The Marshes of San Francisco Bay:

Their Attributes and Values

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I. Dynamics of Salt Water Marshes

Introduction

The marshes of San Francisco Bay have both unique characteristics of their own and general characteristics which they share with marshes throughout the world. A very important attribute of any marsh is its plant life. Plants establish the character of each marsh and provide the basic food for animals that live there and in adjacent estuarine waters.

Tidal marshes are dynamic ecosystems, changing with fluctuations in sea level and water quality. They are generally considered temporary communities since sedimentation alters their composition and ultimate fate. In this report, we will examine the nature and importance of the tidal marshes of San Francisco Bay.

Geologic History of Bay Marshes

As recently as 20,000 years ago San Francisco Bay did not exist. The Pacific Ocean surface was at least 300 feet lower than at present. In time it gradually rose as the glaciers melted and, in fact, sea level continues to rise in the Bay area (Fig. 1) but at a slower rate. Sea level is still rising at San Francisco about one-half foot per hundred years. This rise in sea level has caused ancient marshes of the Bay to be covered by water, sediments and eventually new marshes.

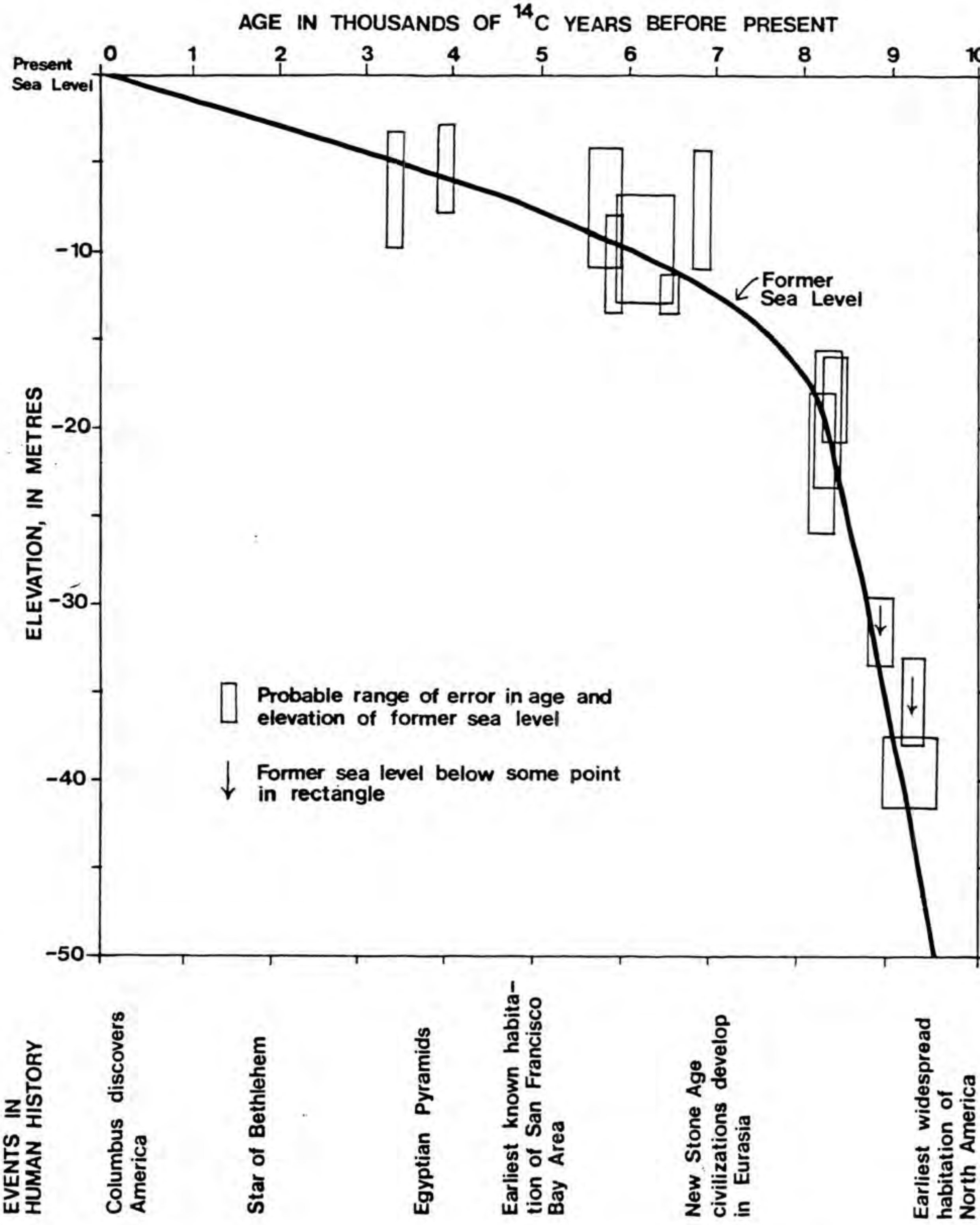

Fig. 1. Rise of sea level in San Francisco Bay in last 10,000 years (after Atwater et al, 1977)

Studies of cores taken near San Francisco suggest that tidal marshes 8-10,000 years ago were restricted to narrow bands along the margins of a small growing bay (Atwater & Hedel 1976). When sea level approached 15 meters below the present level, the rate of rise slowed to such a degree that marsh formation could ultimately spread into the broad shallow waters of the expanding Bay.

Recent developments in the past 120 years have modified greatly the extent of marshes in San Francisco Bay. Historically, marshes covered about 313 square miles according to Nichols and Wright (1971). They reported that most of these tidal marshes of San Francisco Bay were subsequently destroyed. Some of the present marshes are relatively new, in that they have developed since the mid-to-late 1800's. Nichols and Wright (1971) report 125 square miles of tidal marsh were in existence in 1970. This figure does not include the marshes which have been lost since that date. Fig. 2 shows the sites of present tidal marshes with respect to those in existence in 1850, according to Atwater and Hedel (1976).

Marshes in general

Everyone seems to know a marsh when they see one, yet it is surprising how difficult it is to describe clearly those properties that make it a marsh. We will define a marsh as a herbaceous water-loving plant community e.g. tules and cattails. It is even more difficult to give a simple account of the role of marshes in nature and in human affairs. Why have people all over the world suddenly become concerned about the welfare, protection and reconstruction of marshes?

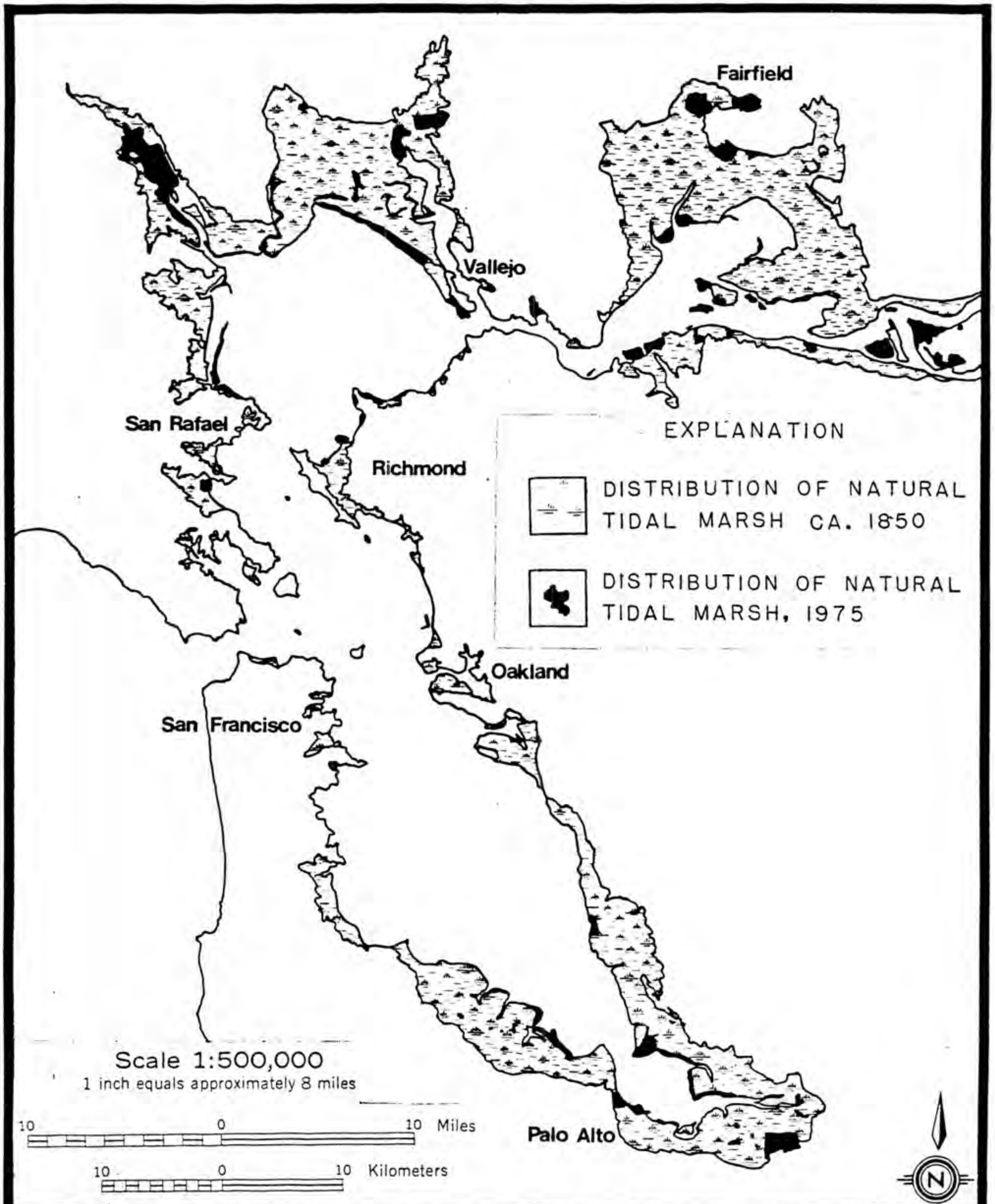

Fig. 2. Distribution of tidal marsh in San Francisco Bay ca. 1850 vs. 1975 (after Atwater and Hedel, 1976)

People, it seems, have become aware of the vital role of marshes in the sustained yield of some natural resources. Marshes are important to the maintenance of the water quality of bays, lakes, rivers and streams which are part of the human environment. While most people are cognizant of the deterioration of their immediate environment, only recently have they begun to realize that a part of this deterioration has been due to the loss of marshes. The great English mathematician, A. N. Whitehead, pointed out that whoever destroys the resources upon which he depends is committing suicide. Past cultures have disappeared through the destruction or overuse of the resources upon which they depended. The abandoned agricultural terraces of the Inca in Peru, the overgrazed hillsides of Greece, and the erosion of the once great agricultural lands of the Tigris and Euphrates Valley bear testimony to cultural decline as possibly the result in part of natural resource mismanagement. The current decline in the harvests from our bays and estuaries may be traced to the destruction of the marshes upon which these fragile resources depended.

We will define San Francisco Bay as consisting of Southern S. F. Bay, Central S. F. Bay, San Pablo and Suisun Bays, each of which has one or more smaller embayments. The Bays receive fresh water from rivers, creeks and local run off. Along most of the creeks and rivers are brackish marshes. The main source of fresh water for the Bay as whole, however, enters from the Sacramento and San Joaquin River systems at a point just below their confluence. From Suisun Bay this water flows into San Pablo Bay and from there into the Central and South Bay.

Since 1850, nearly 190 square miles of marshland have been destroyed in the San Francisco Bay. Most recent was the conversion into salt pans by the Leslie Salt Company of most of the remaining marsh at the mouth of the Napa River. Nichols and Wright (1971) indicated that about 125 square miles of tidal marshland still exist today, of which about 50 square miles are new marsh that have developed since 1850.

Oysters, clams, crabs and shrimp, once abundant commercial fisheries in San Francisco Bay, have nearly all disappeared. Until very recently, the volume of pollutants has steadily increased while the volume of fresh water to dilute them has steadily decreased. Though marsh organisms act to strip many pollutants from the water, few marshes remain to aid in this gigantic task of water purification. The net result has been the impoverishment of the Bay's renewable natural resources that can only be maintained by bringing water quality back to a reasonable standard. Much of the destruction happened so long ago that many present day residents of the Bay Area do not know that such fisheries ever existed.

Systematic monitoring by the State Water Quality Control Board in conjunction with State Fish and Game has contributed much to our understanding of the fluctuation of salinity in the diked marshes adjacent to Suisun Bay. Some excellent work on plant response has been reported for these marshes by Mall (1969) and for San Pablo Bay by Atwater and Hedel (1976).

In this report, we will be especially concerned with the vegetation response to salinity and how the salinity gradient maintains a vegetation gradient from the salt marshes of Central San Francisco Bay to the brackish water marshes of Suisun Bay to fresh water marshes of the Delta. However, because of geographic variations in habitat, of seasonal water fluctuations and of genetic variations in plant populations, vegetation characteristics along a gradient provide a more precise indicator than does the adaptation of a species to a precise salinity. Important as these plant-salt relations are with respect to any given plant species, we should not be surprised if we find a variation in salt tolerance among different populations of the same species and thus it is perhaps best to evaluate long term salinities by a group of plants rather than just one species.

An example of this is found with a race of bee plant (Scrophularia californica) in the salt marshes of San Pablo Bay. There the soils are influenced by tidal water. The normal range of this plant is in upland regions up to an elevation of 5,000 feet, far away from the influence of maritime salinity. Although this has not yet been investigated, it seems highly probable that, in the Bay, we have a genetic race adapted to high salinities. This kind of adaptation is well known in Botany (Turreson 1922; Clausen, Keck and Hiesey 1940).

These seasonal, tidal and geographic changes in the constitution of the waters provide a mix of ecological conditions for various kinds of plants. These conditions select the races of a given species that thus make up the vegetation type and kinds of plants present.

A distinction is made between the kinds of plants present in a given area and the vegetation type. The concept "vegetation" gains its special meaning from the growth form of the plants that make it up. The vegetation concept of "Forest" gains its meaning from the fact that the dominant plants are trees. Marshes on the other hand are dominated by plants that are herbs. Floristics, in contrast, stem from the kinds of plants that make up the community. In the term redwood forest, redwood is a floristic adjective on the vegetation term, forest. Most plant community concepts are floristic concepts since they are based upon the kinds of plants present. A work dealing with the kinds of plants present in an area is said to be a flora of that area.

The marshes peripheral to San Francisco Bay can be divided into tidal marshes and nontidal marshes (Fig. 3). Tidal marshes are periodically inundated by the tides which is one factor that selects the plants that make up the vegetation cover. Nontidal marshes are not subject to tidal fluctuation.

The amount of time and depths to which plants are submerged by tidal waters are very important ecological conditions that control plant growth. In salt marshes, the tide controls both the composition and distribution of marsh vegetation across a tidal flat. Often zones of a few species occur as bands from low to high elevations. In brackish and fresh water tidal marshes these different zones are not so clear. Some of the zones are masked by a dominance of more widely ranging kinds of plants. We must, therefore, examine zonation in the understory vegetation of the marsh. As a consequence of this masking the community types have passed unnoticed until recently.

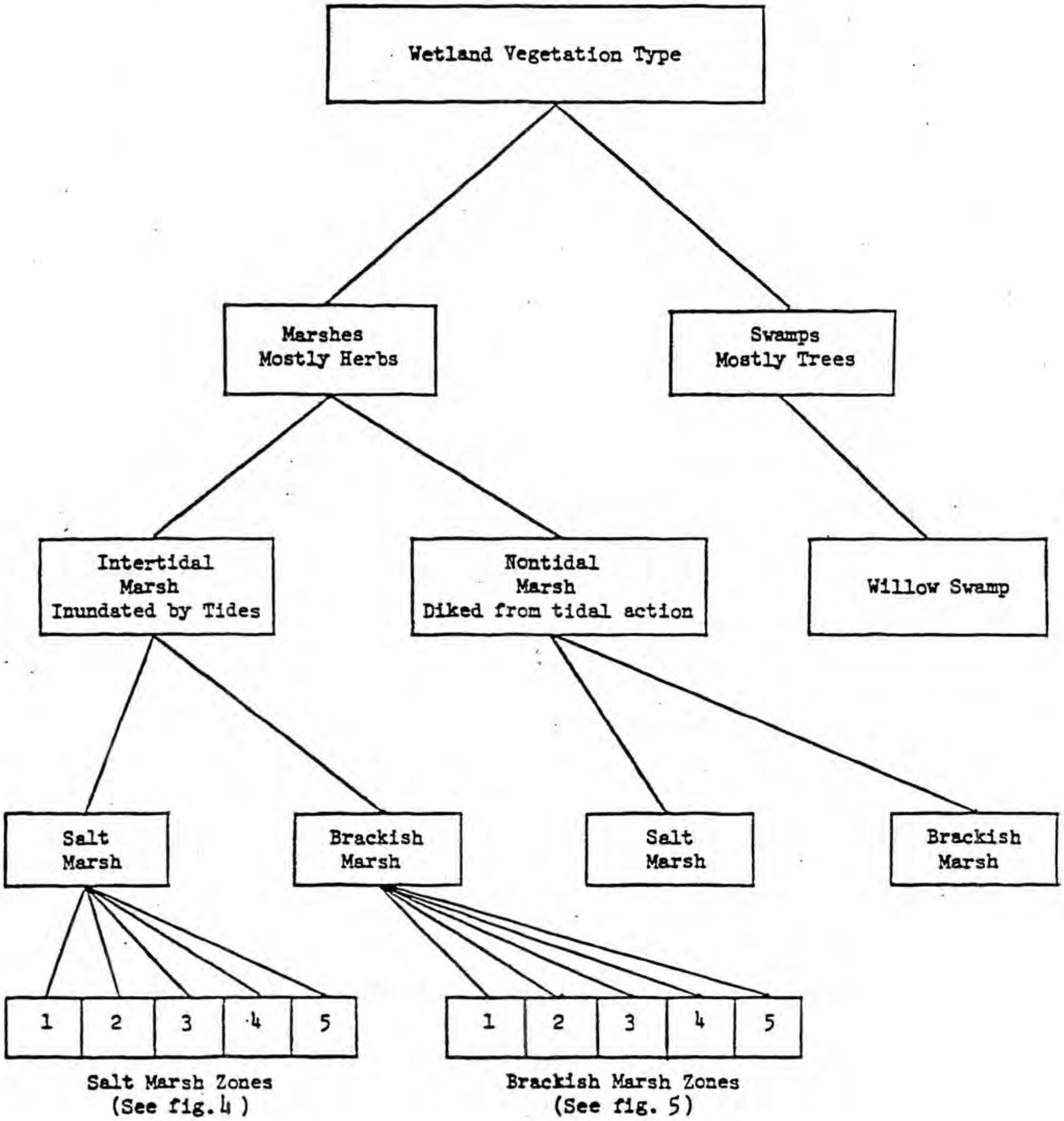

Fig. 3. Suggested heirarchy of vegetated wetland types of San Francisco Bay.

The nontidal marshes peripheral to San Francisco Bay are best developed in Suisun Bay and to a lesser extent in the marshes of the northern area of San Pablo Bay, particularly the marshes between Sonoma Creek and the Napa River. The waters of this area are largely brackish as a consequence of the mix of tidal waters from the Central Bay mixing with the waters of the San Joaquin and Sacramento Rivers. In San Pablo Bay the fresh waters come from the Napa River and Sonoma Creek with considerable dilution of the Bay waters brought in by the Petaluma River. A salinity gradient is shown by the different species composition of the plants in the marshes. For example, willows become less abundant where the salinity is relatively high, as in the brackish marshes of San Pablo Bay. They are relatively rare in the tidal marshes of Suisun Bay where only a few grow on dikes, but they are common in the tidal marshes and on the dikes of the delta. Conversely, pickleweed is common in the salt marshes of South Bay, Central Bay and San Pablo Bay and tends to dominate most of the plant communities in these regions. This species is at present increasing its role in the tidal marshes of Suisun Bay and in the tidal marshes of the Napa Sonoma delta.

Most of the intertidal brackish water marshes are in Suisun Bay and the tributaries of San Pablo Bay. These brackish marshes are dominated by characteristic tules of which California tule (Scirpus californica) is most abundant and common tule (S. acutus) of lesser abundance. The Alkali bulrush (S. robustus) is also common, as might be expected from its normal tolerance of brackish waters (Mall 1969). There are also good stands of the Olney bulrush (S. Olneyi) in brackish waters. The common reedgrass (Phragmites communis) is rarely found in the tidal marshes of Suisun Bay and is probably absent in San Pablo Bay. Intergradiation between brackish marsh and salt marsh occurs. In the last ten years, pickleweed (Salicornia pacifica) has made significant advances into the tidal marshes of Suisun Bay. Conspicuous stands may be seen in marshes with poor drainage such as the marsh just west of Martinez on the south shore. This species is increasing in numbers rapidly in the non-tidal area of Suisun marsh and is found occasionally to frequently in the tidal areas as well. It has had difficulty gaining dominance over the tules but may be found on their shoreward side.

There are basically two types of seasonal marshes in California, one of which is natural and the other artificial. Seasonal marshes naturally occur in areas where there are alternate wet and dry seasons, and occupy sites where rainwater stands during winter and spring but the pools dry completely by midsummer. In California this alternating situation is represented by both the natural areas and the managed wetlands. Agricultural and game management employ seasonal marshes to grow seed crops. Rice is an example of the former; managed wetlands in Suisun Bay where alkali bulrush is managed is an example of the latter. Marsh conditions are created seasonally be flooding the land. To leave the land flooded would be selfdefeating since less desireable plants would take over. Some alkali bulrush, however, is in permanently flooded nontidal marsh.

Only those kinds of marsh plants that can behave as annuals and produce a seed crop can be effectively grown under conditions of seasonal flooding and are reseeded each year either naturally or artificially.

Depending upon the timing of the flooding, some perennials could be grown if the soils do not become too dry in summer and fall. The advantages of the seasonal treatment is largely in the control of undesirable kinds of marsh plants, such as cattails and the taller growing tules, which is very important to the economy of the cultural operation and the growth of desired plant species. Some areas under game management are flooded each year to attract waterfowl into the area as landing and resting sites. These ponds are not to be confused with marshes. Unless the soils remain wet for any reason whatsoever, they do not support marsh plants. The salt marsh plant pickleweed may invade some of these winter wetlands, such as on Joice Island in the Suisun marsh area. Germination of pickleweed seed is lush on lands that are wet during March and April. Pickleweed belongs to a group of plants that produces a very high percentage of agricultural weeds, namely the goosefoot family (Chenopodiaceae). They require saline or subsaline conditions and plenty of moisture to get started; and then, when adults, they can tolerate considerable drought.

Zonation in Marshes

Plant communities of many San Francisco Bay salt marshes show fairly distinctive plant zones (Fig. 4). In the low-low marsh zone there is a pure stand of cordgrass, in the high-low marsh zone a mixture of cordgrass and pickleweed. For the high-high marsh zone, the presence of several peripheral halophytes (salt-tolerant plants) associate with pickleweed in the wetlands of the marsh. The peripheral halophytes constitute the uppermost marsh zone and grade into the adjacent upland community. The names of the four lower zones were borrowed from the terminology used to describe tidal elevations but are not equivalent. The low-low marsh zone is however, the lowest level just as low-low tide is the lowest level of the tide. With a few exceptions, each plant species tends to be associated with the same levels of duration of tidal submergency.

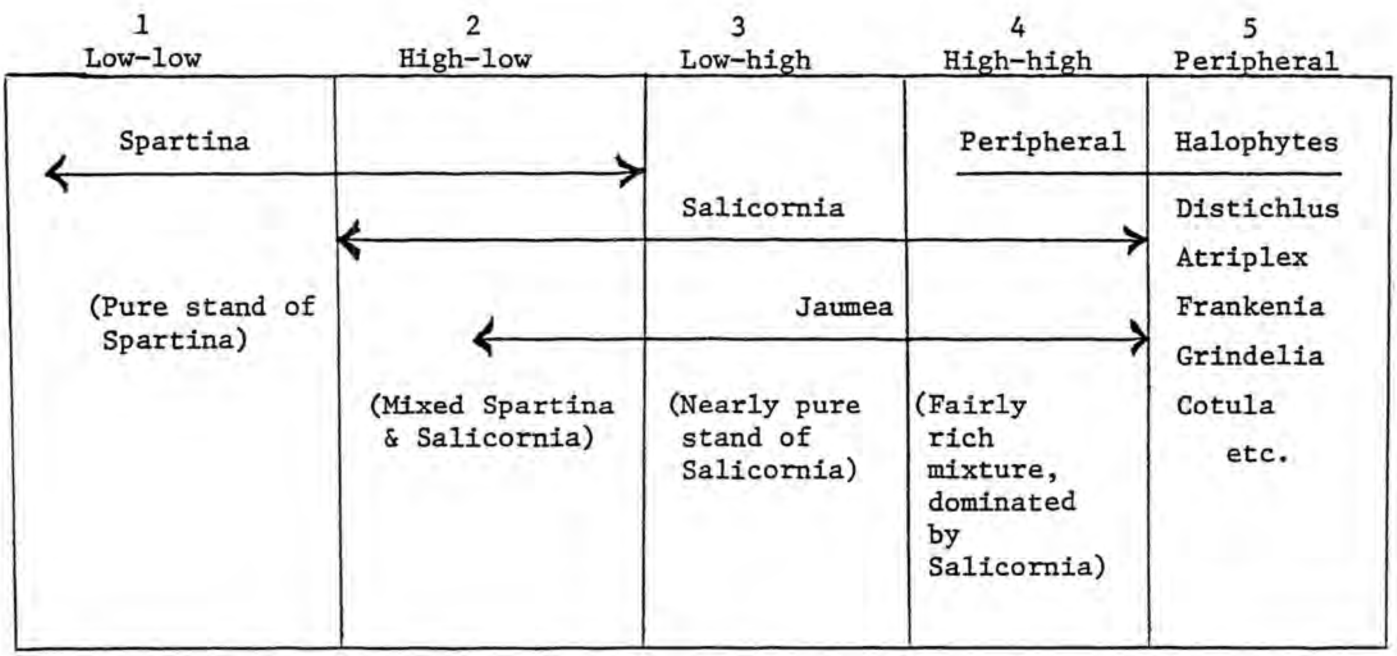

Fig. 4. Suggested salt marsh zones in San Francisco Bay and their plant indicators.

Brackish water marsh plants appear to overlap one another very differently from salt water plants. There are many kinds of overlap so we have selected representatives from at least the upper zones. California tule ranges across the lower three marsh zones and occasionally into the high-high marsh (Fig. 4). Like the cordgrass of the salt marsh, it occurs as a pure stand in the low-low marsh zone, way out at the water's edge. In the high-low marsh zone, the common tule and two kinds of cattail occur--broadleaved cattail (Typha latifolia) and T. domingensis, both with bright green leaves. All of these species extend across the low-high marsh zone and may on occasion be present in the high-high marsh zone. At the low-high marsh zone, two other cattails are found, namely T. glauca and narrow-leaved cattail (T. angustifolia), and the alkali bulrush (Scirpus robustus) and the Olney bulrush (S. Olneyi), as well as a host of other kinds of plants. The two cattails in this zone are readily distinguished from a distance. Narrow-leaved cattail stands out by its very dark green leaves and T. glauca by its glaucous or blue-green leaves. These three community types are well represented and easily accessible in the marsh at the Martinez marina on Suisun Bay, at the city waterfront. One must, however, expect some intergradation between zones. The high-high marsh zone presents a sharp contrast in the pattern of overlap. Its most characteristic element overlaps from the peripheral lowlands across the high-high marsh, and to a slight extent into the low-high marsh. None of the dominant plants of the lower marsh zones have a dominant position in the high-high marsh. Instead the high-high marsh is made up of several kinds of plants that overlap from the peripheral lowland grassland. These include salt grass (Distichlus spicata) in abundance, and gum plant (Grindelia humilus).

There is also an absence of tules and cattails, except in drainage ditches and depressions, giving the appearance of a grassland to this community. Mosaic-like patterns of dark-hued rushes (Juncus) are also diagnostic of the high-high brackish-water tidal marsh. Little of the remaining brackish water high-high marsh has been preserved from overgrazing by cattle or disruption by municipal or industrial fill. There are some fair stands of high-high marsh however, between Martinez and Port Chicago and again between Port Chicago and Pittsburgh.

In Fig. 5, note how few species cross the boundary between the high-high zone and the low-high zone marshes in the brackish water marsh.

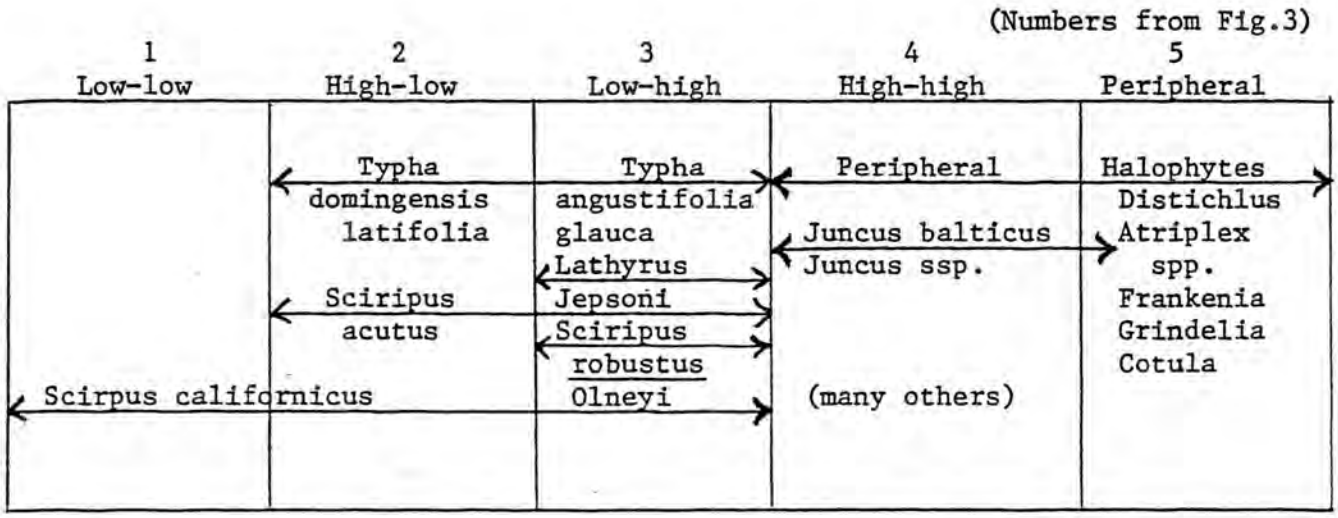

Fig. 5. Suggested brackish water marsh zones in San Francisco Bay as represented by a marsh near Martinez.

Summary

The marshes of San Francisco Bay exhibit several important general features. The gradient from salt to fresh water enables a greater variety of plant species to exist as one goes upstream. They range from about a dozen plants in the Southern and Central Bay marshes to over a hundred species in the Suisun marshes. Within each marsh a vertical zonation also occurs. Cordgrass is the most important species at the lower elevations in the salt marsh, while California tule dominates those elevations in brackish water marshes. At the mid elevations, pickleweed is present in the salt marshes while various cattails and bulrushes flourish at that elevation in brackish water marshes. At the high elevations, peripheral halophytes (salt plants) are present in both types of marshes.

The marshes of San Francisco Bay have changed dramatically in the last 10,000 years, starting from a few square miles along a small Bay to approximately 315 square miles in 1850. After that date the rapid human development of the Bay area destroyed the vast majority of this original tidal marsh (about 90% of it). During the same time, however, new marshes were forming so that at present some of the loss has been compensated for. Only by a current thorough inventory (as described in the Marsh Inventory Guidelines) can the status and extent of tidal and non-tidal marshes be determined.

II. Plant Associations of San Francisco Bay Marshes

Introduction

The plants of S. F. Bay marshes vary in response to environmental conditions. The salinity gradient affects the kinds of plants present in that only those most tolerant to salt are found at the ocean end of the Bay. The species of plants present in a given marsh are referred to as the flora of that marsh.

In discussing the floras of the Bay marshes one will encounter problems in usage of different names for similar plants. For various reasons we will use certain names while others may use others. For example, we prefer California cordgrass (*Spartina foliosa*) which is sometimes called smooth cordgrass (*S. alterniflora*) and common pickleweed (*Salicornia pacifica*) which is called *Salicornia virginica* by some. Both latter names are used for Atlantic coast plants.

Flora of South Bay Marshes

The flora of salt marshes is generally small in number. With the exception of the algae, very few kinds of plants have become adapted to salt water. As a consequence, most salt marsh vegetation is dominated by from one to three species of plants with occasional invaders from the peripheral halophytes. Our salt marshes in San Francisco Bay usually are dominated by California cordgrass and common pickleweed, with the latter usually occupying more area. Sometimes, however, the overlap in these two species is considerable. Jaumea (Jaumea carnosa) is of secondary importance, frequently interspersed throughout the marsh. Most other kinds of plants in our salt marshes give the impression of being intruders from the marginal halophytes since they are often more abundant in the vegetation. As a consequence, the farther out into the marsh one looks, the fewer the kinds of plants one encounters, since the halophytes are unable to tolerate the duration of submergence that characterizes the deeper water intertidal habitats. The flora of the South Bay marshes is listed in Appendix A.

The coyote bush (Baccharis pilularis) is the most conspicuous native plant on nearly all dikes in the South Bay largely because of its size and dark green color. A second seemingly ubiquitous dike inhabitant, gum plant (Grindelia humilis) also penetrates the marshes and is a native, confined to the San Francisco Bay area. It is, however, an aggressive weed around the marshes. Dike flora further consists of typical barnyard weeds, grasses and sedges, and members of the sunflower family.

Marshes of San Pablo Bay

The marshes of San Pablo Bay are of a mixture of two types -- salt marshes and brackish water marshes. The brackish water marshes are best represented along the Napa River, Sonoma Creek, and also along Petaluma River. With respect to the salt marshes, the one bright picture in all of the San Francisco Bay area is San Pablo Bay. The marshes there were extensively diked as elsewhere. However, because of sedimentation due partly to the breakwater built at the tip of Mare Island, mud flats developed and soon were invaded by salt marsh plants and new marshes began. The recovery of this salt marsh has been excellent. One showcase marsh in Marin County just south of Gallinas Creek has added nearly six tenths of a square mile of salt marsh to that relatively short shoreline in the last 100 years. The marsh south of Highway 37 from Vallejo to Tubbs Island is mainly new marsh. The west shore of San Pable Bay from the mouth of Novato Creek, including the Gallinas Creek marsh, is a long strip of new salt marsh mostly in excellent condition and growing vigorously.

The brackish water marshes of the Napa River and Sonoma Creek area are in poor condition, having been diked and rediked. The last sizable brackish water marsh extending some 6 to 8 square miles in this area was recently converted to salt ponds.

The low-low marsh plant zones are better developed in San Pablo Bay than elsewhere. The high-high marsh zone, for most part, is confined to a narrow strip along the dikes. There is, however, a good example of a high-high marsh on the silted mouth of Tolay Creek where the construction of several drainage ditches by the county mosquito abatement authorities has created a disturbance. Rows of Grindelia humilis grow there on the disturbed soil.

The marsh along Highway 37 from Vallejo to Tubbs Island has plant species that are unusually uniform. Along the bay edge of the marsh a zone of cordgrass occurs extending a short distance shoreward where it then mixes with pickleweed. Soon it disappears, leaving an almost pure stand of pickleweed to be followed by a relatively narrow band of mixed pickleweed and typical peripheral halophytes. The banks and dikes of the marginal borrow ponds are covered with a typical growth of coarse weeds. Thus, the areas consist of a very narrow low-low marsh with a fairly narrow high-low marsh, a very extensive low-high marsh (the dominant plant type), and a relatively narrow high-high marsh.

The narrowness of the low-low and the high-low marshes is probably a result of rapid sedimentation in part. All of the salt marshes in this part of the Bay area seem healthy and are extending their areas. Rapid sedimentation would seem to soon build up the marsh surface to a level that no longer would support cordgrass. Hence, there is a narrow band of cordgrass at the edge of the marsh.

The surface of the marsh-land surface is traversed by naturally meandering tidal streams cut largely during ebb tide. Locally these cut deeply into the marsh surface and allow the cordgrass to migrate up the channels into the central area of the marsh.

The total list of plants (Appendix A) is not large due to the fact that the greatest diversity occurs in the high-high marsh on the dikes, which are limited in area. The dike between the marsh on the north shore of San Pablo Bay and the nearby rivers has completely severed any brackish water influence on the marsh and, therefore, allowed a salt marsh to develop.

There are pockets of brackish marshes in the San Pablo Bay region, but these appear to be shifting more toward salt marshes. Mason (unpub. data) found no pickleweed or cordgrass in his study of such marshes in 1945, but in 1956 they appeared and have increased ever since.

Marshes of Suisun Bay

Suisun Bay differs from the other San Francisco bays in that presently its marshes are entirely brackish in spite of some salt water intrusion. As a significant consequence, their floristics are much richer than are the floristics of the other Bay marshes.

At the eastern end of Carquinez Strait along the City of Martinez shoreline is a marsh extending along the coast to the Antioch area. It ranges from narrow to fairly broad in size in a community pattern as represented by Fig. 5. Although not always complete at every locality, it is sufficient to verify the sequence of zones employed. The lower three zones are well developed at the Martinez waterfront with the uppermost obliterated by land fill. The uppermost zone is represented by a broad expanse west of Port Chicago and again between Port Chicago and Pittsburgh. There is, as mentioned previously, a complete break in the general aspect of the floristics of the lower three zones and the uppermost zone. This is especially evident in a comparison of the marshes at the Martinez waterfront and those of the flat expanse of the high-high marsh in the Port Chicago-Pittsburgh interval. The former has a conspicuous tule flora, while the latter is made up largely of rushes (*Juncus* spp.) and salt grass. On the islands near the south shore of Suisun Bay, the marshes tend toward swamps, with trees like willow and alder entering the flora, along with a rich association of marsh herbs. This suggests that the salinity on the south shore of Suisun Bay is less than that in the Suisun Marsh, because willow have been seen only on dikes and not in swamps in the marsh. This difference in flora may reflect a salinity difference in the soils as a result of agricultural practices which brought salts to the surface through evaporation. This is probably the reason that agriculture failed in the Suisun marsh islands. Many of these soils today have had a conspicuous invasion of pickleweed, a salt marsh plant.

The present vegetation of the northern Suisun Marshes can be discussed under three different categories: (1) marshes, both intertidal and managed; (2) vegetation of both cultivated and ruderal (weedy) flatlands; and (3) the vegetation of the dikes. The main contribution to be derived from categories (2) and (3) is their floristic potential and as an indicator of salination in the soils of the marsh islands.

The marshes are of two main kinds: the intertidal, subject to the water exchange brought about by the tides; and the nontidal, where the marsh is diked and not subject to the flow of tides. In some instances the latter are "trapped marshes" since their waters are withheld from communication with the tidal waters of the sloughs. Trapped marshes act as a living filter for their own waters but do not contribute to the filtering of the waters destined to enter the lower San Francisco bays. This could come about if the dikes were breached.

The Intertidal Marshes of the Suisun Marsh Area

An acquaintance with the intertidal marshes of the Suisun area is apt to have been gained largely from those peripheral to the sloughs which often are floristically more interesting where they are very narrow and the ground drops precipitously into the slough. There the plants cling tenaciously to the bank. It should not come as a surprise that there is a pattern of brackish water plant communities analagous to the zonal patterning in salt marshes. One difference between the salt and brackish water marshes is that, in the brackish water marshes, there are not many of the high-high zones in pristine condition. Most have been altered in some way or heavily over-grazed. Consequently, few complete sequences are available, so that one must piece the sequence together and reconstruct it.

The relation of the low-low marsh community to the high-low marsh community in Suisun Bay is very clear at the Martinez waterfront where a walk-way has been built over the marsh spanning the low-low and the high-low zones in the marsh. Like the salt marsh where the low-low marsh community is made up of a single plant species (cordgrass), the low-low marsh community is made up of an almost pure stand of the California tule. It spans three zones from the low-low zone through the low-high zone. Where it occurs as an extensive pure stand, we find that it is in the deeper water of the marsh and is an indicator of the low-low marsh zone. At the higher elevations in shallow water, California tule is well mixed with other kinds of plants.

At the high-low marsh zone two kinds of cattails, Typha latifolia and T. domingensis occur repeatedly in association with California tule. Both cattails have similarly colored light green leaves. There will also be a few plants of the giant common tule which, along with the two cattails, extends into the high-low marsh community. Thus, the overlap of the plants of this community type together with those of the low-low marsh make up the high-low community type.

Two other kinds of cattails characterize the low-high marsh community, *Typha angustifolia* and *T. glauca*. The former stands out in the marsh as a cattail with dark green leaves, while the latter has glaucous or bluish green leaves. While *T. glauca* is not common, in the Suisun Bay area it is always in the low-high zone of the marsh. Alkali bulrush (*Scirpus robustus*), Olney's bulrush (*S. Olneyi*) and delta sweetpea (*Lathyrus Jepsoni*) are also conspicuous members of this plant zone. These five species are most characteristic of the low-high marsh zone.

At the low-high and in the high-high zones the infiltration of salt marsh plants is most rampant, particularly on the Suisun marsh side of the bay. Here common pickleweed grows along with Jaumea (*Jaumea carnosa*). Seaside arrow grass (*Triglochin maritimum*) is conspicuous but is more abundantly distributed in the high-high marsh community. Three-ribbed arrow grass (*T. striata*) is found at a single locality along Hill slough in Suisun marsh.

Extending down from the San Joaquin-Sacramento delta into the low-high and high-high brackish water marsh zones is an interesting sub-zone known by the following criteria: (1) it is repeatable from place to place in the same kind of habitat; (2) it is always made up of members of the same group of plants; and (3) it is repeatable from place to place in the general aspect of the vegetation cover it possesses. It usually occurs where the marsh surface breaks off into the slough growing under California tule or under tufts of Baltic rush (*Juncus balticus*). It has been observed on sandy silt of the open strand along both the Sacramento and San Joaquin Rivers, but it may also be on peat or clayey silt. It is not general in any such habitat but always very local. The largest stand observed occupied about 15 square feet on a muddy shore dipping steeply down from a high-high marsh rush (Juncus patens) community on Midway Island off Port Chicago. Here it contained almost a pure stand of Lileopsis masoni with a single individual of Samolus floribunda. As vegetation it gives the appearance of a bright green lawn or ground cover, usually under much darker colored vegetation. The plants are always submerged during the highest tides. Following is a list of plants which have thus far been established as a part of this community: Triglochin striata, Scirpus koilopsis, Hydrocotyle umbellata, H. verticallata, Lileopsis masoni, Samolus floribunda, Limosella subulata.

No habitat with all of these plant species together was observed, but none had less than two of them. Usually the stands vary from three to five member species. They are more easily discerned from a boat than from shore. Arrow grass (Triglochin) occurs in Suisun marshes and occasionally in other parts of the S. F. Bay. All but Lileopsis masoni are fairly wide spread in fresh and brackish water habitats and, as such it is the common denominator of all of the local occurrences. The small size of the individual plants renders them easily overlooked.

Although many of the plants typical of the high-high marsh extend into the low-high marsh community, there is a very significant break in the low-high marsh community, since there is an observable floristic change of the high-high marsh due to the general absence of bulrushes and cattails. Where these do occur, tidal water lingers in surface depressions. Usually under these circumstances it is the alkali bulrush and the Olney bulrush that are also present. Instead, however, the high-high marsh is dominated by rushes

(Juncus) of which three different kinds are common. They are responsible for the very dark color of the high-high marsh which from a distance may look more like grassland. On undiked land in the Suisun marsh area there is an extensive intrusion of typical salt marsh plants such as common pickleweed, Jaumea and sea-side arrow grass.

In some places the pickleweed occurs at a density well over 100 plants per acre while in other areas it is absent. This suggests a relatively recent invasion by this species. In a few years if salinity increases, these plants will take over the marsh.

Extensive stretches of high-high marsh are not common. It requires only a low dike to keep the flood and the tide out and high-high marshes are too easily turned to other uses by man. They are almost always badly overgrazed, resulting in a rich mixture of halophytic grasses and thus possibly improving the filtering capacity by greater density. The usual peripheral halophytes that intrude into the high-high salt marsh community are conspicuous in that zone in Suisun marsh. These are gum plant (Grindelia humilus), salt grass (Distichlus spicata) and fat hen (Atriplex hastata), a saltbush type.

In the Suisun marsh area the high-high marsh community is fairly well developed along the undiked side of Cut-off Slough opposite Joice Island.

Diked Marshes of Suisun Bay

The diked marshes in the Suisun marsh area are now wholly managed by withholding the tidal waters of Suisun Bay. Management ranges from this minimum practice to agriculturally preparing seed beds for planting, and by periodic flooding. Some of the trapped marshes may have had a tidal marsh beginning. The largest apparently natural stand of alkali bulrush that was encountered in California by Mason (1956) was on Grizzly Island and that marsh is still in existence. But this was before the extensive artificial planting of this species by the California Department of Fish and Game. Today there is much more alkali bulrush as a consequence of public and private management plantings.

The managed alkali bulrush marshes are the only extensive marshes on the diked lands; however, small patches of cattails, tules and Olney's bulrush are frequent in low undrained spots and drainage canals. Since the alkali bulrush will produce seed in the first year of growth, it can be managed as a seasonal marsh if so desired. There are also patches of red knotweed (Polygonum coccinium) in ponds and artificially flooded areas.

Other managed lands entail the growing of extensive fields of brass buttons (Cotula coronopifolia), a plant long ago introduced from South Africa. Its seeds were the most prevalent in the crops of ducks taken at the public shooting grounds on Grizzly Island (Mall 1969). In the natural habitat, it ranges from soils that are slightly alkaline or saline to typical salt marsh habitats.

It is impressive to see a profusion of cattails, tules and other bulrushes breaking through the ground that had been prepared as seedbed for managed crops. This indicates that there is already a good stand of these plants to begin an intertidal marsh should tidal flood waters enter and the water be not too deep for their survival.

The dikes are currently covered with a coarse weedly type of vegetation that is largely shrubs and typical agricultural herbaceous weeds. The weeds are made up of both native and introduced plants. An interesting aspect of this vegetation when compared with the vegetation on the dikes of the delta is that, with the exception of a few places, there is almost a complete absence of willows in Suisun Marsh. On the dikes of the delta, however, willows are prehaps the most common woody plant and there are many small willow swamps. The common reed (Phragmites), occasional in Suisun Marsh, is very common in the marshes and on the dikes of the delta. No alders were observed in Suisun Marsh, but there are a few on the island opposite Antioch in Suisun Bay. This suggests a salinity for Suisun marshes which is much greater than that of the Sacramento-San Joaquin delta and even higher than that of the marshes on the islands on the opposite side of Suisun Bay. The floral list for Suisun Bay is given in Appendix B.

III. Preservation of Natural Marshes

Introduction

The natural tidal marshes of San Francisco Bay originally existed in such wide expanse because of several physical features. The primary factor is geological. A valley system was invaded by sea water when sea level rose. Relatively flat areas of alluvium provided a base for marsh development. Recent deposits of estuarine clays and silts now cover much of the Bay margin and allow a variety of marsh plants to grow. These plants vary in their tolerances of tidal submergence and to the quality of the water. The quality of water varies as freshwater flows into salt. Because San Francisco Bay is an estuary, there is this gradient from salt to fresh water. The diversity and distribution of plants is based upon this gradient, and in doing so demonstrates a wide spectrum of capacities and requirements for survival. For example, at one extreme is cordgrass which requires daily submergence by salt water. Its seeds must soak in cool salt water and then be washed with relatively fresh water to germinate. It is restricted, therefore, mainly to the marsh margins of San Pablo, Central and Southern Bay habitats.

On the other hand, alkali bulrush seems to require brackish water of about 7 to 14‰ salinity for its seeds to germinate (Mall 1969) and thus is found in Suisun Bay marshes and around the freshwater inflows to the other bays. Each plant species has its range of requirements and tolerances and is found accordingly across the broad spectra of tidal, water quality and substrate conditions found throughout San Francisco Bay.

The Role of Marshes in Land Building

Marshes play a role in the geological and physiographic processes that base-level the land. Repeated flooding, cutting and silting which alter the marsh surface tend to reach equilibrium. This is because the soils upon which marshes grow yield readily to erosive forces and these areas are also prime deposit sites. The biota, for the most part, are helpless against excessive sedimentation. In the wake of such antithetical forces of erosion and sedimentation new channels or ponds are formed at the expense of marsh and new land surfaces appear ready for colonization by a new flora and fauna. Sedimentation produces an increase of the level of the soil until an equilibrium may be reached where subsidence and deposition are equal (Pestrong 1972) provided there is a gradual rise of sea level, as is the case in San Francisco Bay. However, falling sea level would shift marshes to an upland community type, such as a meadow.

Land building operations occur when the marsh plants perceptably slow the speed of running water and cause it to drop the sediment it is carrying. Sediment tends to build up in the marshes and may enrich the habitat, if not excessive, which causes a rapid new growth of plants and an even greater obstacle to the flow of water.

By such development the marsh vegetation through time reclaims what once was an open waterway. The resulting marsh flat supports a vegetation that slows the speed of subsequent floodwaters, causing it to lose its load and further build up the marsh. At length new habitats are created and new vegetation types may take over in a successional pattern from low-low marsh to high-high marsh.

As a consequence of these natural processes, marshes are ephemeral features. Their natural survival and growth rests upon being able to take over new areas as proper conditions develop and as they can build up the marsh surface. For example, our salt marshes are in some areas moving out onto mud flats in the Bay and losing ground along the shore side. This happens with a loss in size to the Bay open water so that not all of the loss of water area of San Francisco Bay has occurred because of human activity.

Erosion

Erosion of tidal marshes entails the undercutting of the shoreline vegetation into large blocks which then slump into the bay. What seems to be happening is that the marsh floor is being reduced to base level i.e. the level of local mud flats. Floyd (pers. comm.) suggests that the boring of a marine isopod (*Spheroma quoyana*), similar to the pillbug, may be weakening the marsh substrate. Perhaps after degradation it will be reinvaded by marsh plants and a new cycle of marsh development will occur. It is clear that the present state of wave action is continuing the erosion which is fairly general in the South Bay.

As a consequence of erosion and of the so-called "reclamation" of the high-high marsh by diking, the usual marsh scene entails only the middle section of the community sequence. There are some good stands of low-low marsh cordgrass, however, which are usually located along the few remaining sloughs.

The point is that, although secondary recovery of the Southern Bay salt marshes has been substantial, they appear to be threatened by a regime of intertidal erosion on a scale that seems to be degrading some marshes back to the status of a mud flat.

Preservation and Protection of Salt Marshes

The preservation of a salt marsh is through the protection of those dynamic processes that maintain the salt marsh. Given a rising sea level, the upland edge of the marsh advances landward and the seaward side retreats and thus the salt marsh persists through time and space. It is this continuity in time and space that we seek to preserve, therefore, a buffer at the upland side must be set aside.

Once rising sea levels stabilize, however, marshes may grow at the expense of the water area of a bay. And even with rising sea level, if sediment loads are heavy and water currents are altered, some marshes advance bayward. Such an occurrence is along the northeast edge of San Pablo Bay. Preservation is also preventing destruction by human activities. It is the fulfillment of a plan in which the know-how has been previously worked out and put into operation.

Biologists tell us that the most devastating destruction in nature is the destruction of habitats. Individuals die or are killed and are replaced. When habitats are destroyed, it nearly always means the end of the life that depended on that habitat, and that is what has happened to our marshes. it will take nature many years to replace the loss of marsh habitat due to human activity. The return of the marshes will have to await nature's slow building of new habitats or be aided by human intervention.

The first fundamental of salt marsh protection is the safequarding of the habitat. This means learning what the agents of habitat destruction are and keeping them out of the marshes. It demands an alert monitoring system directed toward assessing the well-being of each marsh, thus determining which factors appear to alter the marsh.

Marsh education centers for the public at strategic places around the Bay, like the one at the Palo Alto marsh, are extremely informative. Another strategic site for a center is the Martinez waterfront where a beautifully diverse marsh invites public use. This spring a marsh wren built one of its intricate woven nests only four feet from the railing of the walkway to the Marina. Collaboration of the Regional Parks in maintaining an educational program is possible here since they are considering taking jurisdiction over this marsh.

The preservation of the marshes of San Francisco Bay means, to a large extent, leaving nature alone. However, there are destructive forces that have been encouraged by man's activities and these need to be more clearly defined and remedied. Erosion is one such force destroying marshes in the South Bay. This, in part, may be due to an introduced mud-boring pillbug that weakens the substrate.

Changes in water and soil salinity have apparently altered the flora of San Pablo and Suisun Bay marshes, and a more refined monitoring program is needed to assess these changes. If enhancing plant diversity is deemed vital to stabilize the community and reduce pollution, then steps will be needed to ensure this condition.

In addition to the two major geological factors that may adversely affect marshes (erosion and sedimentation) floristic considerations should also be addressed. The spread of undesirable exotics such as Salsola soda needs attention. A relative of Russian thistle this plant is invading the marshes of Southern S. F. Bay. Its mode of introduction to the area is at present unknown.

Similar problems may develop through the introduction of exotic plants (foreign to the area) for intentional reasons. Some have suggested using foreign species of cordgrass and other plants to lessen erosion of marsh edges or dikes. It has also been proposed that exotics might be used to stabilize mud flats better than native species.

The point of discharge of sewage effluent also may affect marshes. The increasing volume and treatment of effluents flowing into the Bay are altering the plant species composition of the receiving marshes. In general it appears to be a shift to more brackish and fresh water species near outfalls. This is not necessarily an adverse effect for the increased diversity enriches the biotic community and is probable more like conditions prior to 1850.

Subsidence has affected the plant composition in tidal marshes in the Southern Bay. It occurred rapidly enough in the 1950s to cause a shift from a pickleweed marsh to more cordgrass, near Palo Alto. With subsequent halting of the subsidence, the marsh composition also appears stabilized.

It is in the public's interest to halt subsidence including the value of preserving marsh-land.

Although most marshes around the Bay are diked on the upland side, runoff carrying sediment could, in a few places, adversely affect a tidal marsh. Such sedimentation may raise the land surface to a point where marsh vegetation can no longer persist because it becomes too high to be affected by the tides. On the new land surface, upland plant and animal species could be established.

IV. Value of Marshes

Introduction

The marshes of San Francisco Bay are of value in part because of the plants and animals which reside there. There are also numerous indirect values that rest largely on the marshes in rather obscure ways. The detritus (organic debris) feeding organisms of the mud flats are an example. These animals filter out minute bits of decaying plant and animal matter from the water or from the mud surface and use them for food. They, in turn, are fed upon by larger forms such as the shorebirds and certain fish of the Bay. These invertebrate forms (over 100 different kinds) are a vital link in the food chain. Due to limitations of space in this paper, only those species of direct value i.e. shellfish, will be discussed. The other invertebrates of the marsh will also be given only cursory coverage.

The salt marsh is not noted for supporting, in place, a great biomass (living weight) of herbivores. A few species of mice, particularly the salt marsh harvest mouse (Reithrodontomys sp.) and seed eating birds such as the salt marsh song sparrow are about the largest forms of life present. Most of the productivity of the marsh goes into the Bay waters to become detritus for filter feeders such as clams and mussels. There is, however, a fairly diverse group of insects to be found in the marsh. In a study of San Pablo Bay marsh, Cameron (1972) reported over 100 different species of insects in the cordgrass and pickleweed zones. Flies were most numerous with beetles and wasps second and third in abundance. The populations of insects fluctuated in proportion to the productivity of the plants upon which they fed. These insects, in turn, served as food for larger animals in the marsh.

Wildlife Values of San Francisco Bay Terrestrial Species

Even after considerable reduction in size, San Francisco Bay still remains the largest estuarine area along the Pacific Coast of North America. Its well-being is absolutely vital to the myriad of wildlife forms which utilize the Bay during all or part of their life cycles. The Bay and its associated habitats afford feeding and wintering grounds for a major portion of the migratory waterfowl along the Pacific flyway. In addition, a host of wildlife forms reside within the marshes and adjacent areas of the Bay. These include several rare or endangered forms plus several which, because of their dependency on the Bay's estuarine areas, could become threatened if adequate protective measures were not afforded to the Bay. The Bay, because of its size and diversity of habitats, also attracts several unusual wildlife forms from other parts of North and South America. For example, a flamingo wintered for several years in the salt ponds west of Coyote Hills.

An assessment of the importance of San Francisco Bay to terrestrial wildlife species, including the aquatic species which breed on land, will be presented by geographic areas within the Bay, i.e., Suisun Bay, San Pablo Bay (including the Napa marshes and Petaluma River), Central San Francisco Bay and South San Francisco Bay (Plates 1-4 in the appendices). Each area, because of differences in salinity, water depth, physiographic features, food sources, and man's alteration of the area tend to support a somewhat different variety and abundance of terrestrial wildlife.

Southern San Francisco Bay

The southern arm of San Francisco Bay is characterized by shallow water, reduced tidal flushing, broad tidal flats, moderate areas of tidal marsh, and extensive salt evaporation ponds. Freshwater inflow from local streams to the southern Bay is limited, with Alameda, San Lorenzo, Coyote and Redwood Creeks providing most of the input.

Various combinations of these habitats support some of the most diverse wildlife forms associated with the San Francisco Bay estuary. Some 200 different species of birds and 40 species of mammals utilize south San Francisco Bay during all or part of their life cycles. Included are three rare or endangered bird species and one endangered mammal. Two additional races of birds are unique to the marshes of the southern Bay.

By far the most obvious wildlife feature of the south Bay is its large wintering and migratory shorebird populations. The extensive tidal flats used for feeding, and the salt ponds and their associated levees used for nesting and loafing attract most of the shorebirds using the Bay (Jurek 1973; Recher 1966; Bollman 1970; Gill 1972, 1973; Anderson 1970). In contrast to the large wintering populations, few species remain to breed in the Bay area. Among those that do are the American avocet, black-necked stilt, snowy plover and killdeer. The south Bay supports the largest breeding populations of all these species in the entire Bay.

Southern San Francisco Bay is also heavily used by wintering waterfowl

Pintail, shoveler, wigeon, scaup and canvasback are the most common species of ducks. These tend to be equally distributed among open Bay, salt ponds and tidal flats. Limited waterfowl nesting occurs along the fringing marshes of most tidal sloughs and on some of the larger marsh islands in the south Bay. Where salt pond levees support a significant vegetation cover, waterfowl can also be found nesting. Gadwall, pintail, mallard, cinnamon teal and ruddy ducks are the most common nesting species, but poor nesting success results from the lack of adequate freshwater (Gill 1973).

Within the salt marshes are found the largest remaining populations of the California clapper rail and the south Bay race of the song sparrow. During winter months the marshes become critical for Virginia, sora and California black rails. The latter is considered a rare species in California. The salt marsh yellowthroat also depends on these marshes for its winter home.

Over the past 70 years the salt evaporation ponds of the south Bay have indirectly produced several additions to San Francisco Bay bird life (avifauna). Most of these occur in the form of breeding range extensions for several shorebird and tern species (Gill 1973). Included is the endangered California least tern. All of these new breeding species utilize salt pond levees or filled areas to nest. The conversion of former tidal marsh to salt ponds has also produced population changes in several wintering species. The south Bay now supports larger populations of Wilson's and northern phalaropes and eared and horned grebes than in the pre-salt pond era.

Other man caused alterations of native estuarine habitat have further diversified the wildlife of the Southern Bay. Dredge spoil deposits on former marshland have been colonized by upland plant species which, in turn, act as nesting platforms for the largest colony of snowy egrets and black-crowned night herons in the Bay area. A small number of great blue herons also nest in association with these other large wading birds (Gill 1973). The California least tern has also benefitsed from such habitat conversions. The northernmost and only nesting colonies of least terns in the entire Bay area occur on Bair Island, San Mateo County and on Bay Farm Island, Alameda County. Other species benefitsed from land use changes in the south Bay include the short-eared owl, white-tailed kite, and burrowing owl. However, while several species have benefitsed from these land use changes, others like the clapper rail, black rail, salt marsh song sparrow and salt marsh harvest mouse have not. More importantly, this conversion of tidal marsh has reduced the overall biological productivity of the Bay system.

Southern San Francisco Bay is also important to several mammalian species. The largest harbor seal breeding ground in the entire Bay occurs along Mowry Slough, Alameda County. Several other areas in the south Bay are used as hauling grounds by portions of this population. In those parts of the south Bay still having a significant freshwater influence, populations of muskrat and racoon can be found. The salt pond levees, adjacent uplands and dredge spoil areas support numbers of black-tailed jackrabbits, California ground squirrels, long-tailed weasels, black and Norway rats, and several species of microtine mice. The remaining salt marsh, both inboard and outboard of existing levees, supports populations of the endangered salt marsh harvest mouse (Shellhammer, pers. comm.; Schaub 1971).

Central San Francisco Bay

Central San Francisco Bay is defined here as that area south of a line running from Pt. San Pedro, Marin County to Pt. Pinole, Contra Costa County to the Oakland-San Francisco Bay Bridge. The estuarine area within this portion of the Bay is characterized by deep water, fast currents, numerous islands and peninsulas with steep rocky interfaces, relatively small tidal flats, and considerable areas of Bay fill for industrial and urban expansion. These features dictate a still different wildlife element from that found in other parts of San Francisco Bay.

As with all portions of the Bay, the bird life is the prominent wildlife form, and central San Francisco Bay has an extremely varied avifauna. The tidal flats near Emeryville, Albany, Wildcat Creek, Richardson Bay and Corte Madera, although limited in size compared to other such areas in the Bay, support a significant portion of San Francisco Bay's wintering shorebird population (Jurek 1973). The four census areas encompassed by central San Francisco Bay as part of a two year, Bay-wide waterbird count, produced the highest counts of shorebirds, western grebes, gull and tern species and waterfowl within the entire Bay (Bollman 1970; Gill 1972).

Besides high values for wintering birds by providing suitable habitat, the central Bay also affords several unique features for the nesting birds of this area. The Marin Islands off San Rafael support one of the largest rookeries of great blue heron, snowy egrets, and black-crowned night heron within the Bay. These islands, plus Red Rock west of Richmond, support the only nesting sites by Western gulls inside the Bay. These areas, in addition to Alcatraz, Angel and Yerba Buena Islands, afford resting and roosting areas for large numbers of cormorants and several species of gulls.

At certain times of the year, especially during severe storms, the central portion of San Francisco Bay is heavily used by birds associated with the outer coast and open ocean, including shearwaters, auklets, murrlets, red phalaropes, turnstones and jeagers. Once inside the Golden Gate, these birds tend to wander to all parts of the Bay.

The deepwater portions of the central Bay attract a variety of marine mammals, the most common being the harbor seal. This small seal is known to breed near Castro Rocks, south of Castro Point to use the rocky areas around Peninsula Point and Strawberry Point as hauling grounds (Map plates 1-4). The California and Steller's sea lions also are found frequently within the Bay between Treasure Island and Tiburon. The elephant seal, with its recent breeding range extensions to the central California coast, may become more common at the mouth of the Bay. Other marine mammals occasionally recorded within the Central Bay include the gray whale, Pacific white-sided dolphin and the harbor porpoise.

San Pablo Bay (Including the Napa, Sonoma and Petaluma Drainages)

San Pablo Bay, including the marshes and tidal flats of Sonoma Creek and the Napa and Petaluma Rivers, represents a unique floristic and faunistic transition between the brackish Suisun Marsh and the more saline marshes of central and south San Francisco Bay. The importance of this area to wildlife arises from a combination of expansive tidal flats adjacent to salt marsh, multi-salinity salt evaporation ponds, extensive areas of dry land farming, and several freshwater drainages besides the Sacramento-San Joaquin Rivers.

Although these features result in valuable nesting and feeding sites, San Pablo Bay is probably of greatest importance to migrating and wintering shorebirds and waterfowl. The vast tidal flats encircling San Pablo Bay attract tens of thousands of western and least sandpipers. Gill (1972), during a review of a two year waterbird count of San Francisco Bay, reported that San Pablo Bay accounted for over 50% of all least sandpiper sightings in the Bay. Similarly, San Pablo Bay attracts approximately 50% of the Bay's wintering canvasback population which, on the average, represents 70% of the entire California population and 50% of the Pacific flyway population (Delisle 1966). The 1976 Department of Fish and Game winter waterfowl inventory of San Francisco Bay found over 18,000 canvasbacks on San Pablo Bay, including over 9,000 from the Napa marshes. In addition, over half of the Bay's scaup population (60,000) was reported from San Pablo Bay.

The conversion of over 90 square miles of former tidal marsh to agriculture and salt production lands has reduced the overall biological productivity of San Pablo Bay; but at the same time, habitat diversity has been increased and several new wildlife forms are now dependent on the area. Included are substantial breeding populations of American avocets, black-necked stilts, white-tailed kites and Forster's and Caspian terns. A small, tree-nesting colony of great blue heron is now found in the Napa marshes as well as the only tree-nesting colonies of double-crested cormorants in the San Francisco Bay area.

With this conversion of habitat and these new additions to the San Pablo Bay avifauna came a reduction in populations of the California clapper rail, salt marsh harvest mouse, Samuel's song sparrow and California black rail (Appendix C). The loss of tidal marsh is directly responsible for the endangered or threatened status of these species. All of these species, however, continue to thrive within the marshes surrounding San Pablo Bay. Indeed, the Napa Marshes now support the largest California clapper rail population north of Mowry Slough, Alameda County. Recent distribution studies of the salt marsh harvest mouse have shown that the Napa Marshes are also important habitat for this species.

The species composition and abundance of waterbirds using salt evaporation ponds of the San Pablo Bay is similar to that described by Anderson (1970) for salt ponds in southern San Francisco Bay.

Large mammals of the San Pablo Bay estuary mainly include racoon, striped skunk, muskrat, brush rabbit and black-tailed hare. There have been several recent sightings of river otter from the Napa Marsh, Pinole Creek, and upper Sonoma Creek areas. Marine mammals are few or absent since they seldom venture away from the deeper channels into the shallow tidal flat-marsh areas of San Pablo Bay.

Suisun Bay Marshes

The Suisun Bay Marshes are largely managed wetlands. Many of the factors affecting vegetation and wildlife are seasonally controlled by man, to produce the highest value for wintering waterfowl. The almost 90 square miles of marsh represents approximately 10% of the remaining wetlands in California and during dry years or periods of delayed rainfall the Suisun Marsh has supported over 20% of the central California waterfowl population (Jones and Stokes 1975). Peak waterfowl populations vary between 500,000 to 1,000,000 ducks during mid-winter. Pintail, American wigeon, northern shoveler and mallard ducks are the most common species found in the marsh. An additional 26 species of water-fowl also have been recorded for the marsh.

Although the marsh is a major wintering area for waterfowl, its value as a nesting area is relatively low. Over the past 20 years, an average of only 1,500 pairs of ducks has nested in the marsh; these were mostly mallard, gadwall and cinammon teal. The low waterfowl productivity has been attributed to dense vegetation, predation, and steep-sided sloughs (Anderson 1960), and to high water salinities during the breeding season. The marshes along the north shore of Contra Costa County are even less important for wildlife because of the significant alteration resulting from urban and industrial development.

Other Water Birds

Sixty species of waterbirds are found in the Suisun Bay Marshes, including the larger wading birds (great blue heron, great egret, snowy egret, black-crowned night heron, American bittern) which are found throughout the marsh during all seasons. With the exception of the snowy egret and black-crowned night heron, all of these species nest within the marshes of Suisun Bay.

The open bays and sloughs, especially Suisun and Honker Bays, provide critical resting and feeding areas for several species of diving birds, including grebes, loons and cormorants.

The Suisun Bay marshes act as a transition feeding and resting area for the migratory shorebirds of the coast and interior Sacramento Valley. Grizzly and Joice Islands are heavily used during March and April by least and western sandpipers, dunlins and dowitchers (Jurek 1974). American avocet, black-necked stilt and killdeer remain to breed in the marshes in the spring.

Birds of Prey

Because of its size, location and support of abundant prey species, the Suisun Marsh area is one of the most important bird predator (raptor) wintering areas in the Bay region (Jones and Stokes 1975). Some 23 species of raptors have been observed in the marsh, the most common being marsh harriers, red-tailed hawks, white-tailed kites, American kestrels, rough-legged hawks, short-eared owls and barn owls. Of these, all but the rough-legged hawk breed in the marsh. The endangered peregrine falcon is a frequent winter visitor to the marsh area.

Song Birds

This broad category encompasses 80 species of birds, of which approximately half are "true" song birds. Several are year-round residents such as the Suisun song sparrow, yellowthroat, long-billed marsh wren, red-winged blackbird and loggerhead shrike. Recent studies by Gill have shown these marshes and their associated woodland-brush and riparian habitats to be an important stopover point during fall and spring migrations for other birds. Included are six species of wood warblers, six species of flycatchers, and seven species of Fringilides (finches). Kinglets, thrushes and vireos are also common during migration and use the marsh as a feeding and resting area.

While some 45 different mammals have been recorded from the Suisun Marsh, only a few are considered common. Included among these are Suisun shrew, racoon, river otter, striped skunk, valley pocket gopher, western and salt marsh harvest mice, California vole, muskrat, house mouse, black and Norway rats, black-tailed jackrabbit, Audubon's cottontail and brush rabbit. An additional 14 species of bats are also known from the marsh. The marsh supports major populations of river otter, muskrat, and salt marsh harvest mouse (Schaub 1971, DF & G unpub. data). The latter species is listed as endangered by both the U.S. Fish and Wildlife Service and the California Department of Fish and Game.

Marsh Food Production for Bay Fisheries (both finned and shellfish types)

In her 1972 book The Edge of Life, Peggy Wayburn makes the point that, "Nothing exists alone. All life forms and land forms are intricately and inextricably linked into a continuum." Bigelow (1955) in explaining the complexity of the sea to his students used the following analogy:

> When one picks up a fish one may be said, allegorically, to hold one of the knots in an endless web of netting of which the countless other knots represent other facts, whether of marine chemistry, physics or geology, or other plants and animals. And much as one cannot make a fishnet until one has tied all the knots in their proper positions, so one cannot hope to comprehend this web until one can see its internodes in their true relationship.

An examination of the published and unpublished literature along with extensive field observations of the San Francisco Bay ecosystem leads one to the same conclusion as Wayburn and Bigelow. One cannot isolate the marsh (and/or mud flats) and indicate that it produces a given percentage of shellfish and/or finfish. San Francisco Bay ecosystem is a closely meshed system of almost infinite complexity. Its elements involve rivers and other drainage that carry nutrient-rich fresh water into the ecosystem, salt and freshwater marshes with their tremendous ability to convert the sun's energy through photosynthesis into materials that can be utilized by other organisms, winding creeks, shallow bays, and mud flats where organic compounds produced by the marsh are made further available to marine organisms, and the coastal shelf waters where photosynthesis makes use of the rich supplies of nutrients in the water. These nutrients are dispersed by and feed not only the residents of the bay but also migratory animals which move from the ocean back into the estuary at some point in their life cycle i.e., salmon, American shad and lamprey which generally die after spawning in freshwater. After death, the nutrients in the bodies of these animals are recycled by bacteria into the river systems which flow into the Bay.

The rivers tributary to the San Francisco Bay complex have always been carriers of nutrients from the land to the sea, but in the last few decades they carry more than ever before (San Francisco Bay Regional Water Quality Control Board 1967). Nitrates from farmers' chemical fertilizers and/or domestic animals and human wastes eventually find their way to the estuary where they are utilized by the marsh vegetation, mud flat diatoms, phytoplankton, etc. These, in turn, are converted into shellfish and/or finfish.

Again, it should be emphasized that the San Francisco Bay system is only a knot in the web of a complex ecosystem which includes the whole aquatic and terrestrial drainage of the Central Valley system. However, to illustrate the importance of the Bay, one should recognize that most of the commercial and sport fisheries of the Central Valley and of the Bay are dependent on the continued existence of the quality and quantity of marshes, mud flats, open water and permanently submerged areas. Classical examples are the striped bass, American shad, sturgeon, salmon and steelhead trout, all of which use the estuary as a nursery ground and transportation system.

In order to understand the direct value of the marshes of the Bay and Delta to the shellfish and finfish populations, one need only examine the key or central role detritus plays in the system (Fig. 6). The easiest way to demonstrate this value would be through some food chain or pyramid of numbers concept. However, a word of caution is necessary at this point. Darnell (1961) in his studies of the food habits of 36 of the most important consumer species in a shallow windswept estuary in Louisiana, concluded that in natural communities it cannot be assumed that every species will conform to specific trophic (feeding) levels. Individual species do not appear to conform because of (a) omnivory on the part of most, if not all, of the major consumer species, (b) changes in the food habits through various life history stages, (c) nutritional opportunities among the consumers, (d) the importance of organic detritus in the nutrition of the consumer species and, (e) the complex nature of the origin of detritus.

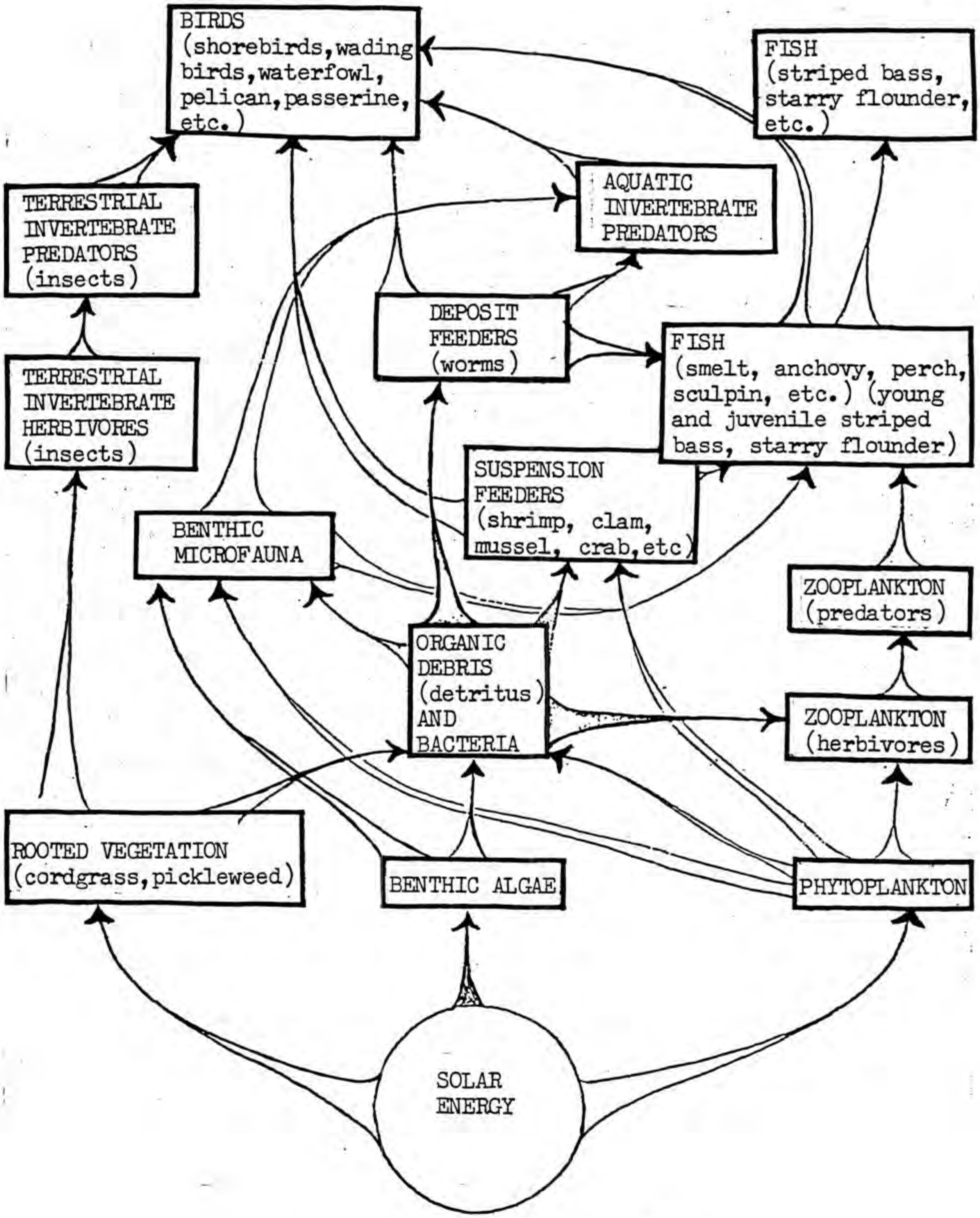

Fig. 6. Role of Detritus in Food Webs (based on a flow of net primary energy)

McHugh (1971) in a review of the book Marine Food Chains indicates

> It is clear that transfer of matter and energy through the food web is not particularly efficient, and that, especially in shallow coastal areas, the waste products support rich bottom communities. Food chains or webs are far from simple, and the concept of trophic levels in not very useful in practice.

How do we determine the importance of detritus to the finfish, shellfish and crustacea of the Bay? First, we must learn what are the major species of the Bay and, in turn, how they relate to each other and to the detritus food base. A review of the literature was necessary to determine what finfish, shellfish and crustaceans are found in the intertidal and open water areas, what their principal foods are and what organisms feed upon them.

Finfish and Shellfish Intertidal Areas

Finfish

The salt marshes and shallow water areas of San Francisco Bay provide habitat for the larvae, young, juvenile and adult of numerous species of fish and shellfish. The quantity and quality of fishery resources of these areas has been documented in the Bay by several authors. Beach seining by Wooster (1971) yielded 18 species of fish and two genera of shrimp. Shiner perch, top smelt and staghorn sculpin were the predominant forage species collected. On-going and past shore seining and shallow water trawling studies by the U.S. Fish and Wildlife Service (1975) adjacent to marshes in San Pablo Bay near Richmond Sanitary Service and in south San Francisco Bay from Foster City to Greco Island, substantiate the findings of Wooster (1971). Wild (1966) sampled the macrofauna associated with Plummer Creek and its adjacent salt marsh. Using a fixed net he collected fish and invertebrates which were channelled into the net on the outgoing tide. He found the dominant organisms caught were three species of fish -- topsmelt, shiner perch and three-spine stickleback -- and one invertebrate, bay shrimp.

The species composition of the shallow areas was determined by what shore and pier anglers catch. Wooster (1968) from creel censuses of the Bay and review of the literature, found that shiner perch, staghorn sculpin and smelt were found in great abundance. Other types of fish associated with the shallow areas of the Bay were striped bass; large perch (white, walleye, pile, black, rainbow, rubberlip); flounder; sharks, skates and rays; kingfish; and rockfish.

Spratt (1975) conducted surveys in the Bay which demonstrated the importance of the intertidal zone and immediately adjacent subtidal areas to spawning herring (Fig. 7). At times during the period December through March, herring literally covered the shoreline with spawn, so that the spawning biomass was estimated at 20,000 tons.

Finfish - Open Water Areas

The open water areas of the San Francisco Bay estuary provide habitat for a variety of bottom (demersal), marine, anadromous and, in the tributaries, freshwater fishes (Appendix D). Detailed reviews of these resources can be found in Skinner (1962), Alpin (1967), U.S. Fish and Wildlife Service (1970), Newcombe and Mason (1972), California Department of Fish and Game (1968), Tetra Tech, Inc. (1976), and California Department of Fish and Game (1972a and 1972b).

California Department of Fish and Game (1972b) contains an excellent summary of the fishery resources of the open waters given below.

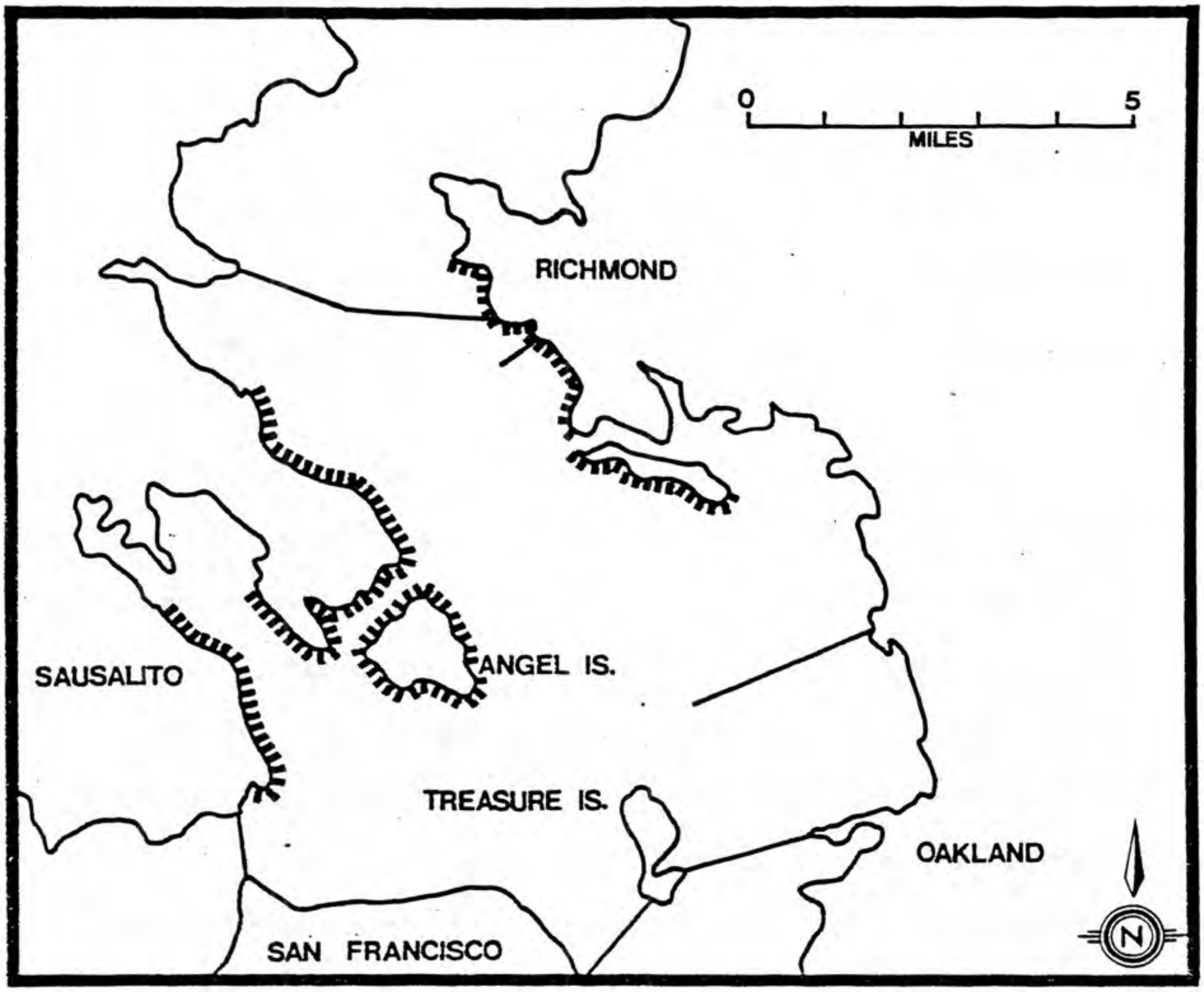

Fig. 7. Herring Spawning Areas (after Spratt, 1975)
▮▮▮▮▮ = Shoreline sites.

Marine Types

Marine species are distributed through North and South San Francisco Bay and San Pablo Bay. Reduced freshwater flows allow saline water to move upstream in summer, and many marine species enter Carquinez Strait and Suisun Bay.

Sharks, rays and skates, limited to San Francisco and San Pablo Bays, are most abundant in San Francisco Bay where they are a minor sport species.

Northern anchovies and Pacific herring are commercially important species harvested in San Francisco Bay. Almost all are used as bait, either live or frozen. Anchovies also are abundant in San Pablo Bay and extend into Suisun Bay during the summer. Adult Pacific herring enter San Francisco Bay from the ocean in winter to spawn. Although adults rarely go beyond Carquinez Strait, young-of-the-year herring are sometimes abundant off Pittsburg in April and May. At times the size of the herring runs is large enough to support a small commercial fishery in San Francisco Bay. Both herring and anchovies are important as food for striped bass and other fish.

Surfperch are an important sport fish common in San Francisco and San Pablo Bays and at times may be taken commercially. Surfperch commonly taken by anglers are white seaperch, pile perch, walleye surfperch, black perch, and shiner perch. Besides being an important sport fish, surfperch are important as forage for striped bass as will be pointed out later.

Jacksmelt and topsmelt, members of the silverside family, are popular sport fish abundant in San Pablo and San Francisco Bays. They are occasionally found in Suisun Bay. Members of the true smelt family as well as white croaker and Pacific tomcod are found in the Bay and appear in the sport catch. All of these fish are fed upon by striped bass.

Starry flounder and diamond turbot are flatfish which contribute to the sport catch of the Bay area. Flatfish are rare above San Pablo Bay, with the exception of the starry flounder which is abundant in Suisun Bay. Juvenile English sole, which may contribute to offshore commercial landings as adults, utilize San Francisco Bay as a nursery area.

Several species of sculpins are found throughout San Francisco and San Pablo Bays. The Pacific staghorn sculpin is commonly caught by pier and shore anglers and is important in the diet of striped bass during the fall in San Pablo Bay.

Anadromous Fishes

The six most important anadromous fishes in the Bays are striped bass, king salmon, steelhead trout, green sturgeon, white sturgeon and American shad. They range from salt to freshwater.

Striped bass are the most important sport fish in the estuary. The adults spend the summer primarily in North San Francisco Bay and the ocean. In the fall, many of them migrate through San Pablo or San Francisco Bays and migrate to the Delta to spawn in the spring. Striped bass spawn in the Sacramento River from near Rio Vista to Butte City and in the San Joaquin River from Antioch to Venice Island and sometimes as far as Mossdale. The eggs and larvae are carried downstream. By summer most young-of-the-year bass are in Suisun Bay. In the fall they begin to enter Carquinez Strait and San Pablo Bay. During the winter, half or more of the population is in San Pablo Bay.

King salmon are very important sport and commercial fish, although few are caught within the limits of this Basin. They spawn in freshwater above the Delta. The adults migrate through north San Francisco Bay, San Pablo Bay, Carquinez Strait and Suisun Bay on their way to the spawning grounds. The young move downstream primarily in May and June on their way to the ocean. They use the same route as the adults but also enter south San Francisco Bay (Heubach 1968).

Steelhead follow much the same migration route as salmon except that some of them enter streams tributary to San Pablo Bay, such as the Napa and Petaluma Rivers (Heubach 1968). They are an important sport species. White sturgeon are found in all of the bays and are most abundant in San Pablo and Suisun Bays. Their migrations are not well understood. Some adult fish move upstream into the lower Sacramento River during the late winter and then migrate up the Sacramento in the spring on a spawning migration (Miller 1972). The sport fishery is small but important because of the interest generated by the large size of the sturgeon.

Green sturgeon are less well known and less common than white sturgeon. There is virtually no fishery for them and it appears they enter the ocean more frequently than white sturgeon.

Adult American shad spend most of their lives in the ocean. They enter San Francisco Bay in the late winter and early spring and proceed upstream to spawn above the Delta. Few enter south San Francisco Bay. The young migrate downstream the following fall, using much the same route as the adults (Kelley 1968). There is no fishery for them in this Basin. They are caught upstream in the Delta and in several Central Valley rivers.

Freshwater Types

Most freshwater fishes are not abundant downstream from the Delta. The exceptions are white catfish, threadfin shad, and split-tail which are abundant or fairly common in Suisun Bay.

Brackish-water Types

This classification includes those fishes that spend most of their lives in the brackish water areas of the estuary. Only two species, pond smelt and Sacramento smelt, fall in this class. Both of them are found mainly in Suisun Bay. Both species migrate into the Delta during the fall and winter to spawn (Radtke 1966). In the spring, young-of-the-year Sacramento smelt are abundant in eastern San Pablo Bay. There is no fishery for them, however, though they are important food for bass.

Appendix D is a composite of all the species of finfish except nonandromous freshwater fishes recorded from the San Francisco Bay Complex.

Shellfish - Intertidal Area

Wooster (1968) conducted an extensive field survey of the shellfish and associated organisms for individual areas of the Bay in the intertidal zone of the San Francisco Bay estuary. His work was summarized by Jones and Stokes (1972).

Two edible clam species occur in the intertidal zone of San Francisco Bay in sufficient numbers to be considered potentially harvestable by a sport fishery. These are the soft-shell clam (Mya arenaria) and the Japanese little neck clam (Protothaca semidecussata). Other clams found in the Bay include the gaper clam (Tresus nuttalli), the native little neck clam (Protothaca staminea), the bent-nosed clam (Macoma nasuta), M. inconspicua, the basket cockle (Clinocardium nuttalli), and the Washington clam (Saxidomus nuttalli). However, most of these species are either too small or occur in numbers too low in the intertidal zone to represent potentially harvestable resources.

The ribbed horsemussel (Volsella demissus) is abundant in south San Francisco Bay, and bay mussels (Mytilus adultis) are common throughout the Bay.

Three species of oysters were harvested commercially in the Bay: the Eastern oyster (Crassostrea virginica), the Pacific oyster (C. gigas), and the native oyster (Ostrea lurida). Only experimental lots of the first two species remain in the Bay, while the native oyster is widespread wherever bottom and salinity conditions are suitable. Major beds in the intertidal zone are shown in Plates 5-7.

Softshell Clam (*Mya arenaria*)

Wooster (1968) estimated that there were approximately 16 million adult soft-shell clams in the intertidal zone of San Francisco and San Pablo Bays.

Little is known about the life history of the soft-shell clam in California; however, the species has been studied in Chesapeake Bay where two spawning cycles occur annually, in May-June and again in September-October. The larvae are free-swimming in the bay waters for at least two weeks, depending on temperatures. These larvae provide a valuable food source for other larger organisms during this period. Larvae, juveniles and adults feed on phytoplankton and detritus which they filter from the water.

The larvae metamorphose and settle to the bottom where they may temporarily attach by threads. Juveniles move about the bottom or are carried by currents until they are about an inch long, at which time they burrow into the substrate.

Growth is influenced by water quality, temperature, currents, food supply and the nature of the substrate. Wooster (1968) found the soft-shell clam in waters where the average salinity was greater than 2%. Within that salinity range, substrate type and food supply appear to be the two main limiting factors.

Japanese Littleneck Clam (*Protothaca semidecussata*)

In 1968 it was estimated that the adult Japanese littleneck clam population in the intertidal areas consisted of approximately 5.3 million individuals (Wooster 1968a).

The Japanese littleneck clam also has two spawning seasons, one in the spring and one in the fall. Japanese studies indicate that the optimum salinity is between 12.3 and 24.6 0/00 for the development of the embryo, and between 18.5 and 28.3 0/00 for the subsequent development of the adult clam. Filice (1958) collected this species from the seaward end of the San Francisco Bay estuary to the point in Carquinez Straits where the average salinity was 0.16 0/00. None were collected in Suisun Bay, but Wooster (1968) found them to be abundant in central and south San Francisco Bay.

This clam was found only in areas where the bottom was partially composed of gravel, rocks and/or shells. None were found on soft mud substrates which may cause clogging of their gills. This clam, as well as the others, is a filter feeder and, as such, depends for food on a ready supply of minute substances ranging from detritus to plankton.

Mussels

The bay mussel is the most abundant mussel in San Francisco Bay. This species is scattered throughout most of the Bay where it is attached to permanent substrates such as rocks or pilings. These mussels are extremely valuable in filtering material out of the water and voiding it as feces or pseudo-feces which then become available to a variety of deposit-feeding organisms such as polychaete worms.

Oysters

The native oyster industry was almost entirely replaced in the mid-1800's by that of the larger, more productive eastern and Pacific oysters. Between 1900 and 1920 this latter industry declined due to reduced water quality.

Both Pacific and eastern oysters tolerate a range of salinity between 1 and 3%. However, predators are more abundant in salinities higher than 2.5% than in the lower end of the range. This results in reduced populations at the higher salinities. The oysters prefer a firm substrate and cannot tolerate sand or siltation which may result in smothering and interference with their filtration mechanism. Experiments indicate that oyster spawning is limited to temperatures between 15 - 35^{o}C; however, major spawning peaks occur only at sustained temperatures above 20^{o}C. Thus, while Bay water temperatures are within the range of adaptability, they do not fall into the optimum range.

Quality oyster and clam beds depend on a food supply carried from a much larger support area than just the water overlying the bed (Galtsoff 1964). A comparison of the historical oyster growing areas in the south Bay and historical marsh areas illustrates how closely associated these two areas were, indicating that the marshes were important sources of food (Fig. 8).

None of the previously mentioned shellfish are presently taken from San Francisco Bay for human consumption as they are contaminated by heavy metals and disease-causing bacteria (Environmental Protection Agency , 1974, 1975; Storrs, Selleck and Pearson, 1963; Graham 1972; Girvin, Hodgson and Panietz 1975).

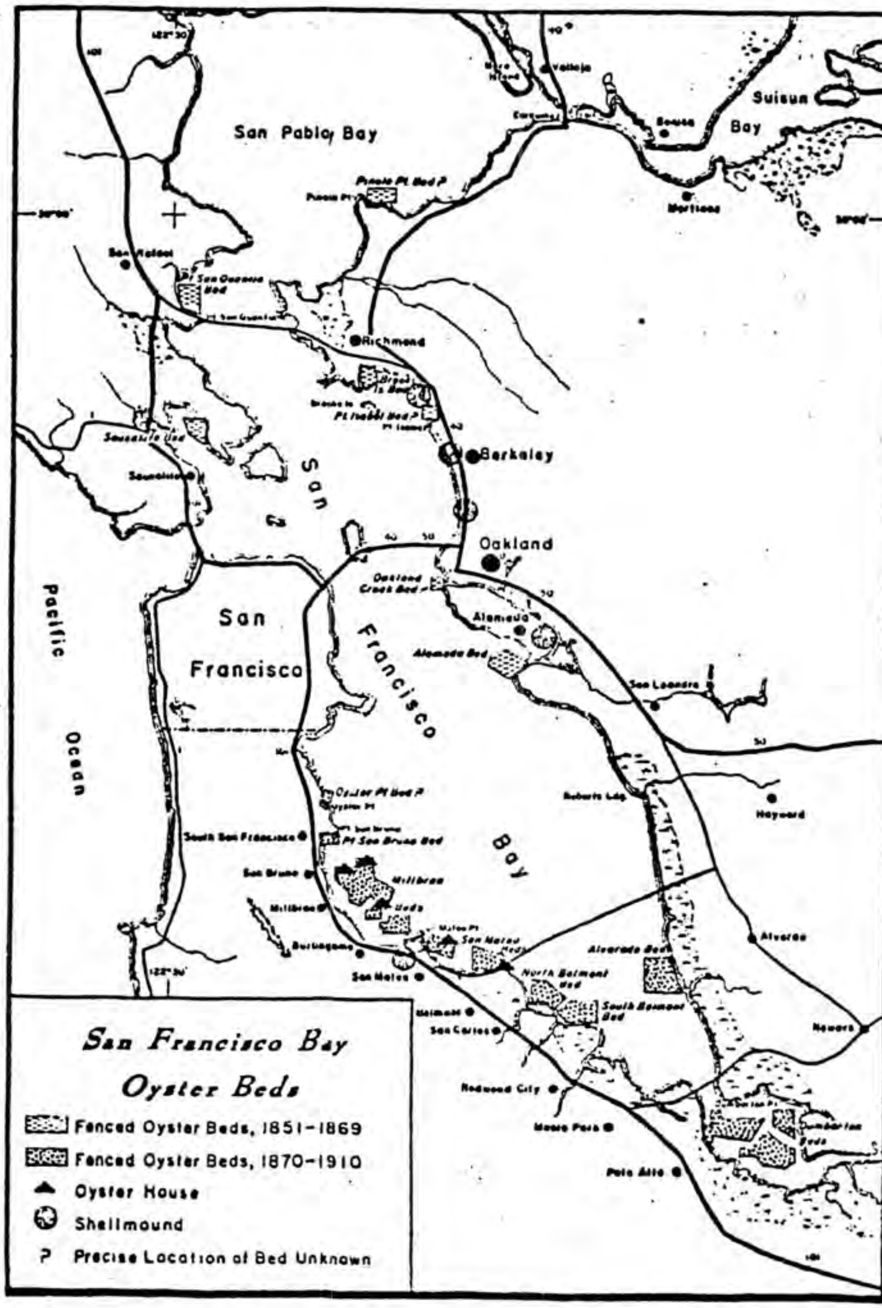

Fig. 8. Oyster Beds and Adjacent Marshes.

(after Barrett 1963)

However, recent studies by Condit and Mackel (1976) and Hallett (1974) indicate that overall contamination problems have decreased substantially in the Bay comple as waste water treatment facilities have been upgraded. As a result, the 1976 San Francisco Board of Supervisors passed Resolution No. 167-76, indicating the Board "feels that the restoration of edible sealife (crabs, clams, oysters and other indigenous seafood) to San Francisco Bay is one of the most urgent tasks ahead as we in the Bay Area try to make peace with nature." What the future holds for again raising oysters in the Bay is an open question, but several groups have recently indicated an interest in raising oysters if all of the legal and environmental restraints can be overcome. One alternative may be to grow them in the Bay and then cleanse them by moving them to another area for a short time.

Crustaceans Throughout the Estuary

Crabs

There are three crabs in the Bay complex which are utilized by sportsmen for food -- red, rock and market crabs. Most of the market crabs in the Bay are immature and, as a result, are less than the 6-1/4" size limit required. In spite of this regulation, many are kept since the fishermen confuse them with other crabs. The estuary and its marshes provide a nursery area and food supply for the market crab. Juvenile market crabs tagged within the Bay have been recovered in the ocean by commercial fishermen illustrating the Bay's importance to the ocean fishery. There is a considerable lack of information on the population dynamics of the market crab in the Bay, so that the California Department of Fish and Game is now conducting intensive studies (Oseutt, Tastro and Wilde, 1975).

Bay Shrimp

Several species of bay shrimp occur in both deep and intertidal waters during the summer throughout San Francisco, San Pablo and Suisun Bays as far as Pittsburg (Wooster, 1971; Ganssle, 1966). The commercial fishery for them is limited by demand and they are almost exclusively used as bait. Their small size makes it economically unsound to shell them for food. About 60,000 pounds are landed annually, with an estimated value of around $100,000 (Table I).

Table I: Yield and value of Bay shrimp harvest

Year	Pounds	Value
1969	77,106	$ 76,822
1970	65,761	76,054
1971	59,621	82,827
1972	73,067	115,856
1973	62,308	115,543

Source: California Department of Fish and Game, Marine Resources Operation

At the end of the last century, about 5 million pounds of shrimp per year were landed. Although landings were limited by legislatively imposed restrictions, populations are believed to be smaller now than during the last century (Skinner, 1962). This reduction in numbers may be partially the result of the loss of 60% of the Bay's marshes in the period 1850 to 1968 (San Francisco BCDC 1971). These marshes are thought to be a major source of the shrimp's primary food -- detritus. The major value of the shrimp resource, however, is that it is an important part of the diet of striped bass, salmon and many other valuable food fishes.

Value of the Finfish, Shellfish and Crustaceans of the Bay System

The value of the above resources to the economic and social well being of humans cannot be satisfactorily measured at this time and further investigations need to be carried out. Several authors, however, have attempted to estimated user days and/or monetary values, including Altorney, Crampon and Willeke (1966) and California Department of Fish and Game (1973).

Kelley (1966) estimated there were between 2.6 and 4.5 million man-days of recreational use spent in fishing. He predicted the use in the year 2000 would increase to between 8.5 and 15 million man-days and put increased pressure on the resource.

The California Department of Fish and Game compiles the pounds and values of the commercial fish landings to ports in Marin and San Francisco counties (Appendix E). These landings include both fish harvested in the Bay and the ocean and, therefore, are not entirely related to the productivity of just the Bay. Most of the species, however, at some time in their life history are dependent on the San Francisco Bay estuary either for spawning, nursery area or as a source of food and/or nutrients to the ocean system. An examination of Appendix E illustrates that several million dollars in economic value can be attributed to the commercial fishery that is dependent on the continued existence of the Bay estuary.

To give some idea of the sport value of the fishery, one has only to look at the use and value estimates made by the California Department of Fish and Game in 1974 for anadromous fisheries of salmon, steelhead, striped bass, shad and sturgeon (Appendices E, F, and G; and Table 2). The values are in the millions of dollars per year for these renewable resources. They are renewable, however, only if the ecosystem is kept intact and the vital role of marshes in providing the basic food is preserved.

Table 2. Bay Sport Fishing Effort and Values

Sport Fishing Effort Expended in the Bay Complex and Rivers (1970)

	Angler Days				
San Francisco Bay	Steelhead	Salmon	Striped Bass	Shad	Sturgeon
South	...	...	124,000	...	...
Central	...	...	239,000	...	...
San Pablo Bay	...	...	235,000	...	...
Suisun Bay	...	...	105,000	...	...
Delta Area	...	...	1,137,000	...	...
Rivers	142,300	127,500	214,000	...	...
TOTAL	142,300	127,500	2,054,000	125,000	8,000

Estimated Expenditures by Sport Fishermen (1970)

Ocean	$ 2,915,300
Bay Complex	29,762,800
River Tributaries to San Francisco & San Pablo Bays	90,000
Rivers Upstream from Delta	4,511,400
TOTAL	$ 37,279,500

The Value of the Marshes of Tideflats to Continued Production of Finfish, Shellfish and Crustaceans

Earlier, the question was raised of how we determine the importance of marsh and its detritus in the Bay's complex of useable organisms. Kelley

(1966) reviewed the studies of others and found that very little work had been done concerning this question for the San Francisco Bay estuary. Further studies since 1968 in the Suisun Marsh and in the marshes of San Pablo Bay have revealed that a compilation of the food habits of the major fish and shellfish (Appendix G and Fig. 9) indicated:

> The dangers to salt marshes stem from human activities, not natural processes...Fish and birds have evolved depending on finding marshes all along the coast, wherever they wander. The preservation of a few marshes here and there will not serve for their existence (Teal 1969).

Every acre of marsh produces plant material which forms the base of the food chain. These plants are consumed by terrestrial insects or are broken down into detritus which is filtered out of the water by mussels. These, in turn, are eaten by fish and wildlife and so the food chain continues. The role of detritus and terrestrial insects is important, therefore, in the health of fisheries in the San Francisco Bay Estuary (Appendix G and Fig. 9). In summary, one finds numerous interconnections between the strands of life, most of which lead back to the marshes of San Francisco Bay as a basic source of food.

The Effect of Marshes on Climate and Pollution

The effect of the Bay on local climate was reported by Harvey (1966). A current study, concerning the role of marshes in moderating climate, is being conducted by C. Felton, a doctoral candidate at U.C. Berkeley and final

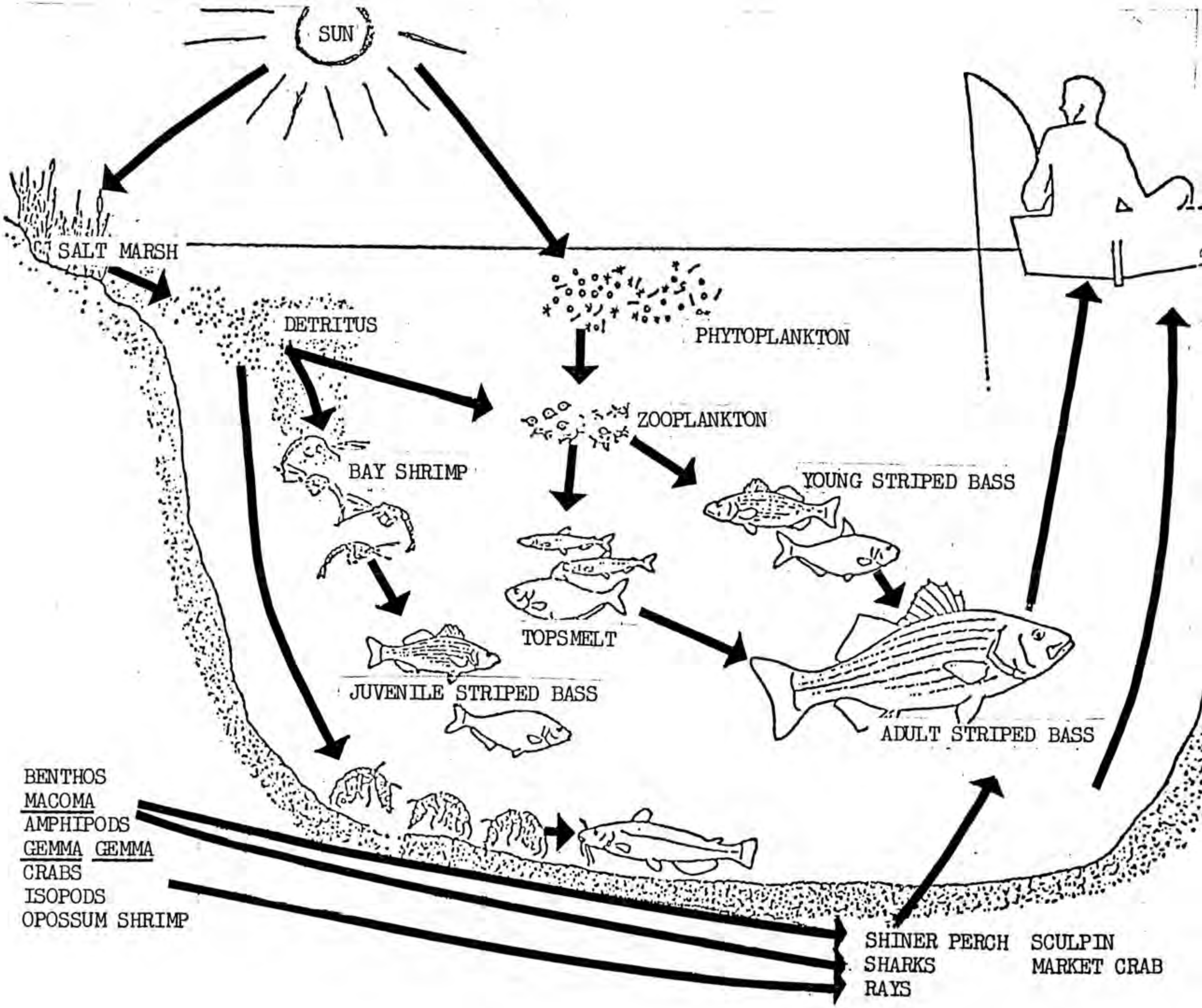

Fig. 9. Food web support of sport fisheries.

results should be ready in a few months. The general effect of the Bay with its marshes and salt ponds is to ameliorate the climate. Further conversion of heat sinks like the Bay into terrestrial habitat may well result in increased temperatures in the summer and decreased temperatures in the winter for land communities down-wind of the Bay.

Regarding air pollution, a preliminary investigation by Martin (1973) indicates that marsh plants may serve as a temporary sink for carbon monoxide. Other studies show that soil fungi are the final sink for carbon monoxide in the Bay area.

In a study of water quality at Faber Tract marsh, Smith (pers. comm.) found that during late March and early April incoming water had higher nitrate and phosphate than outgoing water. Dissolved oxygen was greater in the outgoing than in the incoming water. Concentrations of all three substances were about equal during the months of July and August when 13 different determinations were made. These preliminary studies in San Francisco Bay are consistent with those from eastern marshes (Grant and Patrick 1969) that showed reduction of pollutants and an increase in dissolved oxygen.

The probable role of marshes in BOD (Biochemical Oxygen Demand) production is complicated. The water quality characteristic of BOD load is a measure of pollution. If the BOD load is high, oxygen requiring organisms are impaired in their activities. The vegetation from the marsh contributes to this load but in a different manner than domestic sewage. The basic difference is timing. The natural tidal marshes release their load of BOD into the water in the winter months (Cameron 1972), during which oxygen concentrations are at their highest due to low temperatures and storm waves (Storrs, 1963, 1964, 1965). In the summer months the marsh is releasing oxygen into the water at a rate higher than the water's demand. The summer months are least favorable to oxygen absorption from the atmosphere due to higher temperatures and less wave action. The BOD from sewage treatment plants is a year around input but particularly high during the late summer when it can overload the system. Thus, the marsh BOD increase comes at a time when the system can handle it while sewage BOD, in part, comes into the Bay waters when oxygen levels are already low.

Educational and Esthetic Values

As more and more people become aware of and interested in natural areas, the marshes of San Francisco Bay increase in value to them. Over 35,000 people per year in organized groups come to the Palo Alto Interpretive Center on the marsh and there may well be an equal number who come on their own. The Marine Ecological Institute of Redwood City takes classes out to the Bay and has instituted a marsh study program as well. Numerous school groups used the above programs as well as those of local Audubon Societies and other private groups.

Esthetically, the Bay marshes contribute to the quality of life, particularly as educational opportunities are expanded to reach more people. An appreciation for marshes and for their value as the base of the food chain will be greatly enhanced in this way.

Maintenance of Water Quality

As plants grow, they take up substances from the habitat and incorporate these substances into their tissues for growth, maintenance and differentiation. Most plants utilize carbon dioxide from the air and water from the soil or another surrounding medium. Employing energy from the sun by means of an operation called photosynthesis, they manufacture sugar and give off free oxygen to the air or water to the soil. The sugars enter into carbohydrate formation in their tissues producing starches and cellulose. The building blocks for protein synthesis enter the plant as dissolved substances in the soil water or in the surrounding water if in an aquatic habitat. Most of these dissolved substances go directly into the substantive growth and differentiation through biochemical processes taking place within the tissues. Each season's new growth continues this substantive accrual of tissue derived from what might be called a filtering operation of the water. The old growth decomposes in the marsh and enters the soil or is carried by the tides into the Bay's waters.

In the biological operations discussed, substances taken out of solution and incorporated into plant tissue are rendered insoluable. Thus, when we look at a marsh, what we see as plant cover has in substantial part been taken from the water by this living filter operation. Some of these dissolved substances in the water are considered pollution. We will consider any substance added by man's activities to the system, either as an increase or new compound as a pollutant and thus it produces pollution.

Therefore, the plants remove the pollution and on the death of the plant the pollutants are incorporated into the soil or water where they are transformed by other organisms and enter the food web.

For most of these dissolved substances in the water, there is a range of concentration that the plant can tolerate known as the range of tolerance. It may be said of plants, just as for animals, that no two individuals of the same kind are ever exactly alike in any of their properties. This is to say that, with respect to their ranges of tolerance for the various dissolved substances, plants of the same kind will vary from one another in the precise span of each of their ranges of tolerance. Where some plants in this like population might be inhibited by the level of the pollution present, others are busy reducing the level of the pollutant present. Thus for a local population the tolerance span is greater than that of any one individual plant. This population reaches and removes the pollutants from a greater range than would any one individual.

For example, the common pickleweed may tolerate salt concentrations up to 6-7%, while cordgrass can barely tolerate salinities of only 4% maximum (Pheleger 1971). Thus pickleweed can endure a saltier environment than cordgrass. The greater the number of species of plants making up the marsh, the greater the efficiency of that marsh in removing the sundry dissolved pollutants from the water. Pickleweed is important primarily because it takes up salt and, therefore, tastes salty. This means that the salt inside the plant tissues is in fairly high concentration, much more so than in some of the surrounding water.

An example of the use of this diversity in a practical problem entailing marshes is in the planning of the San Luis drain to remove agricultural salts from returned irrigation waters of the San Joaquin Valley. It is expected to collect the agricultural waste waters in an underground drain and thereby remove pesticides by filtering them through soil. It also takes salts that would otherwise become concentrated at the soil surface by evaporation and carry them off in the drain. The waters would then pass through an underground filter, fed with plant material which would act as a necessary carbon source in the denitrification of the dissolved solids. This would allow the final effluent to be within permissible limits for dumping into the bay. The brackish intertidal marshes of Suisun Bay operate similarly to this man-made system in that they support a greater variety of plant species than do salt marshes. The greater variety of plants of Suisun Marshes becomes more important in light of the irreparable destruction to the delta -- 600 square miles of living filter that once maintained the water quality of San Francisco Bay have been removed by diking. The importance of Suisun Bay marshes in maintenance of water quality in part rests on the variety of plants (floristic diversity) of the intertidal marshes There are about 150 species of plants making up these marshes. A thorough search at the height of the growing season might increase the count to about 200. In contrast, the salt marshes of the South Bay contain from 12-15 different species of plants growing in the intertidal waters.

Identification of Wildlife Areas

Along with marsh areas themselves, there are numerous places nearby that have high wildlife value (Plates 1-7). Of special note are the salt ponds. Although salt ponds are man-made additions to the Bay's ecosystem, they have certain unique wildlife values. They house organisms peculiar to high salinities, such as brine shrimp and certain species of single-celled organisms (flagellates). In the California Department of Fish and Game surveys (Bollman et al., 1970) the salt pond habitat maintained the highest density of birds per acre, both wildfowl and shorebirds. Whether it is primarily food or protection from wind and waves that draws them to the ponds is not clear at this time. There is some indication (Anderson 1970a) that low to moderate salinity ponds attract the greater number of birds. Salt pond dikes have two important functions for wild birds. The first is that they serve as nesting sites for several shorebird species (Gill 1972a), especially endangered species such as the least tern (Anderson 1970b; Elliott 1970). The second function is that salt pond dikes provide nesting and resting sites for shorebirds. Thus, in addition to their role as moderators of the Bay Area climate, they possess unique wildlife values as well.

V. Marsh Restoration

Introduction

Programs of diking and filling salt marshes for agricultural purposes have been carried out throughout history (Daiber 1974). In recent years, salt marshes have been established for the reclamation of mud flats. Since the advent of the hybrid Townsend's cordgrass (Spartina townsendii) prior to 1870, the majority of the mud flats of the British Isles have been built up through planting and allowing the subsequent accretion of silt and sand to occur about the bases of these plants (Ranwell 1967). According to Ranwell (1967), plantings of mud flats were done for one or more of the following reasons: (1) to stabilize them for reduction of silting in navigational channels; (2) to protect the coastline from damage by the sea; and, (3) to reclaim the mud flats for agricultural uses. These plantings were largely made in the 1920's to 1930's in widely spaced locales, from which Townsend's cordgrass subsequently spread to other suitable sites (Ranwell 1967).

Some marsh restoration or establishment has occurred in the United States. Williams (1955) pointed out that freshwater marshes in Louisiana which had been salted as a result of inundation were planted with smooth cordgrass. California cordgrass (Spartina foliosa) has been used to reclaim mud flats in California and Townsend's cordgrass has recently been planted in Washington (Ranwell 1967). Smooth cordgrass has been shown to stabilize dredge spoils in North Carolina (Woodhouse et al. 1974;

Seneca 1974). Most marshes, however, have been filled by the process of land reclamation or have been used as dumps for dredge spoils, or have become municipal dump sites, or have been diked and used as pasture or other agricultural lands (Clark 1974; Odum 1959; Ranwell 1967; Teal 1969).

The rate and amount of marsh degradation far outstrips marsh restoration. Some 55% of California's current marshlands lie within the confines of San Francisco Bay (MacDonald and Barbour 1974), and yet most of these have been destroyed or greatly altered by diking and filling. Over 60 square miles of the Bay's marshlands have been treated in this fashion (Dreisbach 1969), producing conditions not conducive to marsh restoration. Filled land, particularly when it is developed, is not likely to be restored. Marinas, ports and industrial developments which occurred in former marshlands are also not economically restorable. There are many square miles of former marshland behind dikes which have good potential for restoration. It will require the individual inspection of each marsh, however, before a prescription for restoration can be suggested. The guidelines of a total Bay marsh inventory, which follow in a later section, include marsh restoration potentials.

Cooper (1969) notes that

> ...given proper elevation there seems no reason why natural or artificial regeneration of marsh species could not be employed. Construction of new marsh land should be viewed with caution, however, for it is clear that to construct new marshes some other estuarine land, perhaps equally as valuable, must be used. There is little merit in destroying one habitat to build another.

With this advice in mind, it remains evident that the Bay Area has several sites available which involve no loss of estuarine habitat. The diked marshlands at Alviso, the thousands of acres of salt ponds of San Pablo Bay and the Southern Bay appear to be potential areas for marsh re-establishment (Harvey 1966). All of the salt ponds have been developed on land that was previously marshland. Although some salt ponds have high wildlife value those of low wildlife value could be returned to tidal marsh. Some 70 square miles of mud flats exist in the Southern Bay, of which some could be considered for conversion to marshland. Although mud flats have their ecological values they have been destroyed at a far lower degree than marshes and therefore might be converted to marsh. A certain degree of dredging should be necessary and the spoils of these operations could be used to raise the elevation of some mud flats to a height suitable for marsh. The stabilization of dredge spoils with marsh vegetation has been found to be quite feasible on the east coast (Woodhouse et al. 1974). Since as much as two thirds of the dredge material in San Francisco Bay comes from previously dredged material (Dreisbach 1969), marsh formation might aid in stabilization of this material.

Two important variables in the restoration of marshlands are the tidal range within the Bay and the rate of sedimentation. The tidal prism (volume of water exchanged by tides) for the four daily tidal flows is about 1,250,000 acre-feet with the two low water portions (low tides) lasting slightly longer than the high tides (Pestrong 1972). The south

Bay typically exhibits higher high tides and lower low tides than the north bays (Dreisbach 1969; Pestrong 1972). Tidal flushing and the rate of sedimentation are high in the north bays and salinity drops towards the Sacramento-San Joaquin Delta (Pestrong 1972). San Pablo Bay receives a great sediment load as the second major body reached by the 6 million cubic yards annually of sediment from the delta (Dreisbach 1969). The sediment is approximately 57% clay and 43% silt when it enters the bay, since most of the sand is lost previously in the Delta region (Pestrong 1972). The colloidal clays are flocculated and deposited when the fresh water stream comes in contact with salt water (Dreisbach 1969). Most of the material that remains in suspension is in the form of silt (with some colloidal clay) but these steadily decrease in concentration toward the southernmost reaches of the south Bay (Pestrong 1972). Tidal flushing is also quite poor in the south Bay. Such factors as sedimentation and reduced tidal flushing result in variability in the composition and structure of the marshes (MacDonald and Barbour 1974). Duration and depths of inundation as well as the rate and composition of sedimentation must be studied further to determine their effects on marsh restoration.

Tidal elevation has a direct bearing on the distribution of salt marsh plant species (Adams 1963), so that slight increases in duration of submergence will apparently prevent colonization of mud flat areas by certain species (Hinde 1954). California cordgrass is an early colonizer of Bay marshes and occurs in relatively pure stands a few feet above the Mean Low

Water. It is replaced at higher elevations by a zone of pickleweed (Salicornia pacifica) which is frequently associated with Jaumea (Jaumea carnosa), alkali heath (Frankenia grandifolia), Salicornia biglovii and or S. europea. The tidal elevation at which each species prospers varies with tidal elevation throughout the Bay. Each site selected for marsh restoration will require tidal elevation determinations followed by the appropriate plantings. Grasses of the genus Spartina (cordgrass) are the species most commonly used in marsh restoration or establishment, largely due to the fact that they are natural colonizers (Ranwell 1967; Williams 1955; Woodhouse et al. 1974). They also have the ability to increase the rate of sediment accretion once established. Transplantation studies have shown that several species are capable of surviving over a large gradient of slope and salinity (Stalter and Batson 1969), even though they occur in nature under relatively restricted zones. Studies carried out by Woodhouse et al. (1974) suggest that the best for transplanting are single cordgrass plants with rhizomes, extra small shoots, and with the previous year's flower stalks removed. Similar work has been performed by the senior author in conjunction with the U.S Army Corps of Engineers using local cordgrass (Spartina foliosa). Transplanting has the advantage of being able to be used over a broad range of conditions (Woodhouse et al. 1974) and may be carried out by hand or machine. Machine planting involves the use of a commercial transplanter pulled by a standard farm tractor and outfitted with dual wheels and flotation tires (Woodhouse et al. 1974). This rig is impractical on the unstable mud flats of San Francisco Bay which usually have a low shear strength. It may be usable, however, on dredge spoils that are somewhat stabilized or in salt ponds which have reverted to natural tidal flow and have been otherwise given over to marsh restoration. In 1976, a small caterpiller tractor pulling a sled was used by the Corps of Engineers in planting pond #3 near the Alameda Creek channel. Transplant stock is taken from wild populations or, if the areas made available for marsh restoration are sufficiently large, nurseries are established such as the one maintained by San Francisco Bay Marine Research Center in Richmond, California.

Seeding is less expensive than transplanting, but has the disadvantage of being restricted to a narrower set of conditions. Our local species, California cordgrass, was at one time thought to be completely inviable (Phleger 1971). Recent work has discounted this, showing that flotation of the seeds and storage in cold salt water is required to attain high germination rates (Floyd pers. comm.). Mooring et al., (1971) found that an after-ripening period of development was involved in germination of smooth cordgrass which necessitates wet storage of seed in estuarine water with a 35-20°C alternating thermoperiod for approximately forty days. Longer periods of storages may be used to delay germination if necessary by reducing the temperature to 2-3°C (Seneca 1974). California cordgrass has a similar after-ripening requirement in initial testing.

It shows an average of nearly 90% germination when stored in brackish water under light conditions at 23°C for 45 days (Cain pers. comm.). Further study will be necessary to determine specifically the exact after-ripening period and best harvest dates. Harvesting could be carried out in natural populations or in established nurseries. Woodhouse suggests broadcasting seed in the upper tide zone at a density of 100 per square meter at low tide and covering it with 1-3 cm of tillage. A process called hydromulch (seeds in a slurry) has also been suggested. Since cordgrass seed appear to germinate best in low salinities (Mooring et al. 1971) the spring months with their attendant rainfall would be most appropriate for seeding. The best dates, however, have yet to be determined for San Francisco Bay. Another technique is to use muslin cloth sheets to cover the seeds.

Erosion brought about by wave action could be a particular problem, especially on substrates which are not well stabilized such as mud flats and recently placed dredge spoil, as it would tend to remove the transplant stock or seed. It would be appropriate, therefore, to avoid planting during periods of heavy winds or in storm periods but still try to seed when there is enough precipitation to lower the salinity.

Restoration of salt marshes in the San Francisco Bay is both necessary and feasible. The techniques required for the proper establishment of marshes within the specifc conditions of the Bay Area have yet to be fully developed and should be a top research priority.

Marsh Restoration in San Francisco Bay

Marsh restoration projects in San Francisco Bay have been modest and of experimental proportions. One of the first attempts was in 1969, when the senior author collected seed from a variety of marsh species and planted them under the Grand Avenue overpass near the Oakland approach to the Bay Bridge. Only nine or ten attempts at planting salt marsh plants have been made in San Francisco Bay to date. The planting was done in test transects of cordgrass, saltgrass and pickleweed. Transects consisted of both plugs and seeds of each species. The seeds had been collected in the fall and stored dry in the refrigerator. The plugs were taken from adjacent marsh areas on the day of planting. Data on the survival of each type demonstrated that common pickleweed will re-establish itself so rapidly, once tidal action covers a restoration area, that very little is gained by planting it. This was further borne out in subsequent experiments. Cordgrass and relatively rare plants such as Jaumea and gumplant, on the other hand, become established in an area much faster by planting than if allowed to do so at their natural rates.

The experiment at the Faber tract in 1971, near Palo Alto, confirmed these tentative observations. Four hundred and forty plugs, approximately four inches in diameter, were placed in three transects down the slope of the dredged spoils from Palo Alto Yacht Harbor. This study demonstrated that cordgrass could be greatly increased by transplanting it in a suitable substrate at the right tidal elevations. Inasmuch as tidal elevations vary throughout the Bay, the proper elevations at each site recommended for restoration would need study beforehand. In their study of marsh plant distribution at a marsh near Pt. San Pedro, Atwater and Hedel (1976) reported that elevations from plus 2 ft. to plus 5 ft. above MLLW had cordgrass, but optimum growth was between 2.3 ft. and 4 ft. In the South Bay, cordgrass grows at elevations up to plus 7 ft. since there is a greater tidal range in that region of the Bay.

An additional study by the senior author of cordgrass growth in the Anza Pacific Lagoon in Burlingame tested four replicate plots of each type of planting. In part it was a test to determine whether the original elevation of the source of the cordgrass made any significant difference in survival and, hence, increased yield per unit effort. It had been hypothesized that the shorter, so-called dwarf cordgrass growing at the highest tidal elevations in marsh areas would not survive at the low elevations. Whereas the tall, so-called robust form is common at the lower tidal elevations, and if transplanted to low elevations, it would survive. Tests were made using seed, seedlings and plugs.

From the results of these low tidal elevation plantings, a few tentative conclusions were drawn. Only in protected areas where wave action or algal growth were not inhibitory did plants become established from seed. Seeds can be used providing they are not stored dry but rather in cold salt water, and that the seed bed is between about +3 to +7 feet above MLLW and is protected from wave action. The seeds should be raked into the substrate to insure remaining in place, or some kind of mulch or sand placed over them. The short form of cordgrass survived and grew as well as the tall form in the early months. There was a difference, however, in the rate of spread. The tall form had more stems come up from the parent plug in the first year after planting than did the short form and, after two years, the plots of the robust form had much more dense stands of plants than those of the dwarf form.

At the Alameda Creek channel, studies were made concurrently by the senior and second authors to assess the value of selecting dwarf or robust cordgrass stock for planting. At that site the upper end of the tidal range for cordgrass was tested in fourteen transects. The dwarf form survived at the higher elevations at a statistically significantly ($p < .05$) higher rate than did the robust form. Its growth at mid elevations, however, was undiscernable from the robust form. What this suggests to us is that both forms are genetically alike but the physiological responses of plants growing at the extremes of the tidal range fit them for transplanting to the appropriate extreme. Without more research, however, it seems premature to make a strong recommendation that only robust cordgrass be planted at low elevations and dwarf cordgrass at high elevations. Perhaps the most sensible approach is to take cordgrass from the middle tidal elevations and transplant it throughout the desired range, but this has not been done yet.

Under the auspices of the U.S. Army Corps of Engineers, a major marsh restoration project in San Francisco Bay was started in May, 1974. The Marine Researsh Center of San Pablo Bay was in charge of planting and supplying seeds and cuttings of the cordgrass and pickleweed for the project on the Alameda Creek channel. Their results indicated that recently dredged material was a suitable substrate for marsh restoration. The major drawback was that the cost of hand planting cuttings, plugs and seedlings ran into the thousands of dollars per acre. They found that planting by seed was only one-fourth as costly in man hours as planting of cuttings (Newcombe and Pride 1975). Moreover, natural seeding by pickleweed is likely to provide adequate cover rapidly, but cordgrass cover remained sparse. The addition of fertilizer did not increase the height of cordgrass plants but did increase the pickleweed biomass. The third phase of this project is currently in progress, in which mechanical methods have been used in planting plugs. The results have not been published as yet. An additional study in marsh restoration is being carried on at Creekside Park in Kentfield by San Francisco Bay Marine Research Center and bears watching as a great variety of plants are being tested. Of special interest are their plantings of some of the rare or unusual plants that have been almost lost due to the extensive deterioration of marshlands around the Bay.

The introduction of plants foreign to an area often leads to problems. The spread of Spanish and Scotch broom in the Bay area and the presence of gorse on the peninsula are cases in point. It is always prudent to limit the restoration of marshes to the use of native plants. Exotic plants are desireable only in cases where it can be shown that they will not take over from nor fill a niche occupied by native species.

In summary, marsh restoration in San Francisco Bay is feasible if three major conditions are met. First, the surface to be restored must lie at a suitable elevation for the establishment of the desired species of plant. Second, the substrate must be suitable for plant growth. Third, adverse conditions such as excessive wave action, algal growth, or predation must be circumvented. Due to the great ecological value of marshes and the fact that most of those in San Francisco Bay have been destroyed, the more marshes that can be restored, the more nearly can we approach the conditions that existed prior to the 1800's. Although some natural marsh development is occurring, it is not located in that portion of the Bay where man-made destruction has occurred. Thus, the restoration of marshes at sites once occupied by tidal marshes is necessary to re-establish the dynamic balance that once existed.

VI. Marsh Inventory Guidelines

A detailed inventory should be made to assess the specific characteristics and values of the marshes of San Francisco Bay. There are several benefits of such an inventory. First, the resource of natural marshes would be known. Second, the sites of potential marsh restoration would be identified. Third, the presence of unique plants and animals in the marshes will be assessed. Fourth, the health and composition of marshes will serve as baseline studies for subsequent evaluations of changes that may occur.

The following guidelines present a comprehensive detailed plan of study for marsh areas. Basic to a marsh inventory would be selection of geographically defined marsh areas of relatively small size (10-200 acres). The guidelines are presented below in outline form.

I. Name of marsh - Local historical name, or name contrived to fit the marsh in question

II. Location -- County and City

   A. Map showing regional location of the marsh with entire Bay divided into four divisions, namely South, Central, San Pablo and Suisun Bays

   B. Map to show boundaries of study area and access routes to the marsh. The Study area should include the late 1800's marshlands of the bay.

III. Ownership

   A. Property owner(s) and ownership map.

   B. Ownership of access route and instructions on proper entry i.e., whom to contact for permission for access.

IV. Geologic History

A. Age of marsh - pre-1850 vs. post-1850.

B. Historic rates of growth or erosion (vertical and horizontal)

C. Historic and pre-historic changes in marsh flora.

V. History of Land Use

A. Previous use(s) of marsh; assessment of potential for restoration

B. Current uses: marshland reserve, wildlife refuge, hunting

VI. Geographical Features

A. Map of marsh including internal access

B. Length of shoreline

C. Aerial photograph of marsh

D. Area of the marsh

E. Topographic characteristics

1. Surface appearance (hummocks, etc.)

2. Presence of dikes (lineal distance, width, availability for trails)

3. Occurrence of drainage ditches and bases of need (mosquito abatement)

4. Levelling surveys to determine elevations with respect to tide levels.

F. Shoreline features -- advancing or being undercut

VII. Substrate Features

A. Soil type -- physical and chemical characteristics

B. Preliminary assessment of soils for potential marsh restoration sites.

VIII. Hydrological Features

A. Map showing watercourses, streams, sloughs, etc. through or adjacent to the marsh

B. Present controls over water level, e.g., tide gates, dams

C. Maintenance of channels or fresh water stream flow which affect water quality

D. Salinity measurements of applied water and soil water.

IX. Flora

A. Mapping dominant plant species by zones, if applicable

B. Distribution of plants within the marsh

C. Identification of transition zone upland to marsh and successional trends if apparent, e.g., peripheral halophytes

D. Rare or endangered plants, or plants of limited distribution

E. Description of dike vegetation where present

F. Plant list -- scientific and common names, with master list in appendix and voucher specimens in reputable herbarium

X. Fauna

A. Invertebrates -- common species present, including both marine and terrestrial, e.g., mussels and insects

B. Vertebrates

1. Herptiles -- amphibians and reptiles

2. Birds -- waterfowl, raptors, indigenous species

3. Mammals -- major species present

C. Status of rare and endangered species in marsh. Live trapping may be necessary to determine presence of harvest mice.

D. Map localities of exceptional wildlife activity such as seal hauling grounds, nesting colonies and shorebird feeding sites. (Many of these are presented in this report.)

XI. Environmental Impacts

A. Extent and location of dumping or filling in marsh

B. Identification of dredging and borrow channels

C. Relative signs of litter (flotsam -- logs, plastic, etc.)

D. Discussion of pollution potential or apparent damage

E. Subsidence -- map and discussion

XII. Scenic Features

A. Special vistas and points of interest indicated on maps

B. Views from within marsh and viewpoints of marsh should be identified

XIII. Master Marsh Maps

A. Map of present marshes in survey area for monitoring changes

B. Map of potential marsh restoration areas

The proposed inventory should be conducted over a minimum of two years, which would ensure a better assessment of the species present and provide information over the seasons. Aerial photographs (regular black and white and color, and infra-red) would be one source of data, but a major element would be the ground evaluation of marshes as presented in the preceeding outline.

Estimated Costs

If the above quidelines were followed completely, the cost would be between $50,000 and $60,000 per year for the study. By eliminating ownership, history, scenic, geographic, substrate and hydrological features, it would be nearer $30,000 to $35,000 per year. A minimal single year general study could possibly be done for about $20,000.

A detailed study as outlined above would serve as an excellent example of the level of protection BCDC is giving to the marshes of the Bay.

Findings and Conclusions Concerning Marshes and Mudflats Around the Bay

Introduction

The senior author was asked to make his summary, conclusions and recommendations in form and language similar to the findings and policies in the section of the San Francisco Bay Plan relating to marshes and mudflats. The purpose of this style of presentation is to facilitate the Commission's consideration of the report in relation to possible changes in the Bay Plan if they appear to be warranted by the material presented. At this time, however, the recommendations are those of the author to the Commission and, other than those that are repeated without change from the Bay Plan, do not represent Commission policy. Changes in the Bay Plan findings and policies would be made only after the Commission has made its own determination of the need to make such changes and has gone through the normal Bay Plan amendment process, including required public hearings.

Many of the following findings and policies are the same as those contained in the San Francisco Bay Plan, pages 11 and 12, adopted by the Commission in 1968. However, suggestions for changes in certain of these have been made by additions, as indicated by underlined words, and deletions as indicated by words marked out. Recommended new findings are contained in f. through n., and recommended new policies are in items 4. through 8.

Findings

a. Salt marshes are extraordinarily ~~fertile~~ productive. Living marsh plants fix the sun's energy ~~of sunlight into~~ in their tissues through photosynthesis, and expel oxygen into the surrounding environment. One type of marsh plant, cordgrass, has from two to seven times the energy-generating capacity ~~or~~ (food value) of an equal acreage of wheat.

b. Large numbers of birds, including ducks and geese, ~~come to the marshes to~~ feed on the lush vegetation or on the brackish-water animals that thrive ~~there~~ in the marshes. ~~Their wastes together with the decomposition products of plant decay and other elements of the complex food web~~ Products of plant and animal waste and decomposition contribute nutrients ~~from the marshes~~ to the mudflats and the shallows of the Bay margin, ~~supporting~~ creating a vast marine nursery.

c. Marshes are vital in the life of the Bay. Most marine life in the Bay ~~either depends directly on the marshes and mudflats for its substenance or indirectly depends upon them by feeding upon other marine life so nourished~~ depends either directly or indirectly on the marshes and mudflats for its sustenance. Shorebirds depend upon the marshes and mudflats for both food and shelter. Marshes are a part of the vital food producing cycle for bay and coastal fisheries and thus ultimately for man.

d. Marsh plants and algae on the mudflats, exposed to abundant light alternating with abundant water, produce and expel oxygen into the water and ~~into the~~ air. ~~This is~~ Marshes and mudflats are an important source of oxygen that water must have both to support marine life and to combat water pollution.

e. The marshlands bordering the Bay now total about ~~75~~ 125 square miles. In 1850, before diking and filling had been begun, marshlands covered ~~some~~ over 300 square miles. Some of the present marsh developed since 1850.

f. Marsh plants ameliorate air pollution by absorbing carbon monoxide, a common air pollutant..

g. Hunting, birdwatching, nature study, hiking, photography, painting and aesthetic appreciation are important recreational opportunities afforded by marshes. The value of marshes for outdoor education and student research is also great.

h. New Marshes are created naturally in part by sedimentation upon mud flats which elevates the area sufficiently to allow for the invasion of marsh plants. Existing fresh water marshes may become salt water marshes if water salinity through tidal influence increases due to reduced downstream flows.

i. Marshes and former marshlands are important habitat for a whole community of animal species. Waterfowl utilize marshes as shelter and nesting sites. Marsh areas are also used by marine mammals as shelter and nesting sites.

j. The marsh flora of San Francisco Bay is not sufficiently understood to separate natural changes from man-induced alternations. In general, however, gradients of species exist vertically in response to tide and horizontally in response to salinity.

k. Under certain conditions natural marsh restoration is possible. If, however, the rapid spread of cordgrass and the relatively rare marsh plants is desired, artificial planting is necessary.

l. Overall, marshes aid in high water quality by removing pollutants and adding oxygen to the tidal waters.

m. Exotic plants are present in Bay marshes and future introductions are contemplated.

n. The water quality of sewage effluent affects the plant species composition of the receiving marsh.

Policies.

1. Marshes and mudflats should be maintained to the fullest possible extent to conserve fish and wildlife and to abate air and water pollution. Filling and diking that eliminate or significantly decrease the quality of marshes and mud flats should therefore be allowed only for purposes providing substantial public benefits and only if there is no reasonable alternative. Marshes and mud flats are an integral part of the Bay tidal system and therefore should be protected in the same manner as open water areas.

2. ~~Any proposed~~ In those instances where fills, dikes, or piers are permitted, they should be thoroughly evaluated to determine their effects on marshes and mud flats, and then modified as necessary to minimize any harmful effects.

3. To offset possible additional losses of marshes due to necessary filling and augment the present marshes, (a) former marshes should be restored when possible through removal of existing dikes; (b) in areas selected on the basis of competent ecological study, new marshes should be created through carefully placed lifts of dredged spoils and by the reintroduction of native marsh plants; and, (c) the quality of existing marshes should be improved by appropriate measures whenever possible. Tidal action should be restored to diked marsh areas whenever possible.

4. Carefully selected, designed and controlled areas should be made accessible to the public so that the unique educational, aesthetic and recreational values that marshes offer can be fully enjoyed.

5. Specific areas, where rare and endangered species exist or where significant amounts or varieties of wildlife occur, should be designated as preserves.

6. An inventory is needed to determine where marsh preserves should be established. A monitoring program should be developed to reflect the change in marsh habitat throughout the Bay over the years. An analysis should be made to determine the detrimental or advantageous influences on marsh habitat.

7. Exotic plant species should not be introduced to Bay marshes and where present removal should be encouraged.

8. Sewage effluent should be considered as a management tool in marsh restoration.

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Appendices and Plates

Index to Plates

Plates 1 - 7 (following page 114) have been specifically keyed to the following lists of symbols.

RE = Rare and endangered, and a number following the RE indicates on the list which species are present at the same numbered site on the plate maps. (Some unique forms not technically classified as rare and endangered are included in this grouping.)

S = Shorebird and waterfowl habitat site with number indicating which species have dominant use.

N = Nesting, roosting, wintering, rookery, feeding or eyrie sites with number indicating which species.

H = Hauling ground (i.e. place where marine mammal comes out on land).

F 1-43 = Numbers of shellfish beds on plates 5 - 7 (see index list of shellfish beds, page 115 following plate 7).

RARE AND ENDANGERED SPECIES
PLUS UNIQUE FORMS

RE1 - Harvest Mouse
RE2 - " "
RE3 - " "
RE4 - " "
RE5 - Rail, Harvest Mouse
RE6 - " " "
RE7 - Harvest Mouse
RE8 - Rail, Harvest Mouse
RE9 - Harvest Mouse
RE10- " "
RE11- " "
RE12- Rail, Harvest Mouse
RE13- Harvest Mouse
RE14- Rail, Harvest Mouse
RE15- " " "
RE16- " " "
RE17- " " "
RE18- Rail
RE19- Rail, Harvest Mouse
RE20- " " "
RE21- " " "
RE22- " " "
RE23- " " "
RE24- Harvest

RE25- Rail, Harvest Mouse
RE26- Harvest Mouse
RE27- Rail, Harvest Mouse
RE28- " " "
RE29- " " "
RE30- Harvest Mouse
RE31- Rail, Harvest Mouse
RE32- Harvest Mouse
RE33- Clapper Rail
RE34- " "
RE35- " "
RE36- " "
RE37- " "
RE38- " "
RE39- " "
RE40- " ", Harvest Mouse
RE41- " " , " "
RE42- " " , " "
RE43- " " , " "
RE44- Snowy Egret, Great Egret,
Harvest Mouse, Clapper Rail
RE45- " " " "
RE46- Clapper Rail
RE47- Forsters Tern, Caspian Tern

RE48- Clapper Rail, Harvest Mouse

RE49- " " " "

RE50- Clapper Rail

RE51- " "

RE52- " " , Harvest Mouse

RE53- Harvest Mouse

RE54- " "

RE55- River Otter

RE56- Egret

RE57- Harvest Mouse

RE58- River Otter

RE59- Black Rail

RE60- Peregrine

RE61- River Otter

RE62- Beaver

RE63- River Otter

RE64- " "

RE65- " "

RE66- " "

RE67- Harvest Mouse

RE68- " "

RE69- River Otter, Peregrine

RE70- Aleutian Canada Goose

RE71- River Otter, Black Rail

RE72- Golden Eagle

RE73- Egret

SHOREBIRD AND WATERFOWL HABITATS

S1 - Canvasback, Scaup

S2 - Western Grebe, Scoter spp., Scaup, Canvasback, Pintail

S3 - Avocet, Godwit, Scaup, Dunlin, Least Sandpiper, Black-bellied Plover, Stilt, Willet

S4 - Surf Scoter, White-winged Scoter, Canvasback

S5 - Canvasback, Scaup, Pintail

S6 - Diving Duck

S7 - Cormorant

S8 - Brandt, Double-crested Cormorant

S9 - Brandt, Double-crested Cormorant

S10 - Cormorant

S11 - Western Grebe, Ruddy Duck, Canvasback

S12 - Canvasback, Scaup

S13 - Canvasback, Scaup, Pintail

S14 - Surf Scoter, Scaup, Canvasback, Ruddy Duck, Scoter, Mallard

S15 - Pintail, Teal

S16 - Canvasback

S17 - Pintail, Canvasback, Ruddy Duck

s18 - Pintail, Canvasback

S19 - Scaup, Canvasback, Pintail, Ruddy Duck, Phalarope, Willet, Godwit, Dunlin, Avocet, Stilt

S20 - Godwit, Willit

S21 - " "

S22 - Canvasback

S23 - " , Scaup, Cormorant, Loon, Scoter

S24 - Mallard

S25 - Long-billed Curlew

S26 - goose, raptor

S27 - White-fronted Goose

S28 - raptor

NESTING, ROOSTING, WINTERING, ROOKERY, FEEDING, AND EYRIE SITES

N1 - Stilt, Avocet

N2 - Forsters Tern

N3 - Snowy Plover

N4 - Forster's Tern

N5 - " "

N6 - Forster's Tern, Avocet

N7 - Caspian Tern

N8 - Avocet

N9 - Forster's Tern

N10 - " "

N11 - Forster's Tern, Avocet, Stilt

N12 - Forster's Tern

N13 - Stilt, Avocet

N14 - Snowy Plover, Avocet, Stilt

N15 - Avocet, Stilt

N16 - Heron, Egret

N17 - Great Blue Heron

N18 - Least Tern

N19 - Caspian Tern

N20 - Least Tern

N21 - Avocet, Stilt

N22 - Least Tern

N23 - Least Tern

N24 - Forster's Tern

N25 - Caspian Tern

N26 - Least Tern

N27 - " "

N28 - Western Gull

N29 - Great Blue Heron, Black-crowned Night Heron, Snowy Egret, Western Gull

N30 - White-tailed Kite, Harrier, Short-eared Owl

N31 - Black-crowned Night Heron, Short-eared Owl

N32 - Double-crested Cormorant, Avocet, Stilt, Forster's Tern, Caspian Tern, Great Blue Heron, Egret

N33 - Great Blue Heron, Egret

N34 - Heron

N35 - White-tailed Kite

N36 - Great Blue Heron

N37 - Golden Eagle

N38 - Great Blue Heron, Egret

HAULING GROUNDS

H1 - Harbor Seal

H2 - " "

H3 - " "

H4 - " "

H5 - " "

H6 - " "

H7 - Marine mammal

H8 - Harbor Seal

H9 - " "

SOUTHERN SOUTH BAY

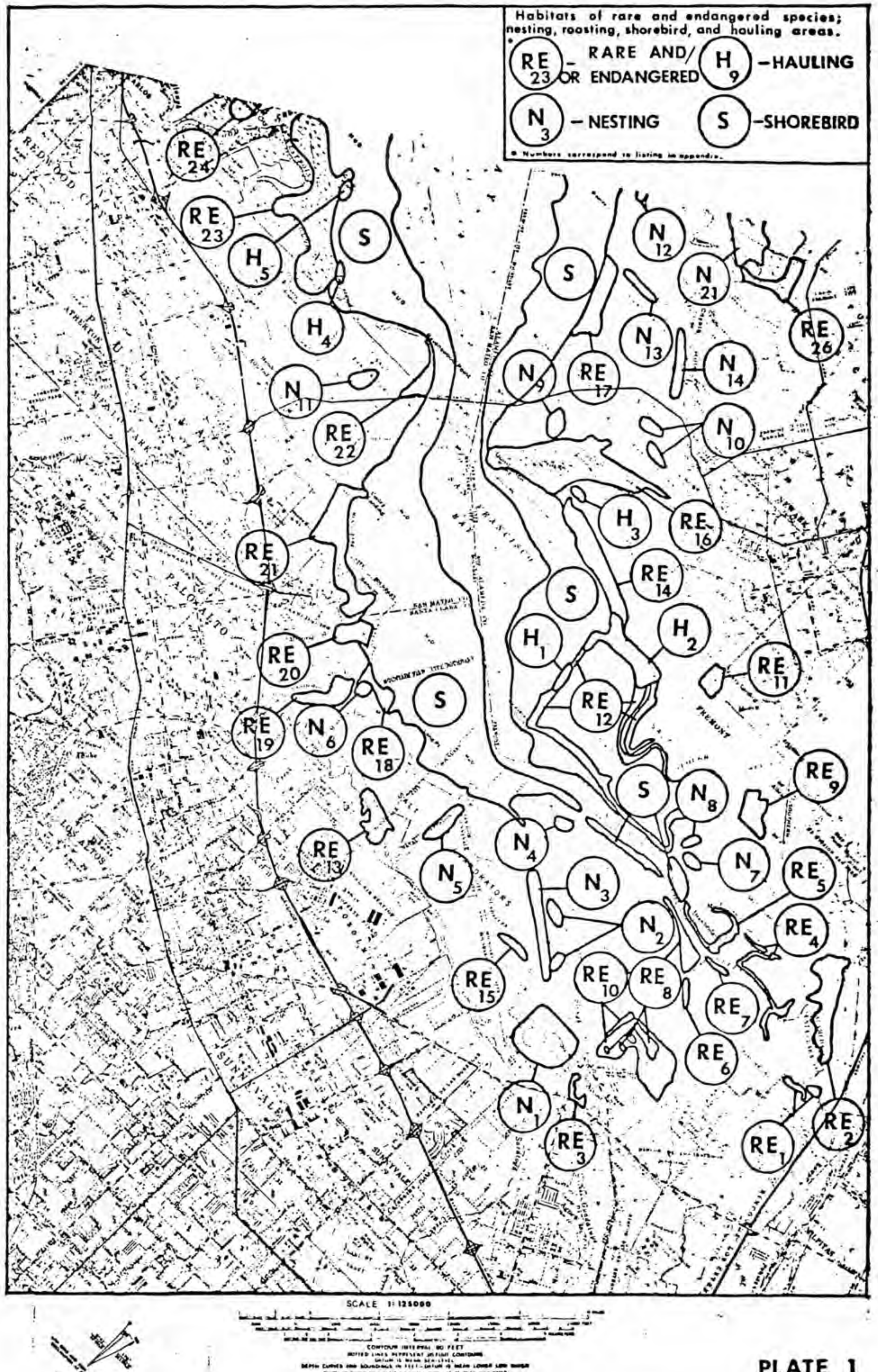
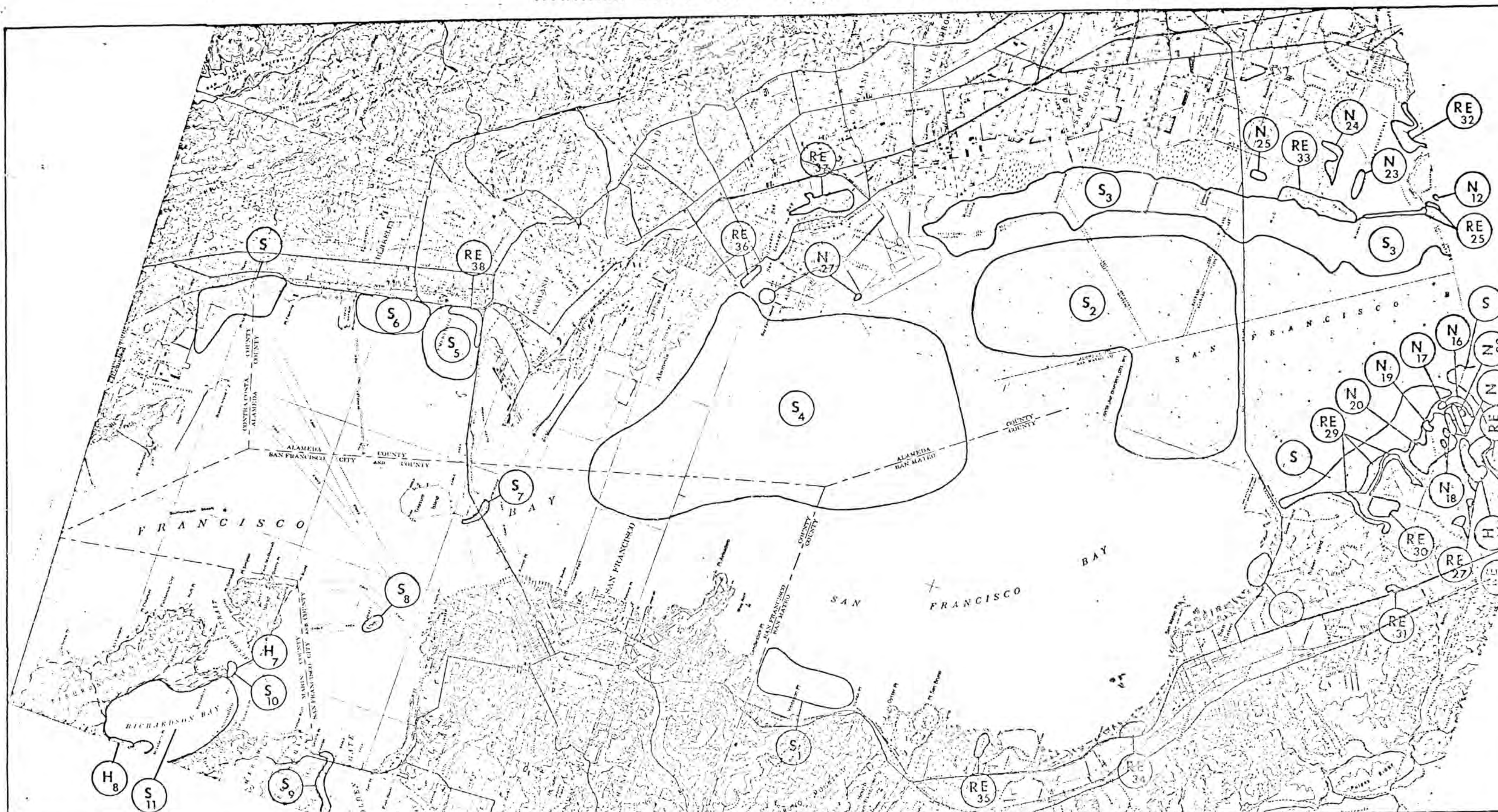


PLATE 1

NORTHERN SOUTH AND SOUTHERN CENTRAL BAY



Habitats of rare and endangered species: nesting, roosting, shorebird, and hauling areas.

RE 36 – RARE AND/OR ENDANGERED

N 7 – NESTING

S 9 – SHOREBIRD AND/OR WATERFOWL

H 4 – HAULING

* Numbers correspond to listing in appendix

PLATE 2

SAN PABLO BAY AND WEST SUISUN BAY

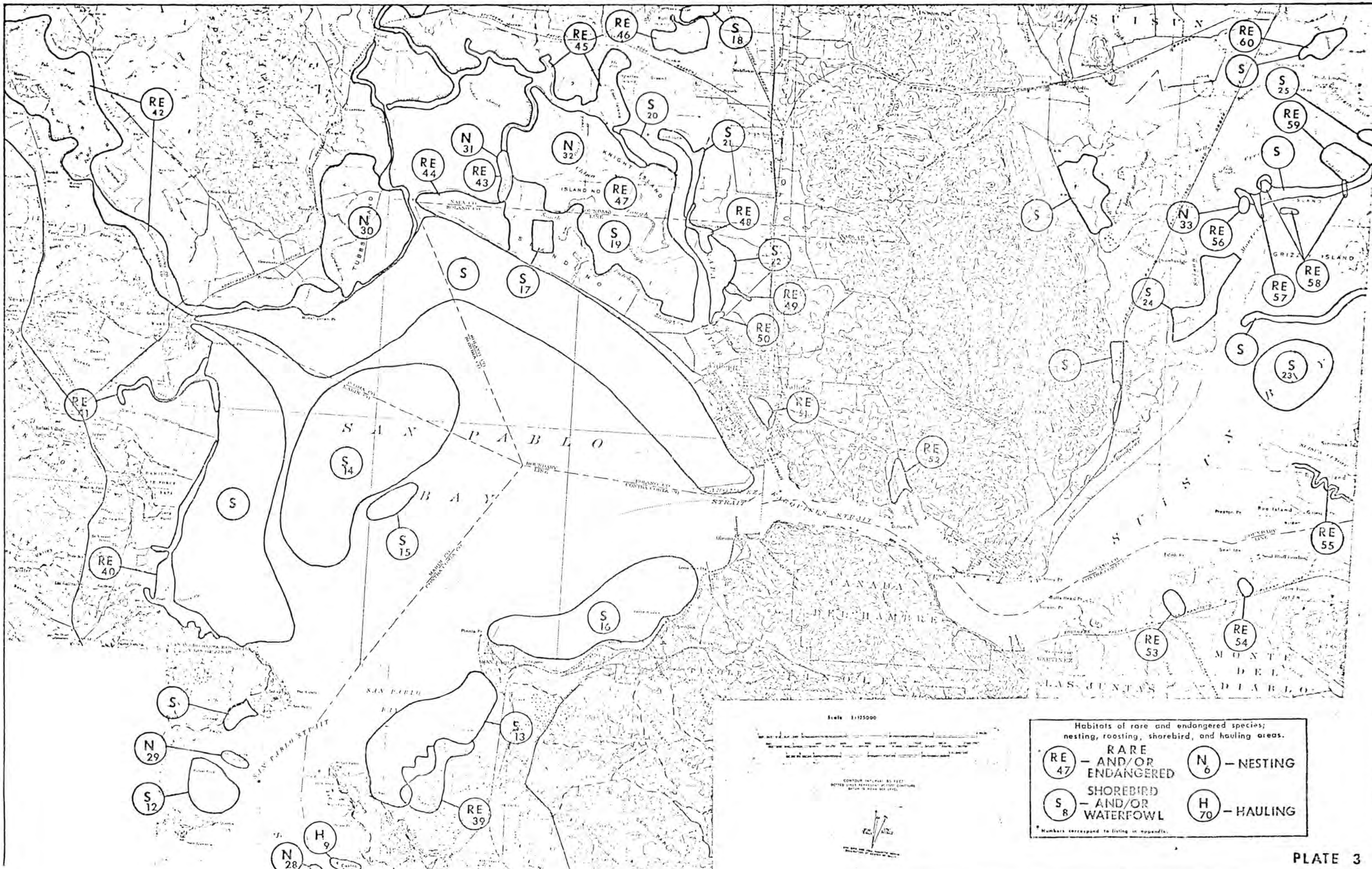
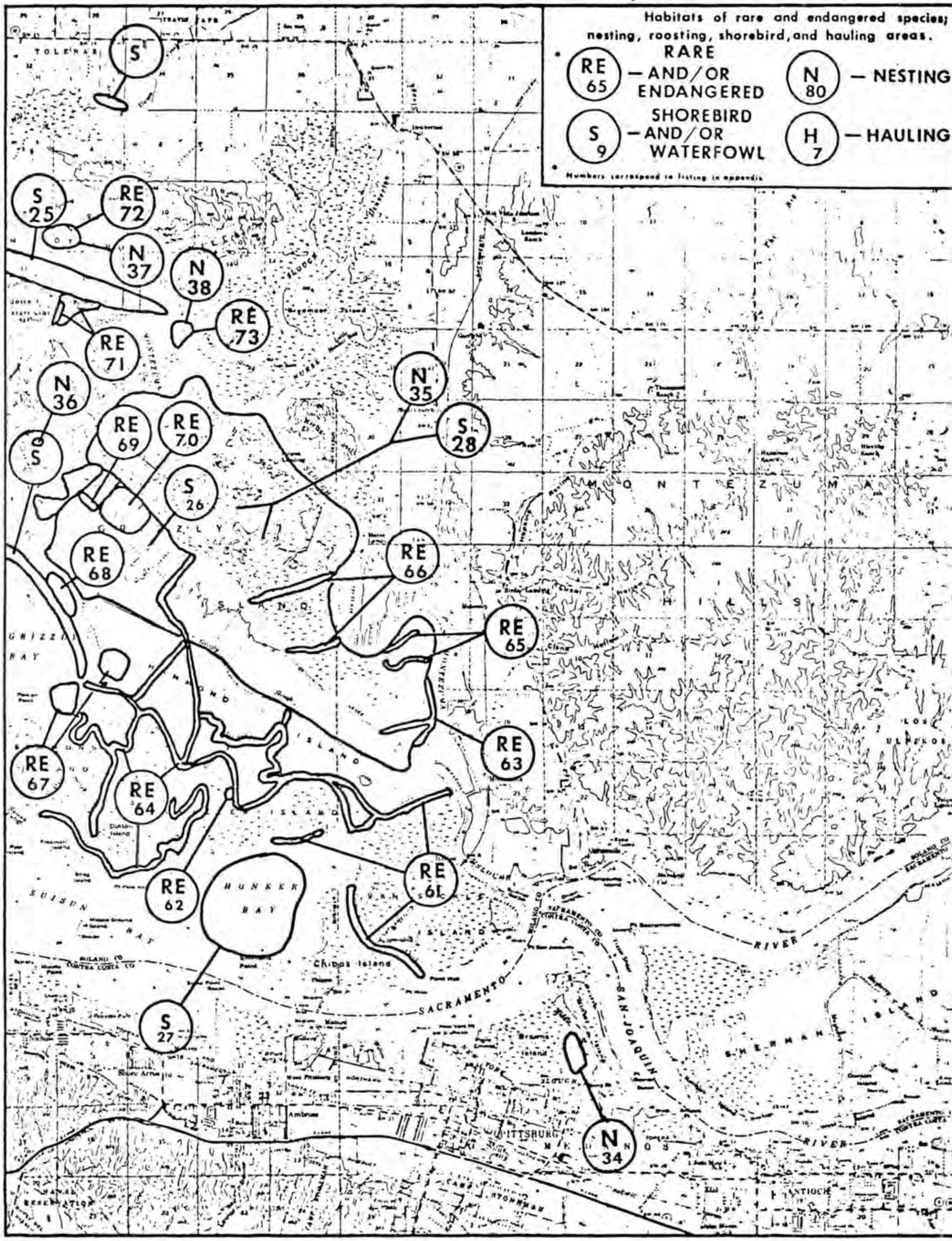


PLATE 3

SUISUN BAY


Habitats of rare and endangered species; nesting, roosting, shorebird, and hauling areas.
RE 65 — RARE AND/OR ENDANGERED
N 80 — NESTING
S 9 — SHOREBIRD AND/OR WATERFOWL
H 7 — HAULING
Numbers correspond to listing in appendix
S
S 25
RE 72
N 37
N 38
RE 73
RE 71
N 36
S
RE 69
RE 70
S 26
N 35
S 28
RE 68
RE 66
RE 65
RE 63
RE 67
RE 64
RE 62
RE 61
S 27
N 34
SUISUN BAY
HONKER BAY
MONTEZUMA
HILLS
SACRAMENTO RIVER
SAN JOAQUIN
SHERMAN ISLAND
GRIZZLY BAY
Chipps Island
PITTSBURG
ANTIOCH
NAVAL RESERVATION
Scale 1:125000
CONTOUR INTERVAL 20 FEET

SOUTHERN SOUTH BAY

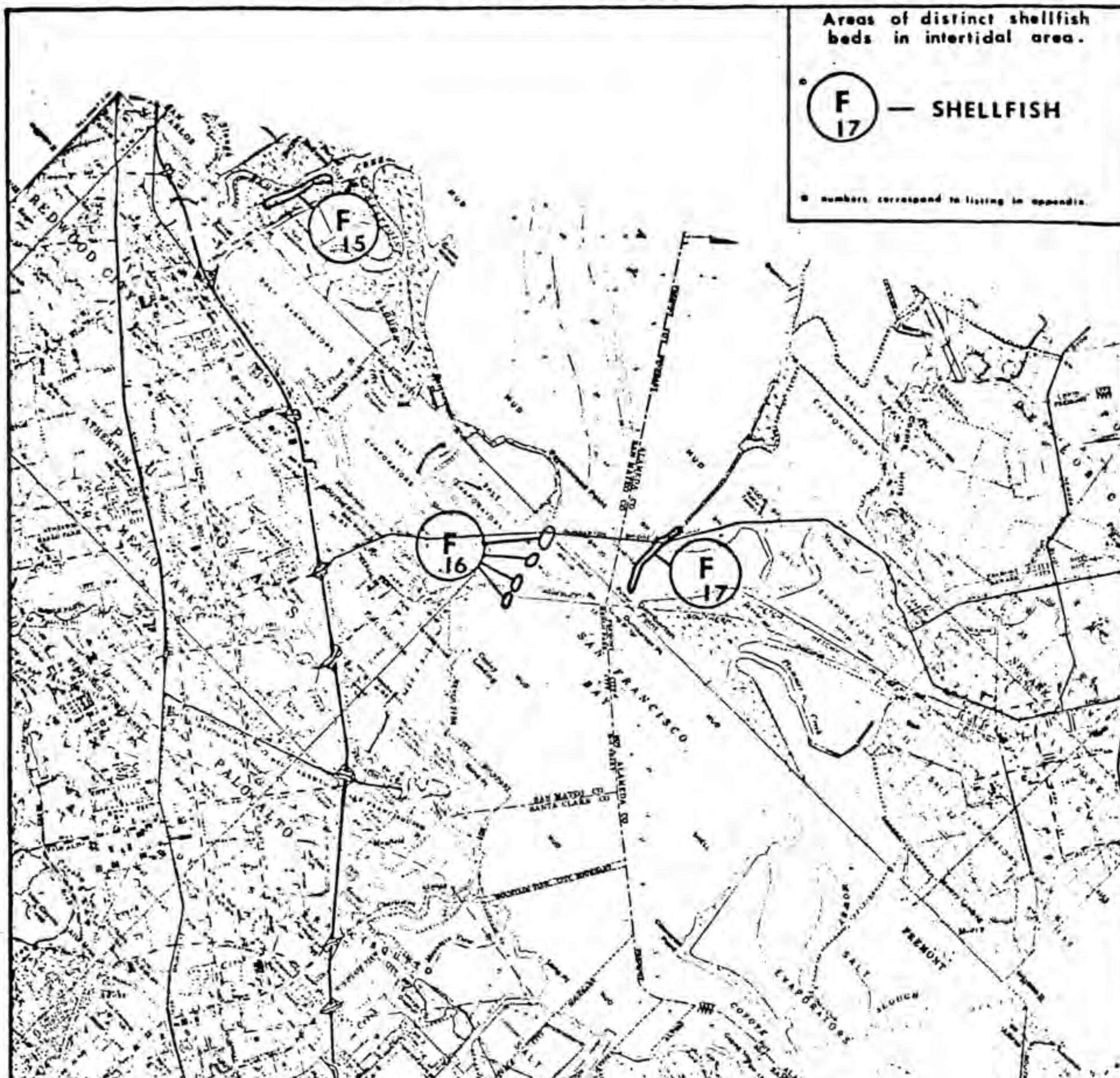
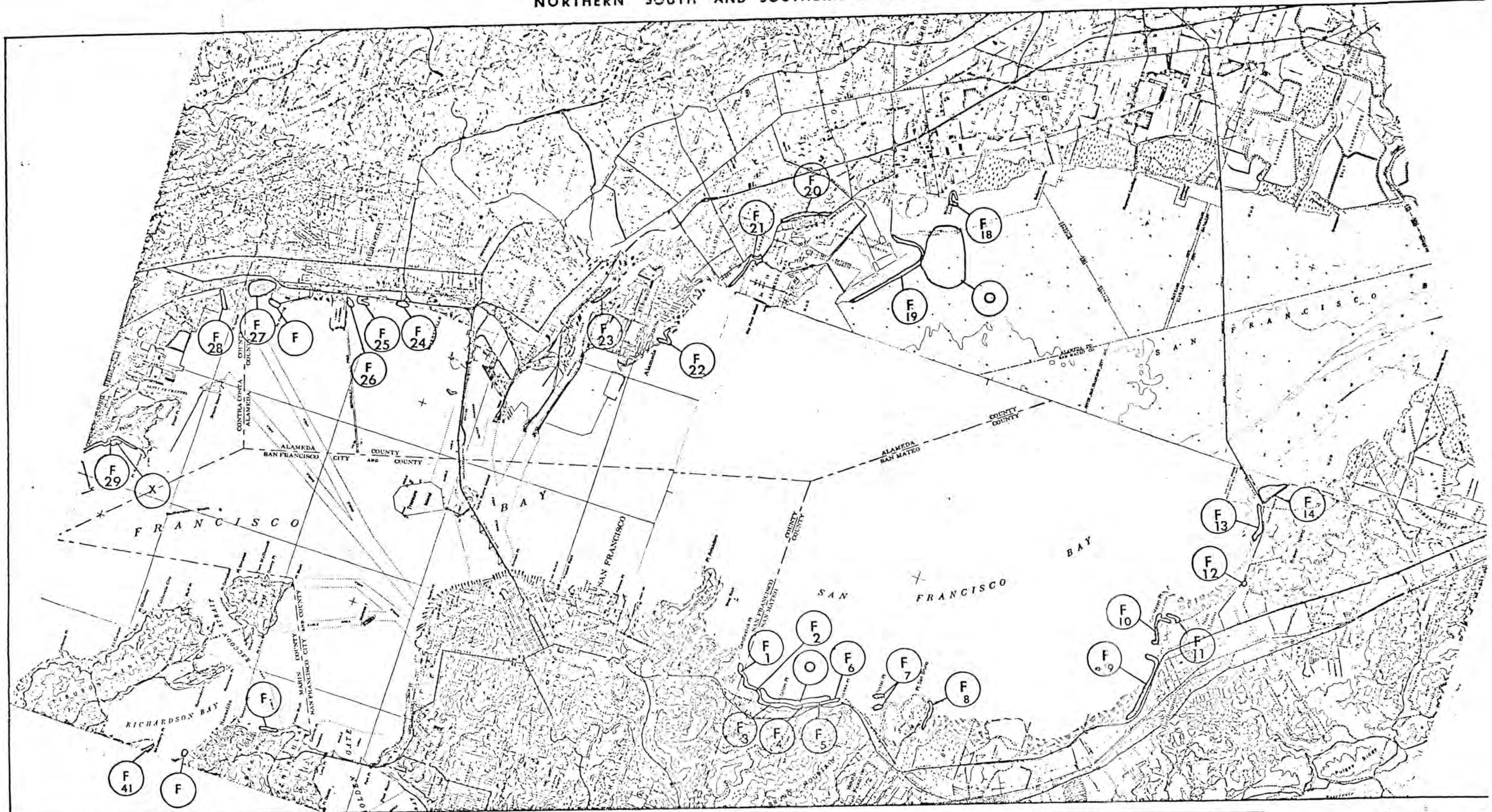


PLATE 5

NORTHERN SOUTH AND SOUTHERN CENTRAL BAY



Areas of distinct shellfish and native oyster beds in intertidal areas as well as Eelgrass bedding.

F 96 — SHELLFISH

O — OYSTER

X — EELGRASS

PLATE 6

SAN PABLO BAY AND WEST SUISUN BAY

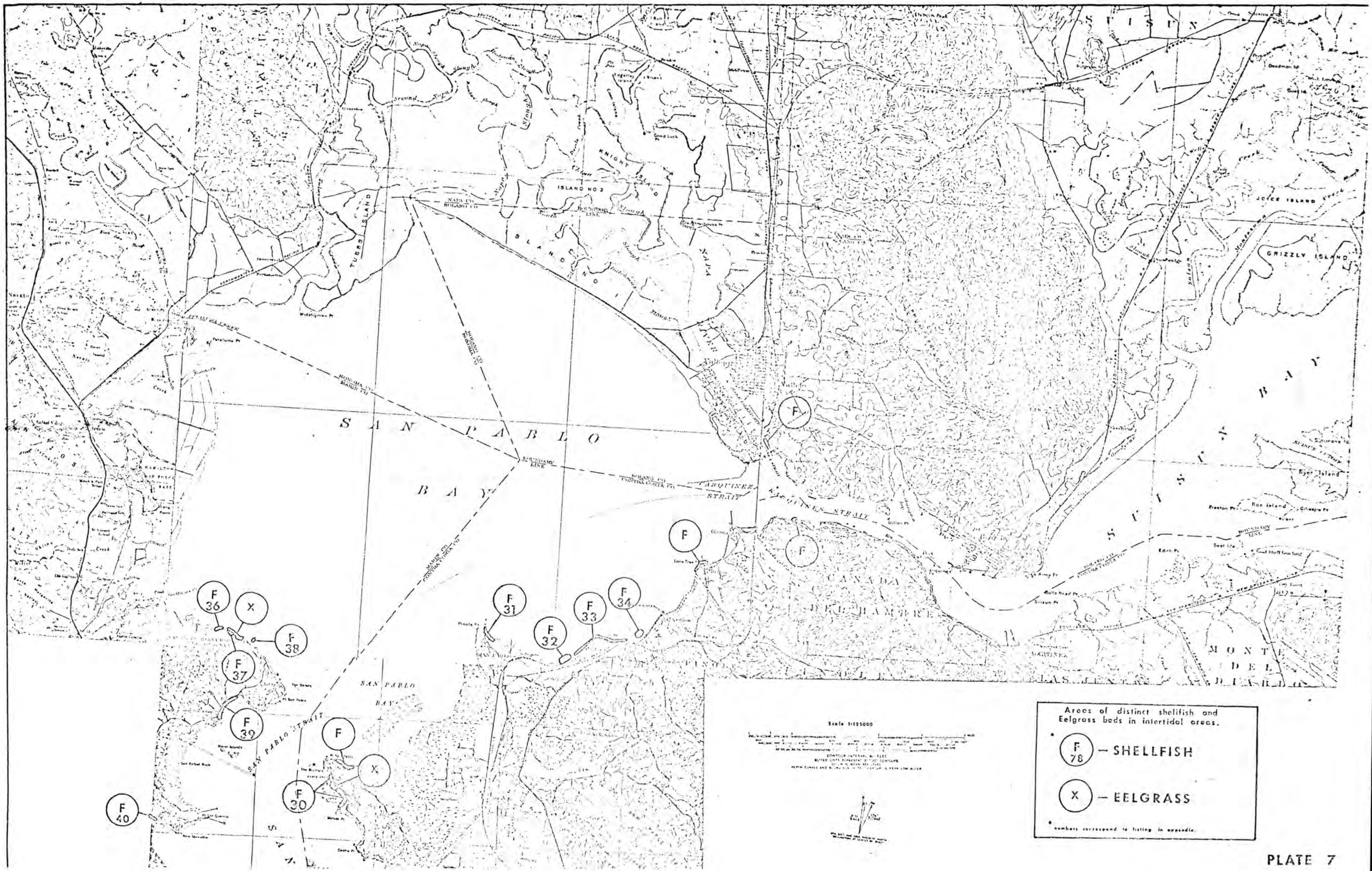


PLATE 7

Index to Plates 5 & 6 and estimates of adult soft-shell and littleneck clams in San Francisco and San Pablo Bay clam beds and presence or absence of native oysters. (Wooster 1968)

			SOFT-SHELL CLAMS		LITTLENECK CLAMS		
	Area of bed in sq. ft.	Sq. ft. sampled	Mean no./sq. ft. of sample	Est. of Total	Mean no./sq. ft. of sample	Est. of Total	Live native oysters present
*1. Candlestick Point	500	1	0	0	1.0	500	Yes
2. Bayview Park, northeast	176	2	1.5	264	1.0	176	Yes
3. Bayview Park	19,008	1	3.0	57,024	2.0	38,016	No
4. Bayshore to the east	1,500	1	1.0	1,500		0	No
5. Visitation Valley, to the east	15,450	3	0	0		41,715	Yes
6. Brisbane, to the east	5,410	3	.02	104		2,750	Yes
7. Oyster Point	600	2	0	0		600	Yes
8. Pt. San Bruno, south side	17,880	6	2.2	38,640		22,880	Yes
9. Burlingame	249,984	19	2.7	664,128		312,270	Yes
10. Coyote Point, north	102,600	8	0.1	10,800		700,600	Yes
11. Coyote Point, south	78,000	3	0	0		78,000	Yes

Index to Plates 5 & 6 (continued)

			SOFT-SHELL CLAMS		LITTLENECK CLAMS		
	Area of bed in sq. ft.	Sq. ft. sampled	Mean no./sq. ft. of sample	Est. of Total	Mean no./sq. ft. of sample	Est. of Total	Live native oysters present
12. San Mateo Creek	± 1,000	1	+ 2	+ 2,000	0	0	No
13. West end of San Mateo Bridge, north	1,200	2	15.5	13,200	0	0	No
14. Foster City	798,912	13	0.2	150,438	3.3	2,609,312	Yes
15. Redwood Creek	18,000	6	5.0	9,000	.3	594	Yes
16. Dumbarton Bridge, west	1,872	2	2.0	3,744	6.0	11,232	No
17. Dumbarton Bridge, east	7,152	4	1.7	11,904	6.2	44,016	No
18. San Leandro Marina	41,400	4	7.7	318,780	0	0	No
19. Oakland Airport	84,000	6	0.1	10,080	0.2	20,160	Yes
20. San Leandro Bay	100,800	6	7.4	705,600.	3.8	383,040	Yes
21. Alameda Island, southwest	7,200	1	3.0	21,600	11.0	79,200	Yes
22. Alameda Memorial State Beach	17,357	6	0.1	1,000	6.7	116,910	Yes
23. Oakland Inner Harbor, (foot of Alice Street)	39,000	5	0	0	13.0	507,000	Yes
24. Emeryville, foot of Ashby Avenue	1,600	1	3.0	4,800	1.0	1,600	Yes

Index to Plates 5 & 6 (continued)

Location of bed	Area of bed in sq. ft.	Sq.ft. sampled	SOFT-SHELL CLAMS Mean no./sq. ft. of sample	Est. of Total	LITTLENECK CLAMS Mean no./sq. ft. of sample	Est. of Total	Live native oysters present
25. Berkeley, foot of Bancroft Way	22,800	14	2.1	48,600	1.0	42,960	No
26. Berkeley, foot of University Avenue	800	1	10.0	8,000	0	0	No
27. Albany Hill	3,780,000	12	3.2	12,096,000	0	0	No
28. Pt. Isqbel, north	1,104	2	14.0	15,456	1.0	1,104	Yes
29. Pt. Richmond	90,000	6	0.2	15,300	1.5	135,000	Yes
30. Castro Pt., Molate Pt., Pt. Orient and Pt. San Pablo	128,400	6	0	64,800	0	49,200	Yes
31. Pt. Pinole, north side	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
32. Tara Hills	48,000	6	6.8	326,400	0	0	No
33. Bed between Tara Hills and Pinole	61,500	4	1.4	86,100	0	0	No
34. Pinole	60,032	5	13.2	792,422	0	0	No
35. Rodeo	5,000	4	8.0	± 40,000	0	0	No
36. Gallinas Creek, south	2,328	2	6.5	15,132	0	0	No
37. Area between Gallinas Creek, south of, and Rat Rock area	1,120	2	15.0	16,800	0	0	No

Index to Plates 5 & 6 (continued)

	Area of bed in sq.ft.	Sq. ft. sampled	SOFT-SHELL CLAMS Mean no./sq. ft. of sample	Est of Total	LITTLENECK CLAMS Mean no./sq. ft. of sample	Est.of Total	Live native oysters present
38. Rat Rock area	2,000	2	8.0	16,000	0	0	No
39. San Rafael Bay	± 25,000	5	± 8.0	± 200,000	± 2	± 50,000	Yes
40. San Quentin	9,600	1	21.0	201,600	0	0	No
41. Strawberry Pt., west side	28,800	9	1.1	31,680	1.8	54,720	Yes
42. Richardson Bay, north end of Highway 101 Bridge	12,000	2	4.5	54,000	0.5	6,000	Yes
Total	5,889,085	203		16,052,896		5,309,555	

1/ Approximately 12 percent of the "Japanese littleneck clams" are native littneck clams and there also are an estimated several hundred gaper clams present.

2/ Several hundred native littleneck clams are also present.

* Number keyed to locations on maps in Plates 5 & 6.

APPENDIX A

FLORAL LIST OF SAN PABLO MARSHES

Low-Low Marsh

Spartina foliosa Trin. — Cord grass

Atriplex hastata L. — Fat Hen

A very succulent single individual of this genetic complex was observed near the outer limit of the *Spartina* colony near the Sonoma Creek bridge. This is both a very unusual occurrence and a very unusual variant of the plant.

High-Low Marsh

Spartina foliosa Trin. — Cord grass

Salicornia pacifica Standley — Pickleweed

Jaumea carnosa (Less.) Gray

Occasional across the marsh. Not as common in the north bay as southward. However it does get into the fresher waters of the marshes along the shores of Suisun Bay.

Low-High Marsh

Distichlus spicata (L) Greene — Salt grass

Not common in this community.

Salicornia pacifica Standl. — Pickleweed

Dominant plant with only a few scattered individuals of other plants listed.

Atriplex patula L. — Fat hen

This common name is used for both this and *A. hastata*.

A. hastata L.

Jaumea carnosa (Less.) Gray

Grindelia humilis H&A — Gum plant

Sometimes the name G. cuneifolia is used which is a later name. Not common in this community.

High-High Marsh

Distichlus spicata (L) Greene — Salt grass

Quite common at this level.

Salicornia pacifica Standl. — Pickle-weed

Dominant but with a fairly rich mixture from the peripheral haliphytes.

S. rubra — Red pickleweed

Atriplex patula L. — Fat Hen

A. hastata L. — Fat Hen

A. semibaccata R. Br. — Australian saltbush

Peripheral Halophytes and other weeds

Distichlus spicata (L) Greene — salt grass

Lolium perrene L. — English ryegrass

Hordeum murinum L. — Wild Barley

Munz follows Govas in regarding this as H. Stebbinsii on n-7.

Bromus maritimus (Piper) Hitchc.

Avena fatua L. — Wild oat

Rumex occidentalis Wats. — Western dock

Atriplex hastata L. — Fat Hen

A. patula L. — Fat Hen

A. semibaccata — Australian salt-bush

Salicornia pacifica — Pickleweed

Salicornia rubra Nel. (S. europea of Munz) — Red pickleweed

Foliage a deep red in the fall (Tolay creed)

Beta vulgaris L. — common beet

escaped from cultivation

Foeniculum vulgare Mill. — Sweet fennel

Plantago Major L. — Common plantain

Scrophularia californica C&S — California figwort

This appears to be a salt tolerant race first reported by Jepson and seemingly confined to the north shore of San Pablo Bay. We have seen it actually in the high-high marsh. (Tolay Cr)

Senecio vulgaris L. — Common groundsel

Appendix B

Floral List of Suisun Marshes

(Not all plants have common names)

Typhaceae Cat-tail family.

Typha angustifolia L Narrow-leaved cat-tail

T. domingensis Pers.

T. glauca Godron.

T. latifolia (our most common cat-tail.) Broad-leaved cat-tail.

Potomogetonaceae Pondweed family

Potomogeton pectinatus L. Sego pondweed

Ruppiaceae Ditchgrass family

Ruppia maritima Ditch grass

Zannichelliaceae Zannichellia family

Zannichellia palustris L

Juncaginaceae Arrow weed family

Triglochin maritimum L.

T. striata Ruiz & Pavon

Gramineae Grass family

Agrostis alba L.

Arundo donax Giant Reed

Bromus hordeaceous L. Soft cheat

B. rigidus Roth. Ripgut

Digitaria sanguinalis (L) Scop.

Dactylus glomeratus L Orchard grass

Distichlus spicata (L) Greene Salt grass

Elymus tritichoides Buchl. Creeping wild rye

Festuca rubra L. Red fescue

Hordeum jubatum L. Foxtail barley

H. murinum L. Wild barley

Leersia oryzoides (L) Swartz Rice cut-grass

Leptochloa fascicularis (Lam) Gray bearded sprangle top

Phalaris Lemmonii Vasey Lemmons canary grass

P. californica H&A California canary grass

P. arundinacea L. Reed canary grass

Phragmites communis Trin. common reed

Polypogon elongatus H.B.K. Ditch polypogon

P. interuptus H.B.K.

P. monspeliensis (L) Desf. Rabbits foot polypogon

Setaria lutescens (Weig.) Hubb yellow bristle-grass

Sorghum halepensis Pers. Johnson grass

(This list of grasses is by no means complete.)

Cyperaceae Sedge family

Carex barbarae Dewey

Cyperus eragrostis Lam

Scirpus acutus Muhl ex Bigel. tule; viscid bullrush

S. AcutúsX californicus a natural hybrid known only from Suisun Bay area

S. californicus (C.A. Mey.) Steud. California bullrush; C. Tule.

S. koilepis Steud

S. Olneyi Gray Olney's bullrush

S. robustus Pursh Alkali bullrush

Juncaceae Sedge family

Juncus acutus var. sphaerocarpum Englm.

J. balticus Willd. Baltic rush

J. effusus var. pacificus Fern & Wieg.

Salicaceae Willow family

Salix lasiolepis Benth Arroyo willow

Betulaceae Birch family

Alnus rhombifolia Nutt. white alder

Urticacea nettle family

Urtica holosericea Nutt common nettle

Polygonaceae Buckwheat family

Polygonum argyrocoleon Steud ex Kuntz Persian wire weed

P. aviculare L. wire grass

P. coccinoum Muhl. ex Willd. Red knotweed

P. natans (Michx.) Eaton Floating knotweed

P. pennsylvanicum L. pinkweed

Rumex acetosella L. Sheep sorrel

R. crispus L Curley leaved dock

R. fenestratus Greene

R. occidentalis Wats. Western cock

R. salicifolius Weinem. Willow leaved dock

R. transitorius Rech.

Chenopodiaceae Goosefoot family

Atriplex hastata Gray

A. nummularia Lindl

A. semibaccata R.Br. Australian saltbush

Beta vulgaris L. common beet

Chenopodium album Lamb's quarters

C. murale L.

C. ambrosioides L. Mexican tea

Salicornia pacifica Standley common pickleweed

Salsola kali L.

Sueda fruiticosa (L) Forsk

Aizoaceae Mesembryanthemum family

Mesembryanthemum equalaterale Haw. sea fig.

Sesuvium sessile Pers.

Caryophyllaceae Chickweed family

Spergularia macrotheca Heynh.

S. marina (L) Griseb.

Cruciferae Mustard family

Lepidium draba L. Pepper grass

Rosaceae Rose family

Potentilla pacifica Howell

Rubus procerus Muell Hymalayan blackberry

Leguminoseae Pea family

Lathyrus Jepsonii Greene Delta sweet pea

Melilotus alba Desv. ex Lam. White sweet clover

M. indica (L) All Indian melilot

Psoralea macrstachya D.C. California hemp

Trifolium variegatum Nutt

Malvaceae Mallow family

Malva borealis Bull mallow

Frankeniaceae Frankenia family

Frankenia grandifolia Chem. & Schl.

Tamaricaceae Salt tree family

Tamarix aphylla (L)Karst. salt tree

Myrtaceae Myrtle family

Eucalyptus sp.

Lythraceae

Ammania auriculata Willd.

Lythrum californicum T & G

Onagraceae Evening primrose family

Epilobium californicum Haus.

E. Watsoni Barbey

Oenothera Hookeri T. & G.

Umbelliferae Carrot family or parsley family

Apium graveolens L. celery

Cicuta Bolanderi Wats. Poison hemlock

Conium maculatum L. Also called poison hemlock

Foemiculum vulgare Mill Sweet fennel

Hydrocotyle umbellata L

H. verticellata Thunb.

Lilaeopsis Masoni ined

Oenanthe sarmentosa Presl

Primulaceae Primrose family

Anagalis arvensis L. common pimpernel

Samolus floribundus H.B.K

Plumbaginaceae Plumbago family

Limonium commune var. Californicum (Gray) Greene

Apocynaceae Dogbane family

Apocynum cannabinum L. Indian hemp

Convolvulaceae Morning glory family

Convolvulus sepium marsh morning glory

Cuscuta salina Endelm. Dodder

Verbenaceae Verbena family

Lippia nodiflora (L) Michx.

Labiatae mint family

Mentha pulegium L. Pennyroyal

Stachys ajugioides Benth

S. Albens Gray

Solanaceae Nightshade family

Solanum nigrum L black nightshade

Scrophulariaceae figwort family

Cordylanthus mollis Gray

Limosella subulata Ives

Mimulus guttatatus Fish. ex D.C. monkey flower

Scrophularia californicum C.&S.

Plantaginaceae Plantago family

Plantago lanceolata L English plantain

P. major L. common plantain

Compositae Sunflower family

Achillea borealis ssp californica (Pollard)Keck Yarrow

Anthemis cotula L Mayweed, dog fennel

Artemisia douglasiana Bess.

Aster chilensis var. lentus (Greene) Jepson

A. exilis Ell

Baccharis pillularis D.C. Coyote bush

B. viminea D.C.

Cirsium hydrophyllum (Greene) Petrak marsh thistle

C. Lanceolatum (L) Scop. Bull thistle

Cotula coronopifolia L Brass buttons

Gnaphalium chilense Spreng Cotton batting plant

Grindelia humulis H & A

Helenium Bolanderi Gray

Helianthus Nuttallii T.&G. Wild sunflower

Jaumea carnosa (Less) Gray

Lactuca scariola L Prickley lettuce

Lasthenia conjugans (F.&B.) Greene

Picris echioides L. Bristly ox tongue

Senecio sp.

S. vulgaris L. common groundsel

Silybum marianum Gaertn. milk thistle

Solidago occidentalis (Nutt) T.&G. Western goldenrod

Xanthium pennsylvenicum Wallr. Cocklebur

X. spinosum L. Spiny cocklebur.

Because of the earliness of the season when this work had to be undertaken and the short time involved for its completion, the above list is far from complete. The time for botanical work in marshes is late summer and early fall. We suspect that this list contains about 75% of the total. It includes our current working list for Suisun Bay. There will be only a very few of them not in Suisun Marsh.

Appendix C

Rare, endangered, and unique vertebrates of the San Francisco Bay Estuary

San Francisco Bay provides critical habitat for seven avian and one mammalian species officially classified as either rare or endangered by both the U. S. Fish and Wildlife Service (1973) and the California Department of Fish and Game (1973).

The following lists the classification of the species, its distribution within San Francisco Bay, critical nesting and/or feeding areas, and its relative abundance within the Bay area.

CALIFORNIA CLAPPER RAIL (*Rallus longirostris obsoletus*).
Classified as endangered by both the U.S. Fish and Wildlife Service and the California Department of Fish and Game. The California clapper rail is an endemic rail of the tidal marshes of San Francisco Bay, excluding Suisun Marsh and the marshes of the north shore of Contra Costa County. A small breeding population exists at Elkhorn Slough, Monterey County. Within San Francisco Bay the California clapper rail is distributed as follows:

Current Distribution

Within its present range, the California clapper rail occupies approximately 5,813 ha (14,363 acres) of estuarine marsh. This represents only 15% of the historic clapper rail habitat. The California clapper rail is now apparently extinct as a breeding species from Humboldt County and Morrow Bay, San Luis Obispo County (Wilbur and Tomlinson 1976; Yocum and Harris 1975). Several unconfirmed reports of this species from both areas in recent years indicate that obsoletus may still occur there, but most likely as vagrants.

San Francisco County

No resident population exists. Virtually all estuarine marsh has been eliminated.

San Mateo County

Resident and breeding in fringing Bay marshes from south San Francisco, south to the county line near Palo Alto. Greco Island, Bird Island and marshes bordering Redwood Creek, Bair Island, Westpoint, Corkscrew, Smith, Steinberger and Belmont Sloughs plus marshes south of Cooley Landing provided most of the remaining habitat. Small marshes near San Bruno Point and Burlingame support small, but stable populations.

Habitat is limited to 809 ha (2,000 acres) of which 771 ha (1921 acres) is presently occupied by obsoletus. With the proposed marsh restoration projects on Bair Island, an additional 250 ha of rail habitat will be available for future colonization.

Santa Clara County

Major populations are found within the marshes of the Palo Alto Baylands Nature Center, at the mouth of Charleston Slough, and along the larger fringing marshes of Guadalupe and Alviso Sloughs. Also present from the mouth of Alviso Slough, east to the old town of Drawbridge. Breeding is not known east of Drawbridge, however, several winter sightings have come from this area. Estuarine marsh is limited to approximately 688 ha (1700 acres) of which 421 ha (1,040 acres) is utilized by obsoletus.

Alameda County

Presently found in numbers along all fringing marsh from Mud Slough to the Dumbarton Bridge, including Mowry Slough, Newark Slough, and the estuarine marshes of Plummer Creek. Present again from approximately 1 km north of the Dumbarton Bridge to the mouth of Mt. Eden Creek. Absent from the recently created Alameda Flood Control channel, but can be expected to colonize this area once suitable habitat develops. North of Mt. Eden Creek populations area limited and confined to San Leandro Bay (Arrowhead Marsh), Alameda South Shore, and Emeryville marshes. Tidal marsh is restricted to approximately 1214 ha (3,000 acres). California clapper rails presently occupy 1095 ha (2,707 acres).

Contra Costa County

Remnant breeding populations continue within the marsh areas between Wildcat and San Pablo Creeks. Occurs sporadically between San Pablo Creek and Point Pinole. Not known to occur as a breeding species elsewhere in the county. Gill considers recent sightings (L. Farrar, Pers. comm.) from West Pittsburg (7 March 1964) and Frank's Tract (5 September 1963) to be dispersing young or wandering adults from possibly Southhampton Bay, but more likely the Napa Marsh. Tidal marsh is limited to 809 ha (2,000 acres), including marshes fronting the Carquinez Straits. Obsoletus is presently restricted to less than 252 ha (624 acres).

Solano County

Resident and breeding from those portions of Dutchman, South, and China Sloughs within Solano County. Similarly found from the mouth of White Slough and fringing marshes from approximately ½ km south of the Vallejo Bridge, north to Slaughterhouse Point. Apparently absent from the broad Salicornia marsh fronting San Pablo Bay. There have been no records of obsoletus from Southhampton Bay since 1958 and the species is no longer throught to breed there. Tidal marsh within the county is restricted to approximately 1963 ha (4,852 acres). Obsoletus is known to inhabit approximately 458 ha (1,131 acres).

Napa County

Presently a common breeding species along Devil, South, China, Napa, Mud, Fagan, and Steamboat Sloughs. Also occurs within marshes from Fly Bay, Coon and Edgerly Island and along the marshes of the Napa River from the county line to Bull Island. Obsoletus was found to occupy approximately 916 ha (2,271 acres) of the existing 1012 ha (2,500 acres) of tidal marsh within the county.

Sonoma County

Present and breeding from Napa, Hudeman, Steamboat, and Second and Third Napa Sloughs. Also occurs, but in reduced numbers, along Sonoma Creek to Wingo and along the Petaluma River to Schulz Creek. Last reported as a breeding bird from lower Tubbs Island in 1971. Apparently absent from upper Tolay Creek. Estuarine marsh is limited to approximately 1619 ha (4,000 acres). Obsoletus was found to occupy approximately 1375 ha (3,397 acres).

Marin County

Occurs abundantly within the Bay marshes from the mouth of Novato Creek, south to the mouth of Gallinas Creek and Miller Creek and upstream approximately ½ km. Present, but in reduced numbers from the mouth of Corte Madera Creek, upstream to State Highway 101, and San Rafael Creek upstream to the power lines. Apparently absent from Richardsons Bay.

The last sighting from this area was in 1967 (Chandik 1967). There have been two sightings from coastal Marin County since 1970 (DeSanta 1970; P. Henderson, pers. comm.). Habitat is restricted to approximately 728 ha (1,800 acres) of which 319 ha (788 acres) was found occupied by obsoletus.

Gill feels the current distribution of the California clapper rail is limited by the following: (1) tidally influenced salt marsh outboard of existing levees, (2) presence of a network of small tidal sloughs, and (3) the presence of an abundant invertebrate fauna; including in various combinations, but not limited to: Modiolus demisse, Macoma balthica, Hemigrapus oregonensis, and Pachygrapus crassipes. Gill has not found the California clapper rail breeding in any marsh lacking the above.

Potential Range Expansion

The California clapper rail can be expected to colonize areas of former tidal marsh which are now being or will be restored. Changes from historic distribution will probably be limited to the Suisun Marsh, marshes along the north shore of Contra Costa County, and the Sacramento-San Joaquin Delta. Bay wide population figures for the California clapper rail are not available. Gill (1973) estimated approximately 2,500 individuals for south San Francisco Bay. Recent work in the Napa Marsh area of San Pablo Bay suggests that a similar number inhabit these areas.

CALIFORNIA BLACK RAIL (Laterallus jamicensis corturniculus).

Classified as rare by the California Department of Fish and Game. This is a small, sparrow sized rail which prefers pickleweed marshes. It is generally considered a winter resident of San Francisco Bay, with breeding occurring in southern California. No confirmed breeding records are available from the Bay area. However, several recent sightings during May from the San Pablo Bay area suggest that a small breeding population might occur in the Bay area. Winter sightings from San Francisco Bay indicate that this species is found throughout the major pickleweed marshes. Critical wintering areas are: Mowry Slough - Dumbarton Bridge, Alameda County; Triangle marsh, Santa Clara County; Corkscrew Slough - Belmont Slough, San Mateo County; Corte Madera marsh, Marin County; Southampton Bay, Joice Island, Grizzly Island, in Solano County. A winter census in 1973-1974 produced sightings of 38 birds, mostly from the above area. Several sightings have been reported since. Most of these from the Southampton Bay area of Solano County.

AMERICAN PEREGRINE FALCON: (Falco peregrinus anatum). Classified as endangered by both U. S. Fish and Wildlife Service and the California Department of Fish and Game. The species is extinct as a breeding species east of the Rocky Mountains. The 1975 California breeding population is thought to be less than 10 pairs. (Mallette pers. comm.) Historical nesting occurred near the Dumbarton Bridge, Alameda County (Sibley 1952). No breeding occurs within the immediate San Francisco Bay area. Presently occurs within the Bay area as a winter visitor. Recently reported near Redwood City, San Mateo County in Jan '74; Suisun Marsh on 11-'75 and 1-'76; Napa Marsh on 10-'75; and near Corte Madera on 9-'75.

SOUTHERN BALD EAGLE (Haliaeetus leucocephalus leucocephalus). Classified as endangered by both the U. S. Fish and Wildlife Service and the California Department of Fish and Game. This bird is usually seen in the Bay area in winter and even then it seldom is found near salt marshes. The state wide breeding population is estimated at less than 25 pairs.

CALIFORNIA BROWN PELICAN (*Pelecanus occidentalis californicus*) Classified as endangered by both the USF&WS and the California Department of Fish and Game. This subspecies occurs on the Pacific Coast from Canada to Mexico. It nests on the Channel Islands off of southern California and on the coastal islands of lower California. Occurs in the San Francisco Bay area in early fall and through mid winter as does the Baja California race. Occurs within the Bay from extreme south San Francisco Bay to upper San Pablo Bay. Numbers are concentrated in the central parts of the Bay and along the outer coastal areas.

CALIFORNIA LEAST TERN (*Sterna albifrons browni*). Classified as endangered by both the USF&WS and the California Department of Fish and Game. Smallest of the terns. A summer resident from April through September in the Bay area. Winters in the southern hemisphere. Known to breed on Bair Island, San Mateo County and on Bay Farm Island, Alameda. These represent the northern most breeding areas for this species. During the 1975 breeding season an estimated 14 pairs nested on Bair Island while and additional 14 pairs nested on Bay Farm Island (Jurek, pers. comm.). Known to wander throughout the Bay after the breeding season. Areas adjacent to the nesting areas appear to be critical feeding areas. The state wide population is estimated at 600 pairs.

ALEUTIAN CANADA GOOSE (*Branta canadensis leucoparia*). Classified as endangered by the U. S. Fish and Wildlife Service. A small goose similar in size and coloring to the cackling canada goose. Difficult to distinguish in the field. Breeds on Buldir Island in the Aleutian chain. During the winter of 1975-1976 a flock of 38 birds resided on the Grizzly Island State Wildlife Area in the Suisun Marsh. Other wintering areas within the Bay area are not known.

SALT MARSH HARVEST MOUSE (Reithrodontomys raviventris).
Classified as endangered by both the USF&WS and the California Department of Fish and Game. This is one of the few endemic mammals of the San Francisco Bay area. It is restricted to salt marsh habitat both outboard and behind levees and is found most frequently associated with a narrow strip of vegetation along levees and is found most frequently associated with a narrow strip of vegetation along levees. Two subspecies have been differentiated within the Bay, R. r. halicoetes in the northern and eastern regions of the Bay, and R. r. raviventris in the central and south Bay. Major populations in Santa Clara County exist within Triangle Marsh, New Chicago Marsh, along the fringing marshes of Alviso and Charleston Sloughs, and at the Palo Alto Baylands marsh. Within Alameda County found at Drawbridge, Ideal Marsh and Albrae Slough. Found on Bird, Bair, Greco Islands and the Belmont Slough within San Mateo County. Populations exist along the north and south sides of Gallinas Creek, Novato Creek, and Corte Madera Creek. In Solano County found at the Figueros tract near Mare Island, along the marshes adjacent to Mare Island, White Slough, and along the Leslie Salt intake east of Sonoma Creek. Major populations exist within the Suisun Marsh and along the marshes of the north shore of Contra Costa County. In Sonoma County found at Tubbs Island, along Sonoma Creek and the Petaluma River. Not known how far up Petaluma River populations exist. Known from Napa County on Coon Island, Fly Bay, and adjacent marshes.

The following are considered unique vertebrate species to the San Francisco Bay estuary.

SALT MARSH SONG SPARROW: Three races of song sparrow (Melospiza melodia) occur only in the tidal marshes of the San Francisco Bay region: Alameda Song Sparrow (M. m. pusillula). Samuel's Song Sparrow (M. m. samuelis), and Suisun Song Sparrow (M. m. maxillaris). The Alameda race occurs in salt marshes of the south arm of San Francisco Bay; the Samuel's song sparrow is found in the salt marshes of San Pablo Bay; and the Suisun race is restricted to the salt and brackish marshes bordering Suisun Bay. While none of these races is presently classified as rare or endangered, the loss of habitat around the Bay has caused the disappearance of all three races from portions of their former range. All three races are presently being studied to determine if an "endangered status" is warranted.

SALT MARSH YELLOWTHROAT (Geothlypis trichas sinuosa).
This small warbler is limited in distribution to the salt and brackish marshes bordering San Francisco and San Pablo Bays. Freshwater marsh areas adjacent to these areas are also critical as breeding areas. Elimination of former marshland and the continual alteration of existing habitat has changed the status of the race. It is being studied to update its status.

SUISUN SHREW (Sorex sinuosus).
This small mammal is limited in distribution to the Suisun Bay Marshes and more specifically to Grizzly Island. While not presently recognized as endangered, rare, or threatened, its limited distribution and narrow habitat requirements dictate special management and land use planning considerations.

Appendix D

I. Demersal Fish of the N. San Francisco Bay-San Pablo Bay Area (Fish and Wildlife Ser., 1970)

Scientific Name	
AGNATHA	
PETROMYZONTIFORMES	
Petromyzontidae	
Lamperta tridentata	Pacific lamprey
CHONDRICHTHYES	
SQUALIFORMES	
Carcharhinidae	
Squalos acanthias	Spiny dogfish
Triakis henlei	Brown smoothhound
Triakis semifasciata	Leopard shark
RAJIFORMES	
Rajidae	
Raja binoculata	Big skate
CADIFORMES	
Gadidae	
Microgadus proximus	Pacific tomcod
GASTEROSTEIFORMES	
Syngnathus griseolineatus	Bay pipefish
PERCIFORMES	
Scianenidae	
Genyonemus ineatus	White croaker

Embiotocidae	
Cymatogaster aggregata	Shiner perch
Hyperprosopon argenteum	Walleye surfperch
Hypsurus caryi	Rainbow seaperch
Phanerodon furcatus	White surfperch
Rhacochilus toxotes	Rubberlip perch
Rhacochilus vacca	Rile Perch
Gobiidae	
Acanthogobius flavimanus	Japanese goby
Scorpaenidae	
Sebastodes auriculatus	Brown rockfish
Sebastodes malanops	Black rockfish
Hexagrammidae	
Ophiodon elongatus	Lingcod
Cottidae	
Hemilepidotus hemilepidotus	Red Irish lord
Leptocottus armatus	Staghorn sculpin
Cyclopteridae	
Liparis pulchellus	Showy snailfish
Pholidae	
Pholis ornata	Saddleback gunnel

PLEURONECTIFORMES

Pleuronectidae

Citharichthys stigmaeus	Speckled sanddab
Hyposopsetta guttulata	Diamond turbot
Parophrys vetulus	English sole
Platichthys stellatus	Starry flounder
Symphurus atricauda	California tonguefish

BATRACHOIDIFORMES

Batrachoididae

Porichthys notatus	Northern midshipman

II. Marine Fish of the Greater San Francisco Bay

AGNATHA	
PETROMYZONTIFORMES	
Petromyzontidae	
Lamperta tridentata	Pacific lamprey
CHONDRICHTHYES	
SQUALIFORMES	
Caracharhinidae	
Squalos acanthias	Spiny dogfish
Triakis henlei	Brown smoothhound
Triakis semifasciata	Leopard shark
RAJIFORMES	
Rajidae	
Raja binoculata	Big skate
OSTEICHTHYES	
CLUPEIFORMES	
Clupeidae	
Clupea harengus pallasi	Pacific herring
Engaulis mordax	Northern anchovy
Osmeridae	
Spirinchus thaleichthys	Sacramento smelt
Spirinchus starksi	Night smelt
Hypomensus pretiosis	Surf smelt
Allosmerus elogatus	White bail smelt

Atherinopsis affinis	Jack smelt
Atherinopsis argenteum	Top smelt
CADIFORMES	
Gadidae	
Microgadus proximus	Pacific tomcod
GASTEROSTEIFORMES	
Syngnathidae	
Syngnathus griseo-lineatus	Bay pipefish
Sciaenidae	
Genyonemus lineatus	White croaker
Embiotocidae	
Cymatogaster aggregata	Shiner perch
Hyperprosopon argenteum	Walleye surfperch
Hypsurus caryi	Rainbow seaperch
Phanerodon fureatus	White surfperch
Rhacochilus toxotes	Rubberlip perch
Rhacochilus vacca	Pile perch
Amphistichus argenteus	Barred surfperch
Embiotoca jacksoni	Black perch
Gobiidae	
Acanthogohius flavimanus	Japanese goby
Lepidogobius lepidus	Bar goby
Scorpaenidae	
Sobastodes auriculatus	Brown rockfish
Sobastodes melanops	Black rockfish
Hexagrammidae	
Ophiodon elongatus	Lingcod

Cottidae

Hemilepidotus hemilepidotus	Red Irish lord
Leptocottus aramatus	Staghorn sculpin

Cyclopteridae

Liparis pulchellus	Showy snailfish

Pholidae

Pholis ornata	Saddleback gunnel

PLEURONECTIFORMES

Pleuronectidae

Hyposopsetta guttulata	Diamond turbot
Parophrys vetulus	English sole
Psettichthys melanostictus	Sand sole
Lyopsetta exilis	Slender sole
Paralichthys californicus	California halibut
Platichthys stellatus	Starry flounder
Symphurus atricauda	California tonguefish

Bothidae

Citharichthys sordidus	Pacific sand dab
Citharichthys stigmaeus	Speckled sand dab

BATRACHOIDIFORMES

Batrachoididae

Porichthys notatus	Northern midshipman

ANACANTHINI

Merlucciidae

Merluccius productus	Pacific hake

SYNENTOGNATHI

Scomberescocidae

Cololabis saira	Pacific saury

STROMATEOIDEA

Stromateidae

Peprilus smillimus	California pompano

III. Anadromous Fish

Green Sturgeon	Acipenser medirostris
Pacific Lamprey	Entosphenus tridentatus
River Lamprey	Lampetra fluviatilis
White Sturgeon	Acipenser transmontanus
*American Shad	Alosa sapidissima
King Salmon	Oncorhynchus tshawytscha
Steelhead Rainbow Trout	Salmo gairdneri gairdneri
Striped Bass	Roccus saxatilus
Silver (Coho) Salmon	Oncorhynchus kisutch
Pink Salmon	Oncorhynchus gorbuscha (uncommon)
Chum Salmon	Oncorhynchus keta
Red Salmon	Oncorhynchus nerka

*Introduced

Appendix E – I

MARIN COUNTY COMMERCIAL FISH LANDINGS
POUNDS AND VALUE* FOR YEARS 1969 - 1973

SPECIES	1969	1970	1971	1972	1973
ANCHOVY	95,099	217,720	318,688	360,727	795,544
Value	$ 8,559	$ 21,772	$ 35,056	$ 28,767	$ 67,081
Average Price	.090	.100	.110	.080	.084
CRAB, MARKET (lbs.)	252,252	158,029	44,446	26,487	18,418
Value	$ 98,727	$ 54,708	$ 17,805	$ 18,074	$ 17,643
Average Price	.391	.346	.401	.682	.958
FLOUNDER	33,580	--	--	1,605	4,123
Value	$ 2,199	--	--	$ 199	$ 354
Average Price	.065	--	--	.074	.086
HALIBUT, CALIF. (lbs.)	6,492	61	240	--	22
Value	$ 1,654	$ 17	$ 70	--	$ 11
Average Price	.255	.279	.292	--	.491
HERRING, PACIFIC (lbs.)	26,432	7,425	18,636	21,700	1,691,319
Value	$ 6,872	$ 2,290	$ 6,597	$ 13,758	$ 55,963
Average Price	.260	.308	.354	.634	.033
LINGCOD (lbs.)	24,176	3,489	3,346	3,683	6,227
Value	$ 1,894	$ 283	$ 276	$ 337	$ 618
Average Price	.078	.081	.082	.091	.099
OYSTER, EASTERN (lbs.)+	16,952	16,667	13,852	9,028	1,148
Value	$ 50,258	$ 49,001	$ 40,725	$ 26,543	$ 4,018
Average Price	2.96	2.94	2.940	2.940	3.500
OYSTER PACIFIC (lbs.)+	222,844	219,135	198,385	95,555	144,963
Value	$ 51,811	$197,222	$172,594	$ 83,132	$166,707
Average Price	.232	.900	.870	.870	1.150
PERCH (lbs.)	8,563	8,438	1,991	6,753	12,478
Value	$ 3,111	$ 2,859	$ 714	$ 2,333	$ 4,798
Average Price	.363	.339	3.359	.345	.384
ROCKFISH (lbs.)	64,838	1,133	8,478	44,539	85,006
Value	$ 4,564	$ 98	$ 593	$ 2,665	$ 8,016
Average Price	.070	.086	.070	.060	.094

(continued)

*Value based on price paid fishermen.

+Packed gallon weight.

Source: California Department of Fish and Game

(E— I)
MARIN COUNTY (cont'd)

SPECIES	1969	1970	1971	1972	1973
SABLEFISH (lbs.)	6,540	-	5,657	63,266	229,398
Value	$ 345	-	$ 287	$ 4,500	$ 17,815
Average Price	.053	-	.051	.071	.078
SALMON (lbs)	538,133	485,212	665,595	452,753	413,851
Value	352,179	$ 394,778	453,928	366,978	430,460
Average Price	.654	.814	.682	.810	1.040
SANDDAB (lbs.)	21,970	-	-	600	3,059
Value	$ 2,022	-	-	$ 70	$ 438
Average Price	.092	-	-	.117	.143
SHARK (lbs.)	11,342	800	6,940	-	3,025
Value	$ 778	$ 25	$ 418	-	$ 205
Average Price	.068	.031	.060	-	.068
SHRIMP, BAY (lbs.)	67,036	46,743	43,090	71,402	61,176
Value	$ 72,514	$ 50,713	$ 61,398	$ 113,433	$ 112,501
Average Price	1.082	1.085	1.425	1.589	1.839
SMELT (lbs)	2,871	4,113	7,799	2,474	1,095
Value	$ 323	$ 603	$ 1,008	$ 418	$ 186
Average Price	.112	.147	.129	.169	.170
SOLE, DOVER (lbs.)	20,803	-	16,806	364,656	324,079
Value	$ 1,375	-	$ 1,232	$ 29,969	$ 33,321
Average Price	.066	-	.073	.082	.103
SOLE, ENGLISH (lbs.)	100,050	-	-	410	3,972
Value	$ 8,495	-	-	$ 47	$ 588
Average Price	.085	-	-	.114	.148
SOLE, PETRALE (lbs.)	57,395	-	2,626	30,088	9,404
Value	$ 8,409	-	$ 429	$ 4,920	$ 1,822
Average Price	.146	-	.163	.164	.194
SOLE, REX (lbs.)	17,115	-	-	927	6,591
Value	$ 1,633	-	-	$ 115	$ 990
Average Price	.095	-	-	.124	.150
SOLE, SAND (lbs.)	13,675	-	-	945	578
Value	$ 1,589	-	-	$ 122	$ 96
Average Price	.116	-	-	.129	.165
TUNA, ALBACORE (lbs.)	312,828	1,639,037	2,646,312	1,084,107	212,256
Value	$ 62,685	$ 423,269	$ 779,604	$ 347,641	$ 84,444
Average Price	.200	.258	.295	.321	.398
TURBOT (lbs.)	1,686	-	-	-	480
Value	$ 83	-	-	-	$ 33
Average Price	.049	-	-	-	.068
ALL OTHERS (lbs.)	3,722	-	4,042	2,120	5,199
Value	$ 181	$ -	$ 251	$ 209	$ 403
Average Price	.049	-	.062	.099	.077
TOTAL:					
Pounds	1,926,394	2,808,002	4,006,929	2,643,825	4,033,411
Value	$ 742,260	$1,197,638	$1,572,985	$1,044,150	$1,008,511

APPENDIX E - II
SAN FRANCISCO COUNTY
COMMERCIAL FISH LANDINGS AND SHIPMENTS
POUNDS AND VALUE* FOR YEARS 1969 - 1973

SPECIES	1969	1970	1971	1972	1973
CRAB, MARKET (lbs.)	616,077	427,867	184,587	166,139	163,990
Value	$ 241,123	$ 148,123	$ 73,946	$ 113,369	$ 157,088
Average Price	.391	.346	.401	.682	.958
CROAKER, WHITE (lbs.)	6,370	4,345	3,311	18,701	38,982
Value	$ 393	$ 584	$ 365	$ 3,575	$ 8,566
Average Price	.062	.134	.110	.191	.220
FLOUNDER (lbs.)	114,805	92,284	79,207	215,082	84,794
Value	$ 7,518	$ 6,449	$ 5,624	$ 14,958	$ 7,276
Average Price	.065	.070	.071	.074	.086
GRENADIERS (lbs.)	-	-	-	-	3,825
Value	-	-	-	-	$ 191
Average Price	-	-	-	-	.050
HAKE, PACIFIC (lbs.)+	22,205	5,400	15,775	9,290	-
Value	$ 444	$ 108	$ 686	$ 228	-
Average Price	.020	.020	.043	.024	-
HALIBUT, CALIF. (lbs.)	48,530	71,217	23,307	51,267	21,173
Value	$ 12,369	$ 19,335	$ 6,796	$ 17,357	$ 10,402
Average Price	.255	.271	.292	.339	.491
HERRING, PACIFIC (lbs.)	900	21,915	-	108	419,331
Value	$ 234	$ 6,759	-	$ 68	$ 13,875
Average Price	.260	.308	-	.630	.033
LINGCOD (lbs.)	79,724	226,229	233,848	300,922	417,335
Value	$ 6,248	$ 18,347	$ 19,362	$ 27,522	$ 41,444
Average Price	.078	.081	.083	.091	.099
PERCH (lbs.)	19,134	30,964	36,872	27,858	18,782
Value	$ 7,031	$ 10,510	$ 13,137	$ 9,653	$ 7,206
Average Price	.367	.339	.356	.346	.384
ROCKFISH (lbs.)	375,235	623,087	820,844	1,059,645	2,426,679
Value	$ 27,695	$ 45,077	$ 60,516	$ 84,210	$ 235,049
Average Price	.074	.072	.074	.079	.097
SABLEFISH (lbs.)	172,313	290,760	526,141	825,610	1,062,155
Value	$ 9,083	$ 15,467	$ 26,675	$ 58,718	$ 82,483
Average Price	.053	.053	.051	.071	.078

(continued)

* Value based on price paid fishermen.

\+ Due to different reporting methods miscellaneous animal food appears as a sizable item beginning in 1961. Major species are arrowtooth flounder, hake, rockfish, sablefish and sole.

(E – II)
SAN FRANCISCO (Cont'd)

SPECIES	1969	1970	1971	1972	1973
SALMON (lbs.)	356,529	341,566	315,553	283,281	264,887
Value	$ 231,072	$ 278,621	$ 223,692	$ 230,870	$ 270,450
Average Price	.648	.816	.707	.815	1.021
SANDDAB (lbs.)	120,726	135,987	202,970	195,705	150,978
Value	$ 11,112	$ 14,119	$ 22,246	$ 22,823	$ 21,631
Average Price	.092	.104	.110	.117	.143
SHARK (lbs.)	20,700	42,453	20,155	32,689	32,379
Value	$ 951	$ 1,923	$ 1,026	$ 1,663	$ 2,645
Average Price	.046	.045	.051	.051	.082
SHRIMP, BAY (lbs.)	10,070	19,018	16,631	1,665	1,132
Value	$ 4,308	$ 25,341	$ 21,429	$ 2,423	$ 3,042
Average Price	4.026	1.322	1.288	1.455	2.687
SKATE (lbs.)	18,150	16,024	3,750	5,240	2,030
Value	$ 224	$ 214	$ 97	$ 135	$ 106
Average Price	.012	.013	.026	.026	.052
SOLE, DOVER (lbs.)	404,583	886,454	1,395,678	2,521,173	2,821,436
Value	$ 26,734	$ 64,356	$ 102,303	$ 207,201	$ 290,093
Average Price	.066	.072	.073	.082	.103
SOLE, ENGLISH (lbs.)	527,015	396,336	505,760	568,264	600,258
Value	$ 44,750	$ 39,673	$ 54,268	$ 65,047	$ 88,853
Average Price	.085	.100	.107	.114	.148
SOLE, PETRALE (lbs.)	341,934	737,575	1,109,242	982,655	662,798
Value	$ 50,095	$ 111,389	$ 181,250	$ 160,689	$ 128,404
Average Price	.146	.151	.163	.164	.194
SOLE, REX (lbs.)	91,560	129,790	154,566	112,139	193,617
Value	$ 8,737	$ 14,293	$ 18,331	$ 13,960	$ 29,083
Average Price	.095	.110	.119	.124	.150
SOLE, SAND (lbs.)	119,680	112,863	141,580	149,714	110,242
Value	$ 13,905	$ 13,972	$ 17,513	$ 19,258	$ 18,221
Average Price	.116	.124	.124	.129	.165
TUNA, ALBACORE (lbs.)	212,045	2,251,778	3,481,922	1,907,853	141,808
Value	$ 42,490	$ 481,505	$1,025,774	$ 611,793	$ 56,417
Average Price	.200	.258	.295	.321	.398
TURBOT (lbs.)	18,525	8,700	4,330	7,910	23,254
Value	$ 910	$ 442	$ 226	$ 495	$ 1,588
Average Price	.049	.051	.052	.063	.068
ALL OTHER (lbs.)	9,949	31,658	9,805	16,480	17,944
Value	$ 3,150	$ 4,642	$ 4,581	$ 6,852	$ 6,120
Average Price	.216	.147	.467	.416	.341
TOTAL					
Pounds	3,706,759	6,904,270	9,286,834	9,549,390	9,679,809
Value	$ 749,657	$1,420,057	$1,879,843	$1,673,867	$1,480,227

Appendix F

Anadromous Fisheries - Salmon, Steelhead, Striped Bass, Shad, Sturgeon

ESTIMATES OF BAY COMPLEX COMMERCIAL
SPORTFISHING EFFORT AND ECONOMIC VALUES*

Fishery	Catch	Est. Angler Days	Expenditure per Angler Day	Total Expenditure	Net Benefit per Angler Day	Total Net Benefit
1970						
SALMON						
Partyboat	42,400	51,300	$20.00	$1,026,000	$6.00	$ 308,000
Private boat	2,000	2,000	"	40,000	"	12,000
Ocean total	44,400	53,300		$1,066,000		$ 320,000
River	17,700	127,500	20.00	2,550,000	4.50	574,000
Total Salmon	62,100	180,800		$3,616,000		$ 894,000
STEELHEAD	20,000	137,300	22.00	$3,021,000	5.00	$ 686,000
1980						
SALMON						
Ocean		67,300	20.00	$1,346,000	6.00	$ 404,000
River		160,300	"	3,206,000	4.50	721,000
Total Salmon		227,600		$4,552,000		$1,125,000
STEELHEAD		172,600	22.00	$3,797,000	5.00	$ 863,000

(continued)

*Estimates in thousands.

Appendix F (cont'd.)

Fishery	Catch	Est. Angler Days	Expenditure per Angler Day	Total Expenditure	Net Benefit per Angler Day	Total Net Benefit
1970						
STRIPED BASS						
Ocean	16	83	$11.00	$ 900	$3.50	$ 300
S.F. Complex						
So. SF Bay	21	124	"	1,350	"	450
Central SF Bay	159	239	"	2,650	"	850
San Pablo Bay	100	235	"	2,600	"	800
Suisun Bay	38	105	"	1,150	"	350
Bay Total	318	703		$ 7,750		$2,450
Delta	308	1,137	"	12,500	"	4,000
Rivers	71	214	"	2,350	"	750
Total Striped Bass	713	2,137		$23,500		$7,500
SHAD	187	125	N.A.	---	2.50	313
STURGEON	25	8	N.A.	---	3.00	28
1980						
STRIPED BASS						
Ocean	18	101	$11.00	$ 1,100	$3.50	$ 350
S.F.Complex						
So.SF Bay	24	151	"	1,650	"	550
Central SF Bay	181	291	"	3,200	"	1,000
San Pablo Bay	114	287	"	3,150	"	1,000
Suisun Bay	43	128	"	1,400	"	450
Bay Total	361	857		$ 9,400		$3,000
Delta	350	1,383	"	15,200	"	4,850
Rivers	81	260	"	2,850	"	900
Total Striped Bass	811	2,601		$28,600		$9,100
SHAD	300	200	N.A.	---	2.50	500
STURGEON	2.5	8	N.A.	---	4.50	36

Appendix G

Food Habits of Selected San Francisco Bay Estuary Fishes.

Fish	Principle food items	Reference
American shad	Neomysis, copepods	Ganssle, 1966
	Crago, larval fish &	Turner, 1966
	Corophium, sp.	Hatton, 1940
Anchovy, northern	indiscriminate filter feeder - zooplankton or phytoplankton, some small fish	Frey, 1971
Goby, oriental	small fishes & crustaceans	Okada, 1961
Herring, Pacific		
Jacksmelt	filter & particulate feeder calanoid copepods, insects, Crangon, polychaetes	Boothe 1967
Salmon, King (young)	aquatic & terrestrial	Rutter 1903
	insects, opossum shrimp	Hatton 1940
	amphipods & isopods	Ganssle 1966
Sardine, Pacific	filter & particulate feeder	Hand & Berner 1959

Shark, sping dogfish	palagic feeder - fish & bay shrimp	Rozum 1952
Shiner Perch	small, benthic organisms - gammarid amphipods, cumaceans bivalved mollusks & polychaetes	Boothe 1967
Sole, English	bottom organisms - segmented worms & clams	Frey 1971
Staghorn Sculpin	shrimp, crabs & bay goby	Boothe 1967
Starry flounder	bivalves, polychaetes, callianassids, & crabs	Boothe 1967
Striped bass (young)	<u>Neomysis</u>, <u>Corophium</u>, annelid worms, bay shrimp	Ganssle 1966 Hanbach Tolk & McCready 1963
(adults)	fish & shrimp	Ganssle 1966
Sturgeon, green white	Benthic animals - clams, crabs, shrimp fish eggs	McKeshnic & Fenner 1971 Radtke 1966 Ganssle 1966
Surfperches	bottom invertebrates - copepods, amphipods, shrimp crabs, mollusks, worms, small fishes	Standing & others 1975 Wooster 1968a Frey 1971

Topsmelt	crustaceans & other plankton species. will work muddy bottoms for food items	Frey 1971

Food Habits of Animal Organisms Used by San Francisco Bay Estuary Fishes

Amphipods		
<u>Corophium</u>	organic detritus & associated organisms	Standing 1975 Green 1968
Clams		Green 1968
<u>Macoma</u>	detritus	Newell 1965 Younge 1949 Vassallo 1969 Rees 1940
<u>Mya</u> <u>arenaria</u> adults	filter feeder, plankton & particulate organic matter	Stickney 1964 U.S. Fish and Wildlife Service 1964
Copepods	"as a group, their diet consists of phytoplankton, smaller zooplankton & organic detritus"	Skinner 1972
Crabs, market	Fish, clams, isopods, amphipods & arthropods	Frey 1971

Insects, terrestrial from salt marshes of S.F. Bay	35 species were herbivores 26 species were saprovores 9 species were predators	Cameron 1972
Isopods	plant materials, cellulose	Schultz 1969
Mud snails Nassarius, etc.	deposit feeder - feeds on microflora found on surface of sediment of intertidal flats	Scheltema 1964 Teal 1969
Mussels	filter feeder - microscopic plant & animal life. detritus (depositional agent for other organisms)	Kuenzler 1961 Teal 1969 (p. 150)
Mysids <u>Neomysis</u>	diatoms, detritus, copepods, amphipods detritus & diatoms	Cannon & Manton 1927 Green 1968 Kost & Knight 1975
Oysters	filter feeder - plankton & nanoplankton	Galtsoff 1964
Polychaete worms	deposit feeders - copepods ostracods, nematodes, diatoms, organic debris	Green 1968 Perkins 1958

Shrimp, Bay	detritus, dead forms	Lloyd & Younge 1947
Crago, etc.	of other animal life	Kelley 1968
		Broad 1965