species at the site. Concentration is generally listed using a descriptive term, such as "high," "medium," or "low". Records for rare and endangered species may also contain "present" or "potential" in the concentration field, where more detailed concentration descriptions are not appropriate or not available. The species seasonality is shown in the next twelve columns, representing the months of the year. If the species is present at that location in a particular month, an "X" is placed in the month column. Submersed habitats and rare plants were mapped as being present year round.

HUMAN-USE FEATURES

The human-use features depicted on the maps are those that could be impacted by an oil spill or could provide access for response operations. All the features are represented by icons indicating the type of human-use resource. Many of the point features were mapped using digital data sources, expert information, published sources (such as the USCG Area Contingency Plan), and USGS topographic maps. Boat ramps and marina locations were supplemented by information gathered from NOAA aerial photography and the shoreline mapping overflights. Management areas were mapped using digital data provided by CDFG, the Teale Data Center, and the East Bay Regional Parks District. Hardcopy maps were also used to supplement or refine the digital management area data.



Access—Location where it is possible to gain vehicular access to the shoreline.

Airport—Location of airports, airfields, landing strips, etc., whether they are manned or unmanned.

Boat Ramp—Location of boat ramps. Boat ramp site names are provided on the data tables for each map, when available.

Coast Guard—Location of Coast Guard facilities.

Commercial Fishing—General areas where commercial fishing activities take place. Commercial fishing sites were generated from digital fisheries data provided by SLC and expert sources. In the Central Bay area, commercial fishing activities targeting spawning Pacific herring are particularly important.

Ferry—Sites where ferry landings are located.

Hoist—Sites with boat hoists, often associated with marina or port facilities.

Historical Site—Location of historic sites. Not all historic sites in the study area are depicted, only key sites located on or near the shoreline, as identified by expert or published sources.

Lock/Dam—Location of locks, dams, or similar structures.

Marina—Location of marinas. Marina names are provided on the data tables for each map, when available.

National Park—Areas managed by the National Park Service, including national parks, national recreation parks, national monuments, etc. The property name, management agency, contact information, and telephone number are provided on the data table for each map.

Recreational Beach—Location of recreational beaches used for activities such as swimming, sun-bathing, fishing, etc.

Recreational Fishing—Location of recreational fishing sites. Fishing sites were generated from digital fisheries data provided by SLC and expert sources.

State/Regional Park—Areas managed by the California Department of Parks and Recreation or the East Bay Regional Park District for recreational and natural resource purposes. The property name, management agency, contact information, and telephone number are provided on the data table for each map.

Water Intake—Location of water intakes. For most water intakes, the site name, owner/ manager, contact person, and telephone number are provided on the data table for each map.

Wildlife Refuge/Wildlife Management Area—Areas managed by the USFWS as National Wildlife Refuges, or by CDFG as State Wildlife Areas, State Ecological Reserves, and related properties. The property name, management agency, contact information, and telephone number are provided on the data table for each map.

GEOGRAPHIC INFORMATION SYSTEM DATA

The entire atlas product is stored in digital form in a Geographic Information System (GIS) as spatial data layers and associated databases. The format for the data varies depending on the type of information or features for which the data are being stored.

Under separate cover is a metadata document which details the data dictionary, processing techniques, data lineage, and other descriptive information for the digital data sets and maps that were used to create this atlas. Below is a brief synopsis of the information contained in the digital version. Refer to the metadata file for a full explanation of the data and its structure.

SHORELINE HABITAT CLASSIFICATION

The shoreline habitat classification is stored as lines and polygons with associated attributes. In many cases, a shoreline may have two or three different classifications. These multiple classifications are represented on the maps by double and triple line patterns and in the database by ESI#1/ESI#2, where ESI#1 is the landward-most classification and ESI#2 is the seaward-most classification. In addition to the line features, tidal flats (ESI = 7, ESI = 9A) and salt and brackish marshes (ESI = 10A) are also stored as polygons. Certain SFEI baylands habitat types are also provided under a separate coverage. Baylands habitat types include tidal marshes, muted tidal marshes, managed marshes, diked marshes, and salt ponds.

SENSITIVE BIOLOGICAL RESOURCES

Biological resources are stored as polygons, points, or lines. Associated with each feature is a unique identification number which is linked to a series of databases that further identify the resources. The first data set consists of a list of the species and the concentration of each species. This dataset is then linked to datasets that describe the life history of each species (temporal presence and reproductive/ life-history time periods at month resolution) for the specified map feature. Other databases linked to the first data set are: the species identification database, which includes common and scientific names and NDDB Global Conservation Status Ranks for all species; the species status database, which gives information for state and/or federal threatened or endangered listings; and the sources database, which provides source metadata for each biological feature. Note that occurrence sites (polygons and points) for rare and endangered species provided by CDFG's NDDB program are included only on the hardcopy maps, not in the digital data set. Interested parties should contact the CDFG Natural Heritage Division (Telephone: 916/445-6383) for the most complete and up to date NDDB information.

HUMAN-USE FEATURES

Human-use features are represented as lines, points, or polygons. The resource name, the owner/manager, a contact person, and an emergency phone number are included in the database for boat ramps, marinas, water intakes, and management areas, when available. All metadata sources are documented at the feature level.

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SPECIES LIST*

Common Name	Species Name
MARINE MAMMALS	
SEALS/SEA LIONS	
California sea lion	*Zalophus californianus*
Harbor seal	*Phoca vitulina*
TERRESTRIAL MAMMALS	
SMALL MAMMALS	
Northern river otter	*Lutra canadensis*
Salt-marsh harvest mouse	*Reithrodontomys raviventris*
Saltmarsh wandering shrew	*Sorex vagrans halicoetes*
San Pablo vole	*Microtus californicus sanpabloensis*
Suisun ornate shrew	*Sorex ornatus sinuosus*
BIRDS	
ALCIDS	
Common murre	*Uria aalge*
Pigeon guillemot	*Cepphus columba*
DIVING BIRDS	
American white pelican	*Pelecanus erythrorhynchos*
Brandt's cormorant	*Phalacrocorax penicillatus*
California brown pelican	*Pelecanus occidentalis californicus*
Clark's grebe	*Aechmophorus clarkii*
Double-crested cormorant	*Phalacrocorax auritus*
Pelagic cormorant	*Phalacrocorax pelagicus*
Western grebe	*Aechmophorus occidentalis*
GULLS AND TERNS	
Black skimmer	*Rynchops niger*
California gull	*Larus californicus*
California least tern	*Sterna antillarum browni*
Caspian tern	*Sterna caspia*
Forster's tern	*Sterna forsteri*
Western gull	*Larus occidentalis*
Gulls	
Terns	
PASSERINE	
Alameda song sparrow	*Melospiza melodia pusillula*
Bank swallow	*Riparia riparia*
Saltmarsh common yellowthroat	*Geothlypis trichas sinuosa*
San Pablo song sparrow	*Melospiza melodia samuelis*
Suisun song sparrow	*Melospiza melodia maxillaris*
Tricolored blackbird	*Agelaius tricolor*
RAPTORS	
Burrowing owl	*Athene cunicularia hypugea*
Golden eagle	*Aquila chrysaetos*
Northern harrier	*Circus cyaneus*
Osprey	*Pandion haliaetus*
Peregrine falcon	*Falco peregrinus*
Short-eared owl	*Asio flammeus*
White-tailed kite	*Elanus leucurus*
SHOREBIRDS	
American avocet	*Recurvirostra americana*
Black oystercatcher	*Haematopus bachmani*
Black-necked stilt	*Himantopus mexicanus*
Killdeer	*Charadrius vociferus*
Red-necked (Northern) phalarope	*Phalaropus lobatus*
Western snowy plover	*Charadrius alexandrinus nivosus*
Shorebirds (see Table 1; Page 3)	

SPECIES LIST*

Common Name	Species Name
BIRDS	
WADING BIRDS	
Black-crowned night-heron	*Nycticorax nycticorax*
California black rail	*Laterallus jamaicensis coturniculus*
California clapper rail	*Rallus longirostris obsoletus*
Cattle egret	*Bubulcus ibis*
Great blue heron	*Ardea herodias*
Great egret	*Ardea alba*
Little blue heron	*Egretta caerulea*
Snowy egret	*Egretta thula*
Sora	*Porzana carolina*
Virginia rail	*Rallus limicola*
Egrets	
Herons	
Wading birds	
WATERFOWL	
American coot	*Fulica americana*
Canada goose	*Branta canadensis*
Canvasback	*Aythya valisineria*
Common moorhen	*Gallinula chloropus*
Greater white-fronted goose	*Anser albifrons*
Northern pintail	*Anas acuta*
Ruddy duck	*Oxyura jamaicensis*
Snow goose	*Chen caerulescens*
Tundra (whistling) swan	*Cygnus columbianus*
Dabbling ducks (see Table 1; Page 3)	
Diving ducks (see Table 1; Page 3)	
Waterfowl	
FISH	
DIADROMOUS (ANADROMOUS)	
American shad	*Alosa sapidissima*
Chinook salmon	*Oncorhynchus tshawytscha*
Chinook salmon (fall)	*Oncorhynchus tshawytscha*
Chinook salmon (late fall)	*Oncorhynchus tshawytscha*
Chinook salmon (spring)	*Oncorhynchus tshawytscha*
Chinook salmon (winter)	*Oncorhynchus tshawytscha*
Green sturgeon	*Acipenser medirostris*
Longfin smelt	*Spirinchus thaleichthys*
Rainbow trout (steelhead)	*Oncorhynchus mykiss*
Striped bass	*Morone saxatilis*
White sturgeon	*Acipenser transmontanus*
ESTUARINE NURSERY	
California halibut	*Paralichthys californicus*
English sole	*Pleuronectes vetulus*
Leopard shark	*Triakis semifasciata*
Pacific herring	*Clupea pallasi*
Starry flounder	*Platichthys stellatus*
White croaker	*Genyonemus lineatus*
ESTUARINE RESIDENT	
Delta smelt	*Hypomesus transpacificus*
FRESHWATER	
Sacramento perch	*Archoplites interruptus*
Sacramento splittail	*Pogonichthys macrolepidotus*
MARINE BENTHIC	
Bat ray	*Myliobatis californica*
Brown rockfish	*Sebastes auriculatus*
REPTILES/AMPHIBIANS	
AMPHIBIANS	
California red-legged frog	*Rana aurora draytonii*
California tiger salamander	*Ambystoma californiense*
TURTLES	
Western pond turtle	*Clemmys marmorata*

* Threatened and endangered species are designated by underlining.

SPECIES LIST*

Common Name	Species Name
INVERTEBRATES	
BIVALVES	
Japanese littleneck clam	*Tapes philippinarum*
CRABS	
Dungeness crab	*Cancer magister*
Pacific rock crab	*Cancer antennarius*
Red rock crab	*Cancer productus*
INSECTS	
Antioch andrenid bee	*Perdita scituta antiochensis*
Antioch efferian robberfly	*Efferia antiochi*
Lange's metalmark butterfly	*Apodemia mormo langei*
Middlekauf's shieldback katydid	*Idiostatus middlekaufi*
Mission blue butterfly	*Icaricia icariodes missionensis*
SHRIMP	
Blacktail bay shrimp	*Crangon nigricauda*
California bay shrimp	*Crangon franciscorum*
Vernal pool tadpole shrimp	*Lepidurus packardi*

SPECIES LIST*

Common Name	Species Name
HABITATS/RARE PLANTS	
EELGRASS/ALGAE	
Eelgrass	*Zostera marina*
Gracilaria	*Gracilaria sp.*
RARE PLANTS	
Alkali milk-vetch	*Astragalus tener tener*
Ambiguous indian paintbrush	*Castilleja ambigua*
Antioch dunes evening-primrose	*Oenothera deltoides howellii*
Brittlescale	*Atriplex depressa*
California seablite	*Suaeda californica*
Contra Costa goldfields	*Lasthenia conjugens*
Contra Costa wallflower	*Erysimum capitatum angustatum*
Delta mudwort	*Limosella subulata*
Delta tule pea	*Lathyrus jepsonii jepsonii*
Marin knotweed	*Polygonum marinense*
Marin western flax	*Hesperolinon congestum*
Marsh sandwort	*Arenaria paludicola*
Mason's lilaeopsis	*Lilaeopsis masonii*
Mojave seablite	*Suaeda moquinii*
Nootka alkaligrass	*Puccinellia nutkaensis*
Point Reyes bird's-beak	*Cordylanthus maritimus palustris*
San Francisco campion	*Silene verecunda verecunda*
San Francisco gumplant	*Grindelia hirsutula maritima*
San Joaquin saltbush	*Atriplex joaquiniana*
Santa Cruz tarplant	*Holocarpha macradenia*
Soft bird's-beak	*Cordylanthus mollis mollis*
Suisun marsh aster	*Aster lentus*
Suisun thistle	*Cirsium hydrophilum hydrophilum*
Yellowray goldfields	*Lasthenia glabrata*
Vernal pool plants	

* Threatened and endangered species are designated by underlining.

EXPOSED ROCKY SHORES — ESI = 1A

DESCRIPTION

- The intertidal zone is steep (>30° slope), with very little width.
- Sediment accumulations are uncommon because waves remove debris that has slumped from the eroding cliffs.
- There is strong vertical zonation of intertidal biological communities.
- Species density and diversity vary greatly, but barnacles, snails, mussels, polychaetes, and macroalgae can be abundant.
- They are common in the Golden Gate area and Alcatraz Island.

PREDICTED OIL BEHAVIOR

- Oil is held offshore by waves reflecting off the steep, hard surface.
- Any oil that is deposited is rapidly removed from exposed faces.
- The most resistant oil would remain as a patchy band at or above the high-tide line.
- Impacts to intertidal communities are expected to be short-term in duration. An exception would be where heavy concentrations of a light refined product came ashore very quickly.

RESPONSE CONSIDERATIONS

- Cleanup is usually not required.
- Access can be difficult and dangerous.

EXPOSED, SOLID MAN-MADE STRUCTURES — ESI = 1B

DESCRIPTION

- These structures are solid, man-made structures such as seawalls, groins, revetments, piers, and port facilities.
- Many structures are constructed of concrete, wood, or metal.
- They are built to protect the shore from erosion by waves, boat wakes, and currents, and thus are exposed to rapid natural removal processes.
- Often there is no exposed substrate at low tide, but multiple habitats are indicated if present.
- Attached animals and plants are sparse to moderate.
- They are common in highly developed waterfront areas such as the San Francisco Peninsula, Oakland Inner Harbor, Hunters Point, and Mare Island Strait.

PREDICTED OIL BEHAVIOR

- Oil is held offshore by waves reflecting off the steep, hard surface in exposed settings.
- Oil readily adheres to the dry, rough surfaces, but it does not adhere to wet substrates.
- The most resistant oil would remain as a patchy band at or above the high-tide line.

RESPONSE CONSIDERATIONS

- Cleanup is usually not required.
- High-pressure water spraying may be conducted to:
  - remove risks of contamination of people or vessels; or
  - improve aesthetics

EXPOSED WAVE-CUT PLATFORMS IN BEDROCK — ESI = 2A

DESCRIPTION

- They are characterized by a narrow shelf or platform that can be flooded depending on water levels.
- They are not very common in the Bay area but are present at Wilson Point in Pinole, Commodore Jones Point in the Carquinez Strait, and portions of the shoreline south of Point San Pablo.

PREDICTED OIL BEHAVIOR

- Oil will not adhere to the wet rock surface, but could penetrate crevices or sediment veneers if present.
- Persistence of oil is usually short-term, except in wave shadows or where the oil was deposited high above normal wave activity.

RESPONSE CONSIDERATIONS

- Cleanup is usually not required.
- Where the high-tide area is accessible, it may be feasible to manually remove heavy oil accumulations and oiled debris.

FINE-TO MEDIUM-GRAINED SAND BEACHES ESI = 3A

DESCRIPTION

- These beaches are flat to moderately sloping and relatively hard packed.
- There can be heavy accumulations of wrack present.
- They are utilized by birds and turtles.
- Upper beach fauna include ghost crabs and amphipods; lower beach fauna can be moderate, but highly variable.
- They are common along Robert Crown Memorial State Beach in Alameda.

PREDICTED OIL BEHAVIOR

- Light oil accumulations will be deposited as oily swashes or bands along the upper intertidal zone.
- Heavy oil accumulations will cover the entire beach surface; oil will be lifted off the lower beach with the rising tide.
- Maximum penetration of oil into fine- to medium-grained sand is about 10-15 cm.
- Burial of oil by clean sand within the first week after a spill typically will be less than 30 cm along the upper beach face.
- Organisms living in the beach sediment may be killed by smothering or lethal oil concentrations in the interstitial water.
- Biological impacts include temporary declines in infauna, which can affect important shorebird foraging areas.

RESPONSE CONSIDERATIONS

- These beaches are among the easiest shoreline types to clean.
- Cleanup should concentrate on removing oil and oily debris from the upper swash zone once oil has come ashore.
- Manual cleanup, rather than road graders and front-end loaders, is advised to minimize the volume of sand removed from the shore and requiring disposal.
- All efforts should focus on preventing the mixture of oil deeper into the sediments by vehicular and foot traffic.
- Mechanical reworking of lightly oiled sediments from the high-tide line to the upper intertidal zone can be effective along exposed beaches.

SCARPS AND STEEP SLOPES IN SAND ESI = 3B

DESCRIPTION

- This shoreline type occurs where sandy bluffs are undercut by waves or currents and slump.
- They normally form along embankments of sandy dredge-spoil material and at cutbanks in rivers.
- Some scarps are fronted by narrow beaches, if the erosion rates are moderate and episodic.
- Trees growing at the top of these slopes are eventually undercut and the logs can accumulate at the base of the scarp.
- Biological utilization by birds and infauna is low.
- They are not very common along the Bay shoreline but are found along eroding levees and dredged spoil mounds.

PREDICTED OIL BEHAVIOR

- Any stranded oil will concentrate at the high-water line and may penetrate sandy sediments.
- Oil will also adhere to the dry surfaces of any logs that have accumulated at the base of the scarp.
- There is little potential for burial except when major slumping of the bluff occurs.
- Active erosion of the scarp will remove the oil.

RESPONSE CONSIDERATIONS

- In most cases, cleanup is not necessary because of the short residence time of the oil
- The need for removal of oiled sediments and debris should be evaluated because of the potential for increased erosion.
- Closely supervised manual labor should be used so that the minimal amount of material is removed during cleanup.

COARSE-GRAINED SAND BEACHES — ESI = 4

DESCRIPTION

- These beaches are moderate-to-steep, of variable width, and have soft sediments.
- Generally species density and diversity is lower than on fine-grained sand beaches.
- They are common at Baker Beach (outer coast), Crissy Field Beach, Portions of the Angel Island shoreline, and at the San Francisco Maritime State Historic Park.

PREDICTED OIL BEHAVIOR

- During small spills, oil will be deposited primarily as a band along the high-tide line.
- Under very heavy accumulations, oil may spread across the entire beach face, though the oil will be lifted off the lower part of the beach with the rising tide.
- Penetration of oil into coarse-grained sand can reach 25 cm.
- Burial of oiled layers by clean sand can be rapid, and to depths of 60 cm or more.
- Burial to depths over one meter is possible if the oil comes ashore at the start of a depositional period.
- Biological impacts include temporary declines in infaunal populations, which can also affect important shorebird foraging areas.

RESPONSE CONSIDERATIONS

- Remove oil primarily from the upper swash lines.
- Removal of sediment should be limited to avoid erosion.
- Use of heavy equipment for oil/sand removal may result in the removal of excessive amounts of sand; manual cleanup may be more effective.
- Mechanical reworking of the sediment into the surf zone may be used to release the oil without sediment removal.

MIXED SAND AND GRAVEL BEACHES — ESI = 5

DESCRIPTION

- These beaches are moderately sloping, composed of a mixture of sand and gravel.
- Because of the mixed sediment sizes, there may be zones of pure sand, pebbles, or cobbles.
- There can be large-scale changes in the sediment distribution patterns depending upon season, because of the transport of the sand fraction offshore during storms.
- Because of desiccation and sediment mobility on exposed beaches, there are low densities of attached animals and plants.
- The presence of attached algae, mussels, and barnacles indicates beaches that are relatively sheltered, with the more stable substrate supporting a richer biota.
- They are found along the north shore of the Carquinez Strait, northwest of Strawberry Point along Richardson Bay, McNears Beach, north of Point San Pedro, and along Belvedere Island.

PREDICTED OIL BEHAVIOR

- During small spills, oil will be deposited along and above the high-tide swash.
- Large spills will spread across the entire intertidal area.
- Oil penetration into the beach sediments may be up to 50 cm; however, the sand fraction can be quite mobile, and oil behavior is much like on a sand beach if the sand fraction exceeds about 40 percent.
- Burial of oil may be deep at and above the high-tide line, where oil tends to persist, particularly where beaches are only intermittently exposed to waves.
- In sheltered pockets on the beach, pavements of asphalted sediments can form if there is no removal of heavy oil accumulations, because most of the oil remains on the surface.
- Once formed, these asphalt pavements can persist for years.

RESPONSE CONSIDERATIONS

- Remove heavy accumulations of pooled oil from the upper beachface.
- All oiled debris should be removed.
- Sediment removal should be limited as much as possible.
- Low-pressure flushing can be used to float oil away from the sediments for recovery by skimmers or sorbents. High-pressure spraying should be avoided because of potential for transporting contaminated finer sediments (sand) to the lower intertidal or subtidal zones.
- Mechanical reworking of oiled sediments from the high-tide zone to the upper intertidal zone can be effective in areas regularly exposed to wave activity (as evidenced by storm berms). However, oiled sediments should not be relocated below the mid-tide zone.
- In-place tilling may be used to reach deeply buried oil layers in the middle zone on exposed beaches.

GRAVEL BEACHES — ESI = 6A

DESCRIPTION

- Gravel beaches can be very steep, with multiple wave-built berms forming the upper beach.
- Because of the high mobility of these sediments on exposed beaches, there are low densities of animals and plants.
- Gravel beaches are found in Saucelito, near Yellow Bluff, at Pinole Point, Point Molate, and Paradise Cove.

PREDICTED OIL BEHAVIOR

- Deep penetration of stranded oil is likely on gravel beaches because of their high permeability.
- Long-term persistence will be controlled by the depth of routine reworking by the waves.
- Along sheltered portions of the shorelines, chronic sheening and the formation of asphalt pavements is likely where accumulations are heavy.

RESPONSE CONSIDERATIONS

- Heavy accumulations of pooled oil should be removed quickly from the upper beach.
- All oiled debris should be removed.
- Sediment removal should be limited as much as possible.
- Low- to high-pressure flushing can be effective, making sure to recover all released oil with skimmers or sorbents.
- Mechanical reworking of oiled sediments from the high-tide line to the lower beachface can be effective in areas regularly exposed to wave activity; the presence of multiple storm berms is evidence of wave activity.
- In-place tilling may be used to reach deeply buried oil layers along the mid-intertidal zone on exposed beaches.

RIPRAP — ESI = 6B

DESCRIPTION

- Riprap structures are composed of cobble- to boulder-sized blocks of granite or limestone.
- Riprap structures are used for shoreline protection and in levee stabilization throughout the Bay area.
- Attached biota is sparse on exposed riprap.
- They are common in highly developed waterfront areas. They are also used to build or repair levees throughout the Bay area.

PREDICTED OIL BEHAVIOR

- Deep penetration of oil between the blocks is likely.
- Oil adheres readily to the rough surfaces of the blocks.
- Uncleaned oil can cause chronic leaching until the oil hardens.

RESPONSE CONSIDERATIONS

- When the oil is fresh and liquid, high pressure spraying and/or water flooding may be effective, making sure to recover all liberated oil.
- Heavy and weathered oils are more difficult to remove, requiring scrapping and/or hot-water spraying.

EXPOSED TIDAL FLATS — ESI = 7

DESCRIPTION

- Exposed tidal flats are broad intertidal areas composed primarily of sand and various amounts of gravel.
- The presence of sand indicates that tidal currents and waves are strong enough to mobilize the sediments.
- They are usually associated with another shoreline type on the landward side of the flat, though they can occur as separate shoals; they are commonly associated with tidal inlets.
- Biological utilization can be very high, with large numbers of infauna, heavy use by birds for roosting and foraging, and use by foraging fish.

PREDICTED OIL BEHAVIOR

- Oil does not usually adhere to the surface of exposed tidal flats, but rather moves across the flat and accumulates at the high-tide line.
- Deposition of oil on the flat may occur on a falling tide if concentrations are heavy.
- Oil does not penetrate water-saturated sediments, but may penetrate coarse-grained sand and any gravel, if present.
- Biological damage may be severe, primarily to infauna, thereby reducing food sources for birds and other predators.

RESPONSE CONSIDERATIONS

- Currents and waves can be very effective in natural removal of the oil.
- Cleanup is very difficult (and possible only during low tides).
- The use of heavy machinery should be restricted to prevent mixing of oil into the sediments.

SHELTERED ROCKY SHORES — ESI = 8A

DESCRIPTION

- These are bedrock shores of variable slope which are sheltered from most wave and tidal energy.
- They are uncommon, but occur along portions of Richardson Bay, in the vicinity of Strawberry Point.

PREDICTED OIL BEHAVIOR

- Oil will adhere readily to dry rough rocky surfaces, particularly at the high-tide line, forming a distinct oil band.
- The lower intertidal zone usually is algae covered and stays wet, preventing oil from adhering.

RESPONSE CONSIDERATIONS

- Low-pressure flushing at ambient temperatures is most effective when the oil is fresh.
- Extreme care must be taken not to spray in the biologically rich lower intertidal zone or when the tidal level reaches that zone.
- Cutting of oiled, attached algae is not recommended; tidal action will eventually float this oil off, so sorbent booms should be deployed.

SHELTERED, SOLID MAN-MADE STRUCTURES — ESI = 8B

DESCRIPTION

- These structures are solid man-made structures such as seawalls, groins, revetments, piers, and port facilities, constructed of concrete, wood, or metal.
- Most structures are designed to protect a single lot, thus their composition, design, and condition are highly variable.
- Often there is no exposed beach at low tide, but multiple habitats are indicated if present.
- Attached animal and plant life can be high.
- They are common in developed waterfront areas such as the San Francisco Peninsula, Oakland Inner Harbor, and Hunters Point.

PREDICTED OIL BEHAVIOR

- Oil will adhere readily to the rough surface, particularly along the high-tide line, forming a distinct oil band.
- The lower intertidal zone usually stays wet (particularly if algae covered), preventing oil from adhering to the surface.

RESPONSE CONSIDERATIONS

- Cleanup of seawalls is usually conducted for aesthetic reasons or to prevent leaching of oil.
- Low- to high-pressure spraying at ambient water temperatures is most effective when the oil is fresh.

SHELTERED RIPRAP — ESI = 8C

DESCRIPTION

- Riprap structures are composed of cobble- to boulder-sized blocks of granite or limestone.
- These structures are found inside harbors and bays in highly developed areas, sheltered from direct exposure to waves.
- Attached animal and plant life can be high.
- They are common in highly developed waterfront areas, boat basins, and marinas.

PREDICTED OIL BEHAVIOR

- Deep penetration of oil between the boulders is likely.
- Oil adheres readily to the rough surfaces.
- If oil is left uncleaned, it may cause chronic leaching until the oil hardens.

RESPONSE CONSIDERATIONS

- High-pressure spraying may be required to remove oil for aesthetic reasons and to prevent leaching of oil from the structure.
- Cleanup crews should make sure to recover all released oil.

SHELTERED TIDAL FLATS — ESI = 9A

DESCRIPTION

- Sheltered tidal flats are composed primarily of mud with minor amounts of sand and shell.
- They are usually present in calm-water habitats, sheltered from major wave activity, and backed by marshes.
- The sediments are very soft and cannot support even light foot traffic in many areas.
- There can be large concentrations of bivalves, worms, and other invertebrates in the sediments.
- They are heavily utilized by birds for feeding.
- They are very common throughout portions of San Pablo Bay and southernmost San Francisco Bay.

PREDICTED OIL BEHAVIOR

- Oil does not usually adhere to the surface of sheltered tidal flats, but rather moves across the flat and accumulates at the high-tide line.
- Deposition of oil on the flat may occur on a falling tide if concentrations are heavy.
- Oil will not penetrate the water-saturated sediments, but could penetrate burrows and desiccation cracks or other crevices in muddy sediments.
- In areas of high suspended sediments, sorption of oil can result in deposition of contaminated sediments on the flats.
- Biological impacts may be severe.

RESPONSE CONSIDERATIONS

- These are high-priority areas for protection since cleanup options are limited.
- Cleanup of the flat surface is very difficult because of the soft substrate; many methods may be restricted.
- Low-pressure flushing and deployment of sorbents from shallow-draft boats may be helpful.

VEGETATED LOW RIVERINE BANKS — ESI = 9B

DESCRIPTION

- This type consists of either low banks with grasses or low eroding banks with trees and tree roots exposed to the water.
- The banks are flooded occasionally by high water.
- These shorelines are generally found in fresh or brackish water localities.
- They are common on the Sacramento and San Joaquin Rivers and along the vegetated earthen levees throughout the Bay.

PREDICTED OIL BEHAVIOR

- During low water stages there is little impact, with the oil coating a narrow band of sediment at the water level.
- During high water, the oil can coat the grasses and trees.
- Oiling may cause loss of the grasses, but the trees should survive unless oil penetrates and persists in the substrate.

RESPONSE CONSIDERATIONS

- Low-pressure flushing of oiled areas is effective in removing moderate to heavy accumulations of oil from along the banks.
- Sorbent and containment boom should be placed on the water side of the cleanup operations to contain and collect oil outflow.
- Low- to high-pressure flushing can be used to remove oil from tree roots and trunks, if deemed necessary in high-use areas.

SALT- AND BRACKISH-WATER MARSHES — ESI = 10A

DESCRIPTION

- This shoreline type consists of intertidal wetlands containing emergent, herbaceous vegetation, including both tidal and muted tidal marshes. Depending on location and interannual variations in rainfall and run-off, vegetation associated with this ESI type in the Bay Area may include species tolerant or adapted to salt, brackish, or even tidal freshwater conditions.
- Width of the marsh can vary widely, from a narrow fringe to extensive areas.
- Sediments are composed of organic muds except on the margins of exposed areas where sand is abundant.
- Exposed areas are located along bays with wide fetches and along heavily trafficked waterways.
- Sheltered areas are not exposed to significant wave or boat wake activity.
- Marsh-associated flora and fauna are abundant with numerous species and high utilization by birds, mammals, fish, and invertebrates.
- They are common throughout the Bay.

PREDICTED OIL BEHAVIOR

- Oil adheres readily to intertidal vegetation.
- The band of coating will vary widely, depending upon the water level at the time oil slicks are in the vegetation. There may be multiple bands.
- Large slicks will persist through multiple tidal cycles and coat the entire stem from the high-tide line to the base.
- If the vegetation is thick, heavy oil coating will be restricted to the outer fringe, although lighter oils can penetrate deeper, to the limit of tidal influence.
- Medium to heavy oils do not readily adhere to or penetrate the fine sediments, but can pool on the surface or in animal burrows.
- Light oils can penetrate the top few centimeters of sediment, under some circumstances oil can penetrate deeply into burrows and cracks (up to one meter).

RESPONSE CONSIDERATIONS

- Under light oiling, the best practice is to let the area recover naturally.
- Natural removal processes and rates should be evaluated prior to conducting cleanup.
- Heavy accumulations of pooled oil can be removed by vacuum, sorbents, or low-pressure flushing. During flushing, care must be taken to prevent transporting oil to sensitive areas down slope or along shore.
- Cleanup activities should be carefully supervised to avoid vegetation damage.
- Any cleanup activity must not mix the oil deeper into the sediments. Trampling of the plants and disturbance of soft sediments must be minimized.
- Aggressive cleanup methods should only be considered when other resources (migratory birds, endangered species) are at greater risk from oiled vegetation left in place.