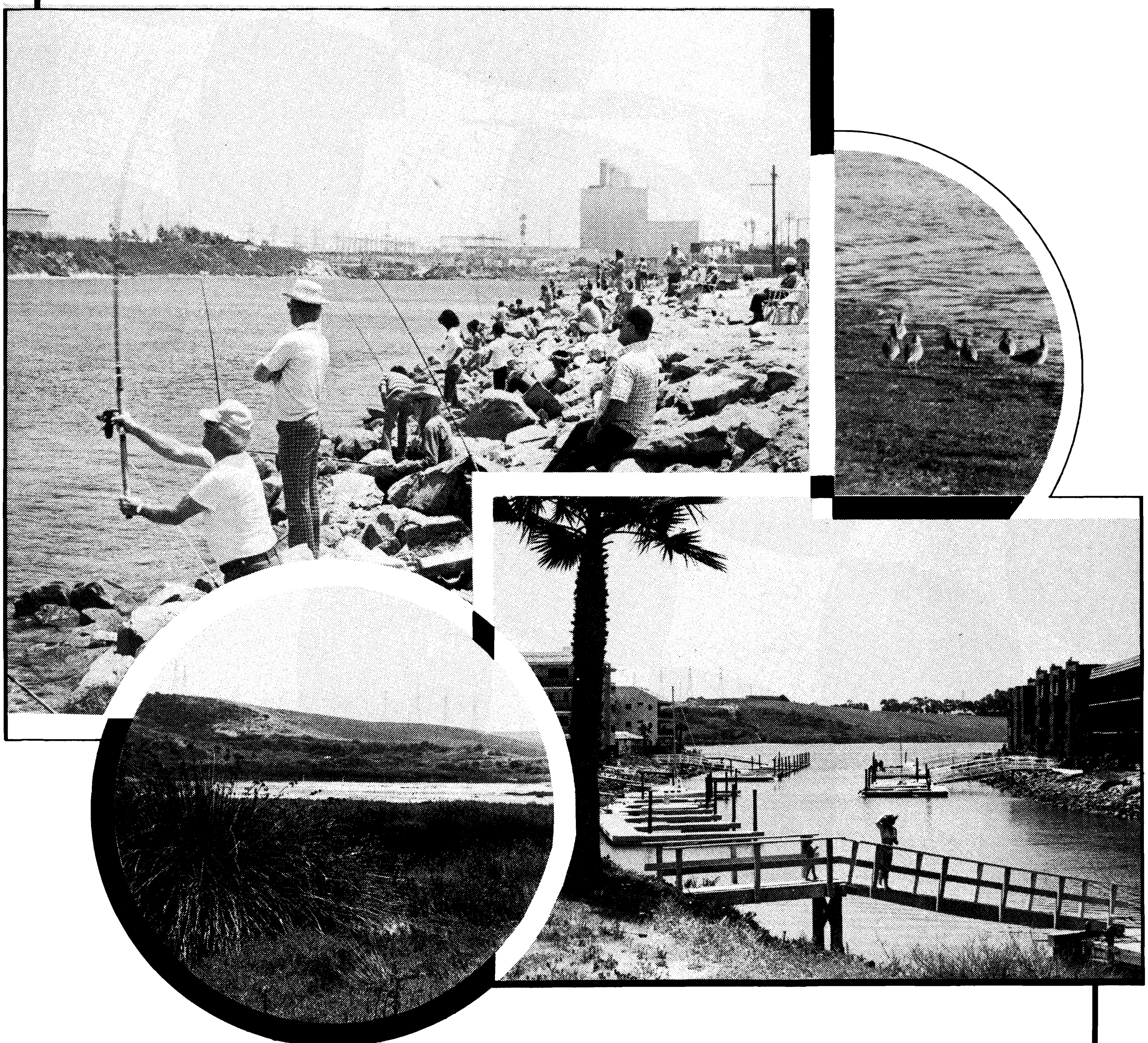
The Natural Resources of AGUA HEDIONDA LAGOON



California Department of Fish and Game
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THE NATURAL RESOURCES

OF

AGUA HEDIONDA LAGOON

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Agua Hedionda Lagoon

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INTRODUCTION

In many ways Agua Hedionda Lagoon is unique among the coastal lagoons of San Diego County. Originally an increasingly-restricted salt marsh habitat (because of choking sedimentation and a normally-closed entrance), the entire lagoon was dredged and permanently opened to the sea in 1952-54. The resultant deepening and tidal flushing created a new deep-water bay environment; and today the lagoon, in addition to its uses as a source of power plant cooling water, supports a wide variety of marine and terrestrial environments. This environment, or ecosystem, contains a highly diverse flora and fauna that, in addition to making a more interesting and attractive lagoon and wetland, provides a wider range of recreational and educational use.

Approximately sixty percent of the wetlands along the coast of California has already been destroyed or degraded. The future of the remaining wetlands that are so vital to many of our marine, estuarine and marsh-oriented fish and wildlife species continues to be threatened. Hence, the urgent need for this and similar reports that are intended as guides for citizens, planners and administrators of all private and public entities interested in the status and future of the coastal wetlands.

This report has been prepared under contract to and fully funded by the Office of Biological Services of the U. S. Fish and Wildlife Service. The goals and purpose of this federal office are to review the impact on fish and wildlife resources of land, mineral and water development practices, such as offshore oil and gas exploration, development and production; construction of inshore pipeline canals and refineries; power plant construction/operation and urban development. This report, and five other southern California reports, covering Carpinteria Marsh (Santa Barbara County), Anaheim Bay-Huntington Harbor (Orange County), Mugu Lagoon (Ventura County), the Northern Santa Barbara County Coastal Wetlands, and the Nipomo Dunes and Wetlands (San Luis Obispo County), are scheduled to be part of the Department's "Coastal Wetland Series" (see inside front cover).

SUMMARY

Agua Hedionda Lagoon is a coastal lagoon located within the city limits of Carlsbad about 20 miles north of San Diego Bay. The lagoon, which is divided into three sections by the railroad and highway, extends inland about 1.7 miles and is 0.5 miles wide at the widest point.

The outer lagoon, 66 acres in size, opens to the ocean through a jettied entrance at the northwest end of the lagoon and provides cooling water for the San Diego Gas and Electric power plant located on the southern shore. At the southwestern corner of the outer lagoon is the power plant ocean outfall and on the western shore, a public fishing area provided by the power company. The middle and smallest lagoon (27 acres) lies between the Santa Fe railway and Interstate 5, and has a YMCA recreational area on its western shore. The inner lagoon (295) acres extends 1800 yards eastward from I-5. On its north shore lays a private marina-condominium development and two private boat-launching facilities. On the south shore are bluffs rising to power plant lands that contain fuel tanks and leased agricultural crops. At the east end are the degraded remnants of a once-extensive salt marsh with about 100 acres each of mudflat and high marsh interspersed with salt flats and alluvial fan. Most of the limited amount of freshwater that enters the lagoon comes from the 29 square mile watershed of Agua Hedionda Creek and its major tributary, Buena Creek. Due to the limited amounts of freshwater, the lagoon has essentially marine characteristics rather than estuarine.

The lagoon is characterized by sub-tropical semi-arid climate, with an average annual rainfall of 10.7 inches. However the lagoon is subject

to intermediate regional floods with estimated magnitudes of 10,500 cubic feet per second.

Agua Hedionda is the drowned mouth of a river-cut valley cut into Eocene and Pleistocene sedimentary rocks. The rising of sea level since the end of the last glaciation filled the valley forming a deep open embayment. Gradually this embayment filled with silt and sand from the creek and with sand from the ocean to form a shallow lagoon with a partial sand barrier across the mouth. Diverse marine lagoon organisms flourished under these open conditions and many shellfish and finfish were harvested by Indians until sometime in the last millenium when the lagoon became so filled with sediment that it no longer remained continuously open.

Indian history around Agua Hedionda dates back more than 9,000 years and represents the best known example of the transition from a large game hunting economy (San Dieguito Culture) to a shellfish and plant gathering economy (La Jollan Culture). During the Spanish occupation the land around the lagoon was used for cattle grazing and salt was harvested from the lagoon. The modern historical period began with the building of the railroad in 1885 and the resulting land boom which was responsible for the founding of the town of Carlsbad in 1887. In 1910 the Coast Highway was constructed, bridging the mouth of the lagoon for the first time. The land adjacent to the lagoon was first dry farmed and later used for vegetable, bulb, flower and avocado production. By 1967 Interstate Highway 5 was completed, dividing the lagoon into its three sections.

Most of the entire lagoon including extensive areas of intertidal mudflat was dredged between 1952 and 1954 and permanently opened to the sea to provide a tidal prism adequate enough to supply cooling water for the San Diego Gas and Electric Company's Encina Power Plant located on the south side of the outer lagoon. Sand from littoral drift enters the lagoon at the rate of more than 100,000 cubic yards per year and must be removed by the power company at approximately two-year intervals to maintain the cooling water basin.

S.D.G.&E. is the record owner of the lagoon; however, there is a question as to the historic title and a public trust easement over the wetland. S.D.G.&E. owns the land on the south and northwest sides of the lagoon. The remaining land, on the north side of the lagoon, is privately owned. Most of the land and water in and around Agua Hedionda Lagoon lies within the city limits of Carlsbad. City zoning plans indicate the lagoon as "open space" and the periphery as residential, agricultural and industrial. A specific city plan for Agua Hedionda and its immediate environs, presently being drawn up to conform with the California Coastal Zone Conservation Commission plan for the region, calls for rezoning as open space some of the lands immediately south and east of the lagoon. At present, the utility company leases to the City (for a token sum) the water area of the middle and inner lagoons and the City allows several types of water-oriented recreational activities in those lagoon sections. Use of the outer lagoon is more restricted; the primary use of this area is for a cooling water intake basin for the power plant. However scientific research, such as experimental mariculture, is permitted and public fishing encouraged by parking facilities provided by the utility company.

Agua Hedionda Lagoon and its surrounding area may be divided into two major ecosystems: marine and terrestrial. The marine ecosystem has two ecological components: a subtidal subsystem and an intertidal subsystem. The subtidal subsystem, occupying a total of 296 acres of submerged habitats, consists of the following habitats: rock habitat (2 acres), sand habitat (169 acres), mud habitat (55 acres), and eel grass habitat (70 acres) and, of course, open water habitat (296 acres) that inundates the other subtidal habitats. The intertidal subsystem, comprising a total of 92 acres, may be divided into the following habitats: rocky shore habitat (4 acres), sandy shore habitat (2 acres), muddy shore habitat (70 acres) and salt marsh habitat (16 acres).

The terrestrial ecosystem is comprised of a maritime and an upland subsystem. The maritime subsystem consists of two habitats: brackish water habitat (5 acres) and maritime habitat (19 acres). The upland subsystem occupies a total of 130 acres and consists primarily of grassland and coastal sage scrub/chaparral.

The subtidal and intertidal habitats at Agua Hedionda Lagoon are well-developed and support healthy and abundant organisms adapted to those kinds of environments. However the salt marsh and upland (terrestrial) environs are generally in a disturbed and degraded condition and support a typical, but depauperate, flora and fauna.

Water-associated birds are the most abundant and obvious of the lagoon wildlife. Fifty-five species of water-associated birds, like the shorebirds, waterfowl, wading birds and other marsh birds, have been identified at Agua Hedionda. Several species of water-associated species that are designated as rare or endangered occur at the lagoon, including

The California least tern and Belding's savannah sparrow, which nest at the eastern end of the lagoon. Other birds commonly seen about the lagoon, but in decline in the San Diego area, are the western grebe, double-crested cormorant and black-crowned night heron. Forty-seven land-birds also have been recorded, as well as 27 mammals, 4 amphibians, 5 lizards and 8 snakes.

No definitive study of the lagoon fishes has been made. However, perfunctory surveys of fish caught in the lagoon and adjacent ocean by area fishermen, and of fish taken off of the cooling water intake screens at the power plant, yield a list of 42 fish species taken from the lagoon and 23 from adjacent ocean waters.

Due to the diversity of subtidal and intertidal habitats, a large tidal prism, and effective and healthful tidal flushing, the invertebrate population at Agua Hedionda Lagoon is very impressive. Over 200 invertebrates have been collected from the lagoon and its environs; 150 from the lagoon, and another 45 from adjacent ocean shore habitats. The list includes corals, anenomes, clams, cockles, mussels, oysters, scallops, snails, amphipods, isopods, crabs, shrimp, barnacles, starfish, sand and brittle stars, sea urchins, sand collars, bryazoa, insects and a host of various kinds of marine worms.

Use of the natural resources at Agua Hedionda Lagoon falls into two categories: appropriative and non-appropriative. Appropriative uses include clamming and harvesting of other invertebrates for food and bait and fishing in the lagoon and ocean. Hunting in the lagoon environs is prohibited by Carlsbad City ordinance, due to the heavy recreational and residential use in the area. Boating, swimming, water-skiing, nature study, bird watching and picnicking are some of the important non-appropriative uses of the lagoon. And, much scientific and educational use of the lagoon's resources is made by local colleges and universities, as well as by primary and secondary schools of the area. Aqua or mari-culture, the artificial rearing of commercially important shellfish, has been an important facet of scientific and educational use of the lagoon waters, mostly in the outer lagoon under permit by the San Diego Gas and Electric Company.

The greatest threat to the present status of Agua Hedionda Lagoon and its wetland habitats is the continuing pressure for development of the lagoon and its watershed. The demand is for three principal types of development: 1) recreational, 2) residential and 3) industrial.

The lagoon has been considered as a potential small craft harbor and as a county regional park. Due to financial considerations, other priorities and considerations, these proposals have been dropped. However, the City of Carlsbad, the California Coastal Zone Conservation Commission and a group of property owners have entered into a cooperative agreement to prepare specific land use plans for Agua Hedionda Lagoon and its immediate environs.

The City Planning Department has prepared a good environmental impact report (EIR) for the Specific Plan that shows much sensitivity to the environmental information available, and the relationship of local, short-term uses of the resources to the preservation, maintenance and enhancement of the long-term productivity of the lagoon. The Specific Plan also enumerates thoroughly environmental impacts that cannot be avoided if the project is implemented, and many sound mitigation measures for those impacts identified. The EIR presently is in review process and will be scrutinized by appropriate agencies including the Department of Fish and Game and U. S. Fish and Wildlife Service.

One alternative to the projects in the Specific Plan prepared by the City is an acquisition proposal offered by a land owner in mitigation for the development of a recreation vehicle park at the northwestern corner of the inner lagoon. This proposal suggests the acquisition and protection of those ecologically sensitive areas at the east end of the lagoon. The protected area would include the remnants of the marsh and mudflat areas, which receive the most intense use by marine avifauna and the riparian, brackish water and maritime habitats, as well as the alluvial fan deposits used by the endangered least tern for nesting. The Department will review the possibilities of this alternative proposal to the City's Specific Plan projects along with the other elements of the EIR.

The Carlsbad City Specific Plan also indicates zoning for residential and recreation-commercial development, but outlines specifically the mitigative measures needed to minimize adverse impacts on lagoon and its habitats.

The 1973 Carlsbad General Plan zoned the southshore of the lagoon as industrial. The Specific Plan now calls for "open space" zoning of the entire inner lagoon and a large portion of its south shore (Plate 18).

Because of the large amount of tidal flushing in Agua Hedionda Lagoon, the water quality of Agua Hedionda Lagoon is rather good. Some sedimentation is present and though not serious at present, should be monitored, especially the shoaling that is occurring at the mouth of the inner lagoon.

RECOMMENDATIONS

Agua Hedionda Lagoon and its immediate upland surroundings comprise an ecosystem of varied habitats that supports numerous fish, wildlife and invertebrate organisms. Because of the physical configuration and spatial relationships of the lagoon sections and their habitats, an opportunity exists to accommodate a variety of uses in the lagoon, with minimum disturbance and destruction of the living resources. To allow for multiple-use, and to maintain the natural resources and values at Agua Hedionda Lagoon, the Department of Fish and Game recommends:

1. Private or public shoreline developments not encroach upon the remaining lagoon wetlands, except in limited situations where such encroachments are required to provide public access to the lagoon. Most of California's coastal wetlands have been altered with consequent loss of living resources. Dredging and development have reclaimed much of Agua Hedionda's once relatively large tidal marshland. If the degraded but still viable salt marsh, in addition to the healthy intertidal habitats, is to retain its value to fish, wildlife and other organisms, further encroachment into the lagoon habitats must be prohibited.

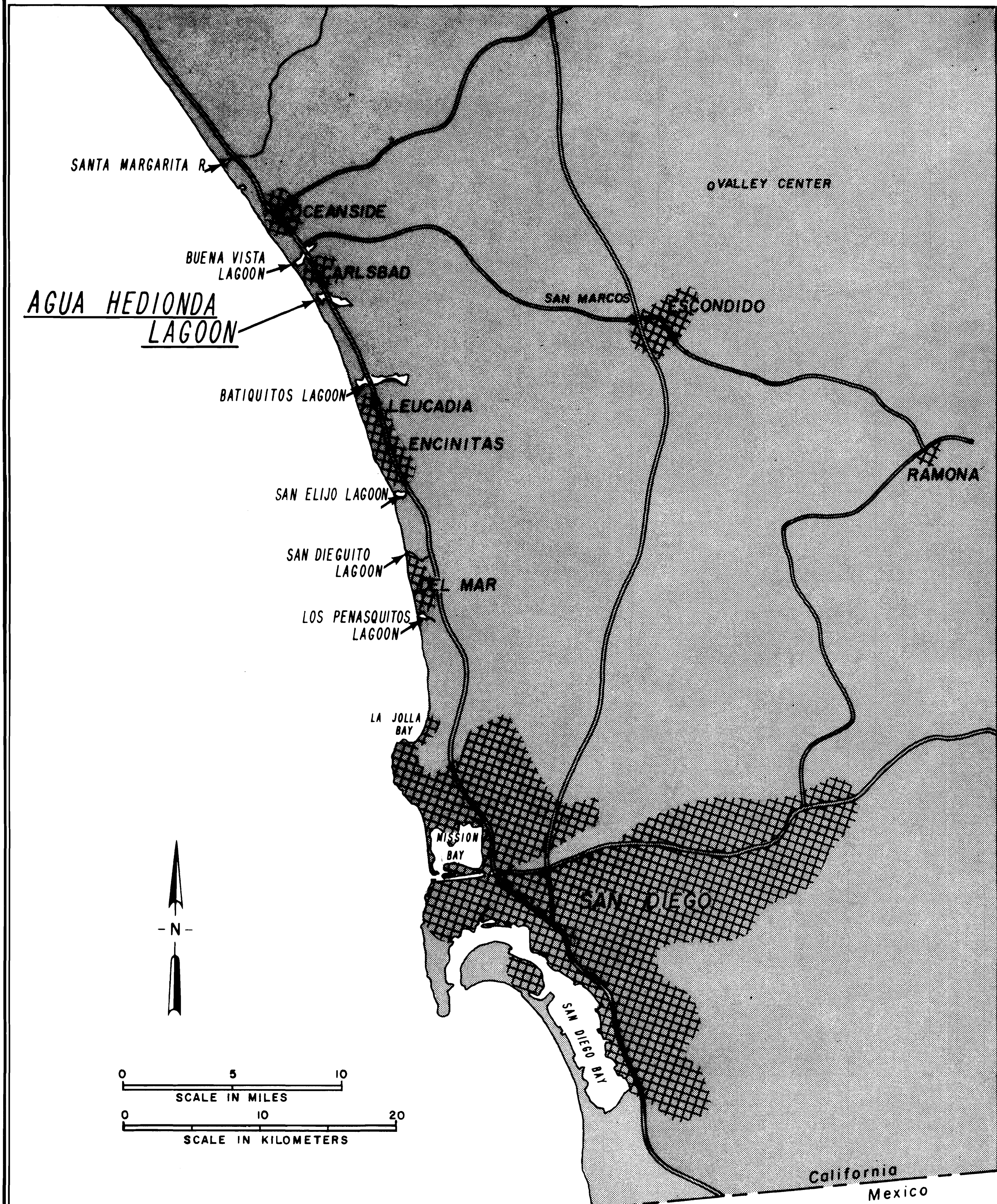
2. The amount and rate of sedimentation in the inner lagoon be determined, and evaluated for possible corrective action. There is considerable shoaling at the mouth of the inner lagoon and it is beginning to have an adverse effect upon the subtidal ecosystem. Both the uplands (erosion) and the ocean (downcoast sand drift) are sources of sedimentation, but the amount and rate from each is unknown.

3. <u>The lower flood plain of Agua Hedionda Creek and the wetlands at the eastern end of the lagoon be acquired and managed to retain natural resource values</u>. The pocket marshes at the eastern end of the lagoon, and the adjacent salt flats, riparian and brackish water habitats and alluvial fans, are remnants of a once-extensive and viable estuarine system. This area of the lagoon has open space and scenic values and receives relatively intensive use by many water-associated and terrestrial forms of wildlife that inhabit or are attracted to the area. The alluvial fans are often used as nesting sites by the endangered California least tern. To ensure the preservation of these important habitats they should be placed in public ownership.

4. <u>Uses of ecologically sensitive areas within and adjacent to the lagoon be limited to those uses compatible with the maintenance of living resource values</u>. While much of the lagoon can be used by such active types of recreation as power boating, water skiing, etc., there are areas which would be damaged by such activities, or their value to fish, wildlife and other organisms, significantly reduced. For instance, the alluvial flats at the eastern end of the lagoon, where California least tern nesting occurs, and the eel grass beds located in the inner and middle lagoons and which support myriads of marine organisms, need protection from human disturbance. Protection of such sensitive areas can be accomplished by measures, or combination of measures, like posting of designated areas, fencing, float barriers, etc.

PLATE I

AGUA HEDIONDA LAGOON AND VICINITY



AGUA HEDIONDA LAGOON AND ENVIRONS

Physical Features

Location

Agua Hedionda Lagoon is a coastal lagoon located in San Diego County within the southern portion of the city limit of Carlsbad, about 20 miles north of the City of San Diego (Plate 1). The lagoon, extending inland for approximately 1.7 miles and ranging from 190 to 850 yards in width, represents the seaward end of the Agua Hedionda Creek drainage basin, which extends eastward into the San Marcus Mountains.

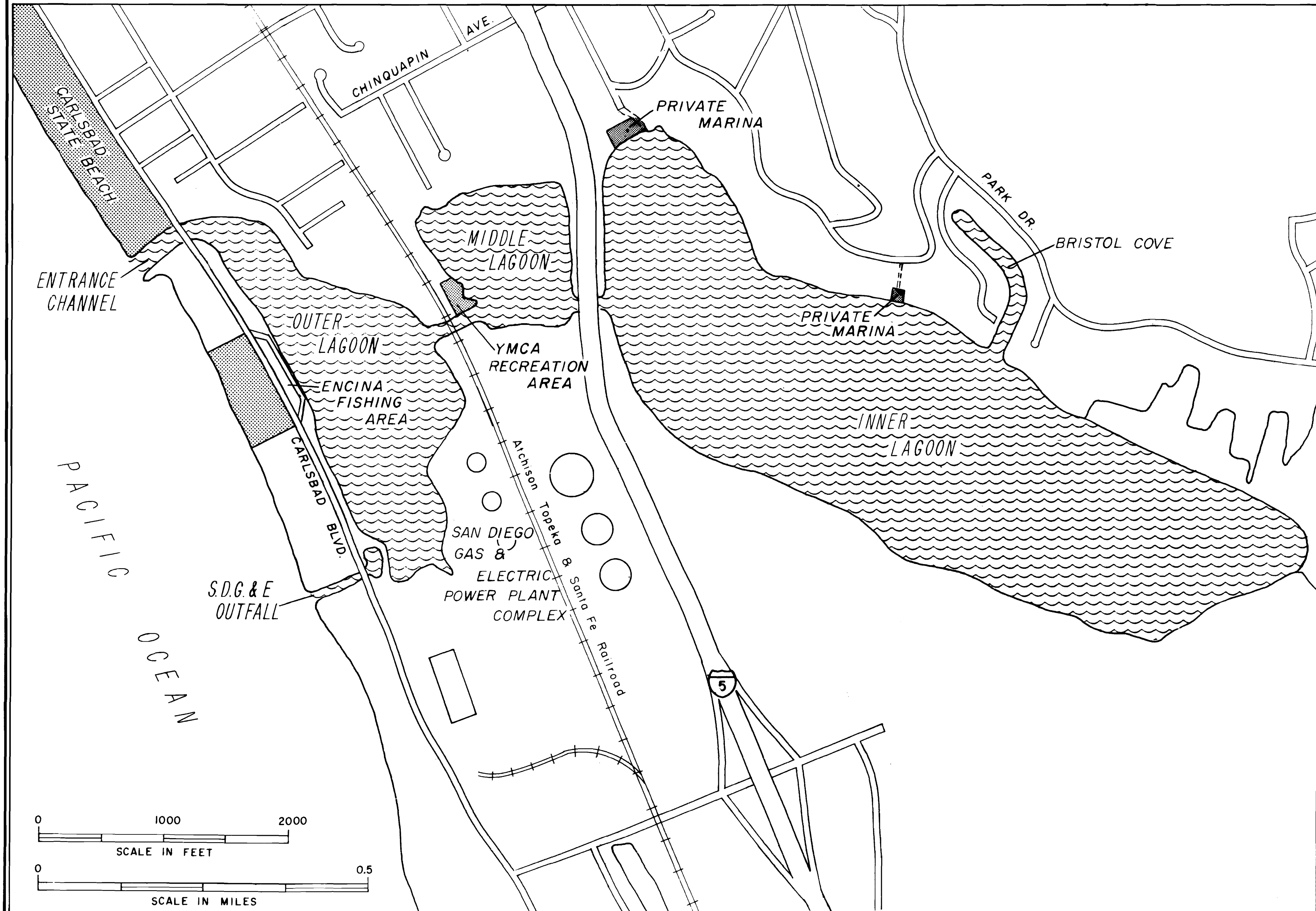
General Description

The lagoon is bounded on the west by the Coast Highway (Carlsbad Boulevard), in the north by the City of Carlsbad residential community, and on the east and south by undeveloped hillslopes and bluffs. Above the bluffs on the south side of the lagoon lie cultivated fields and the Encina Power Plant operated by the San Diego Gas and Electric Company (S.D.G.&E.).

The lagoon is crossed by a Santa Fe railroad trestle and the Interstate 5 freeway. These two thoroughfares divide it into three sections referred to as the "outer," "middle" and "inner" lagoons (Plate 2). The outer section (66 acres) provides cooling water for the power plant located on the south shore. Water enters from the ocean at the northwestern corner of the outer lagoon by a 150-foot wide channel formed by two 300-foot long rock jetties. At the southwestern corner of this outer section is a power plant outfall, also jettied, through the beach lying just west of the highway. To restrict public access, floating booms have been installed between the two jetties, across the channel connecting the outer and middle

PLATE 2

AGUA HEDIONDA AREA MAP



lagoons, and across the southern third of the outer lagoon. And, on the western shore of the outer lagoon between it and the highway is a public fishing access and parking lot provided by S.D.G.&E.

The middle and smallest lagoon (27 acres) is nearly square with sides approximately 300 yards long. The use of this basin is restricted to low-speed boating activities; and the only development is a recreational area and small boat house on the western shore, operated by the YMCA.

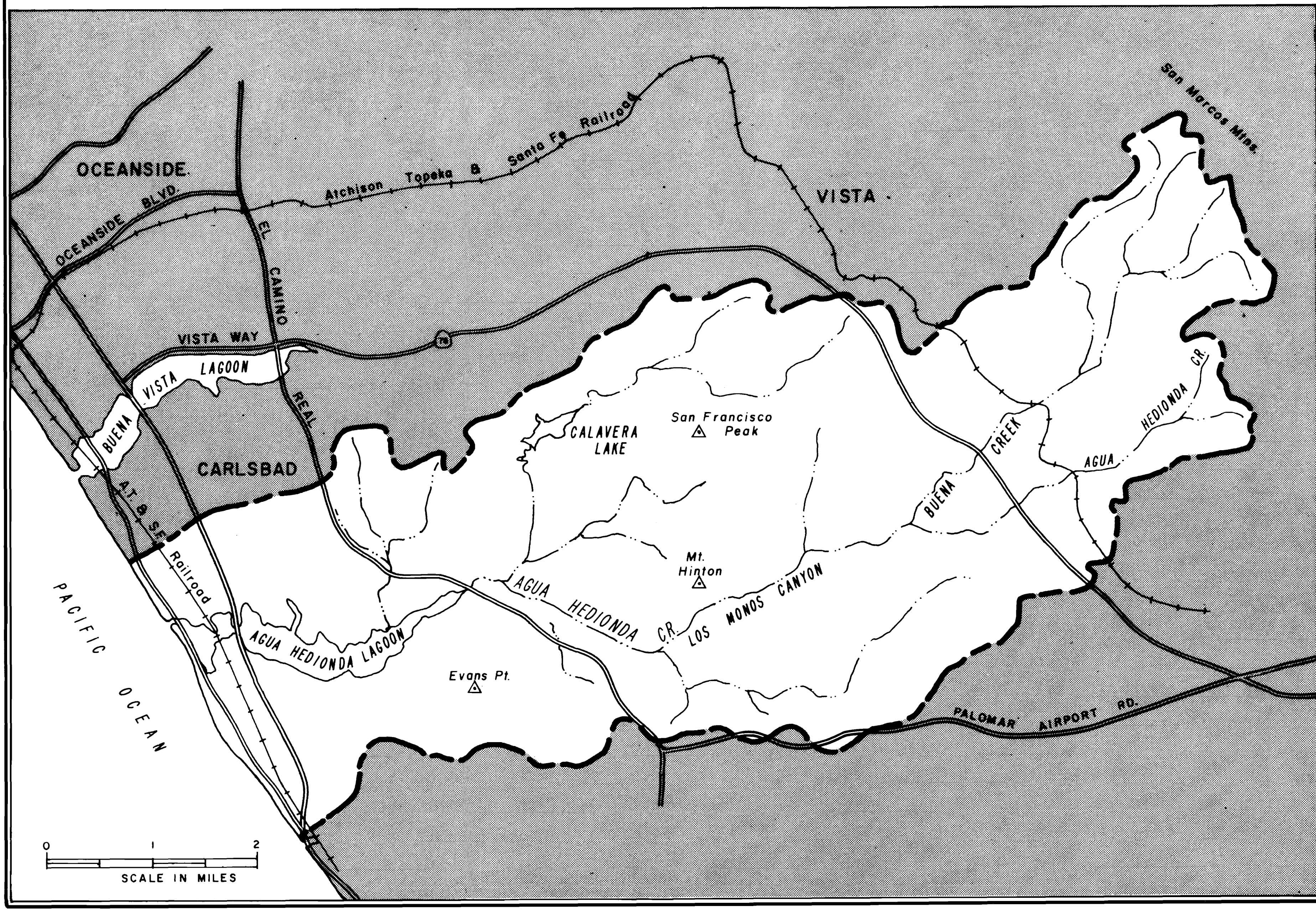
The inner lagoon, by far the largest (295 acres), extends approximately 1800 yards in a southeasterly direction from the Interstate 5 highway bridge. More public use is made of this section than of the outer and middle lagoons; and a private marina-condominium development and several boat-launching facilities have been constructed along the northern shore. Over most of the lagoon area the shoreline rises relatively steeply to the bluffs bordering the lagoon and much of the former, gently-sloping mudflat and salt marsh having been removed by dredging. On the northeast shore, however, several small pockets of salt marsh remain, as a result of dredge and fill operations. Further eastward these pockets extend into about 100 acres of mudflats dotted with small islands of pickleweed marsh. These mudflats form a gradient into about 100 acres of salt flats and high marsh. Further inland fresh and brackish water marsh vegetation fringes the salt flats and high marsh.

Drainage

Minor amounts of local drainage enter the lagoon at various locations throughout the inner, middle and outer sections. Most of the freshwater,

PLATE 3

AGUA HEDIONDA LAGOON WATERSHED



however, enters from Agua Hedionda Creek located at the extreme eastern end of the inner lagoon. Agua Hedionda Creek and a major tributary, Buena Creek, together drain an area of 29 square miles or 18,560 acres (U.S. Army Corps of Engineers, 1973). The drainage area (Plate 3) is bounded to the north by a range of hills just south of State Highway 78; to the south by Palomar Airport Road; and to the northeast by the San Marcos Mountains. Agua Hedionda and Buena Vista creeks originate in the hills south of the San Marcos Mountains, flow southwesterly, for about 3 miles, and then become confluent. From this point Agua Hedionda Creek turns more westerly and 6 miles downstream enters the lagoon. The average stream gradients along Agua Hedionda Creek range from 43 feet per mile (upper reaches) to 35 feet per mile (lower reaches) with the exception of an extremely steep section (Los Monos Canyon) where gradients attain 180 feet per mile. Downstream from Los Monos Canyon, the creek broadens into a shallow, wider channel with gently rolling overbanks. It then changes into an improved channel through the Rancho Carlsbad Mobile Park and golf course. Below El Camino Real the natural channel becomes shallow and indistinct with a very broad flood plain inundates at times of heavy flooding.

The magnitude of the intermediate regional flood (100 year period) is estimated to be 10,500 cubic feet per second while the Standard Project Flood (greatest likely to occur) is projected to be 15,000 cubic feet per second (U.S.A.C.O.E., 1973). Major flooding occurs along the creek and its tributaries, primarily from December to April, although it can occur at any time of the year. Except during these periods there is little streamflow and consequently very little freshwater reaches the lagoon on a regular basis. Historical records indicate that damaging floods have occurred in 1862, 1884, 1895, 1916, 1927, 1932, 1938 and 1942. During these flood periods, considerable sediment presumably entered the lagoon, much of it being deposited in the headward section.

The lagoon has an underwater channel system (Plate 11) which serves as the main conduits of ocean water entering and leaving the lagoon. In the outer basin, one channel with maximum depths below mean low low water (MLLW) of 8 feet leads from the lagoon entrance to the power plant cooling water intake at the southwestern corner. Another channel with maximum depths of 6 feet leads from the entrance to the middle lagoon. In addition, the outer lagoon contains several basins from 8 to 12 feet deep (Bradshaw and Estberg, 1973). While water flows to all parts of the outer lagoon, the strongest current goes into the middle lagoon and continues into the inner lagoon through a channel under the bridges, with depths as great as 30 feet. A sand bar exposed during minus tides separates this deeper channel from the remainder of the middle lagoon where depths average about 8 feet. As the water enters the inner basin it fans out and slows down forming another large sand bar to the east of the highway bridge.

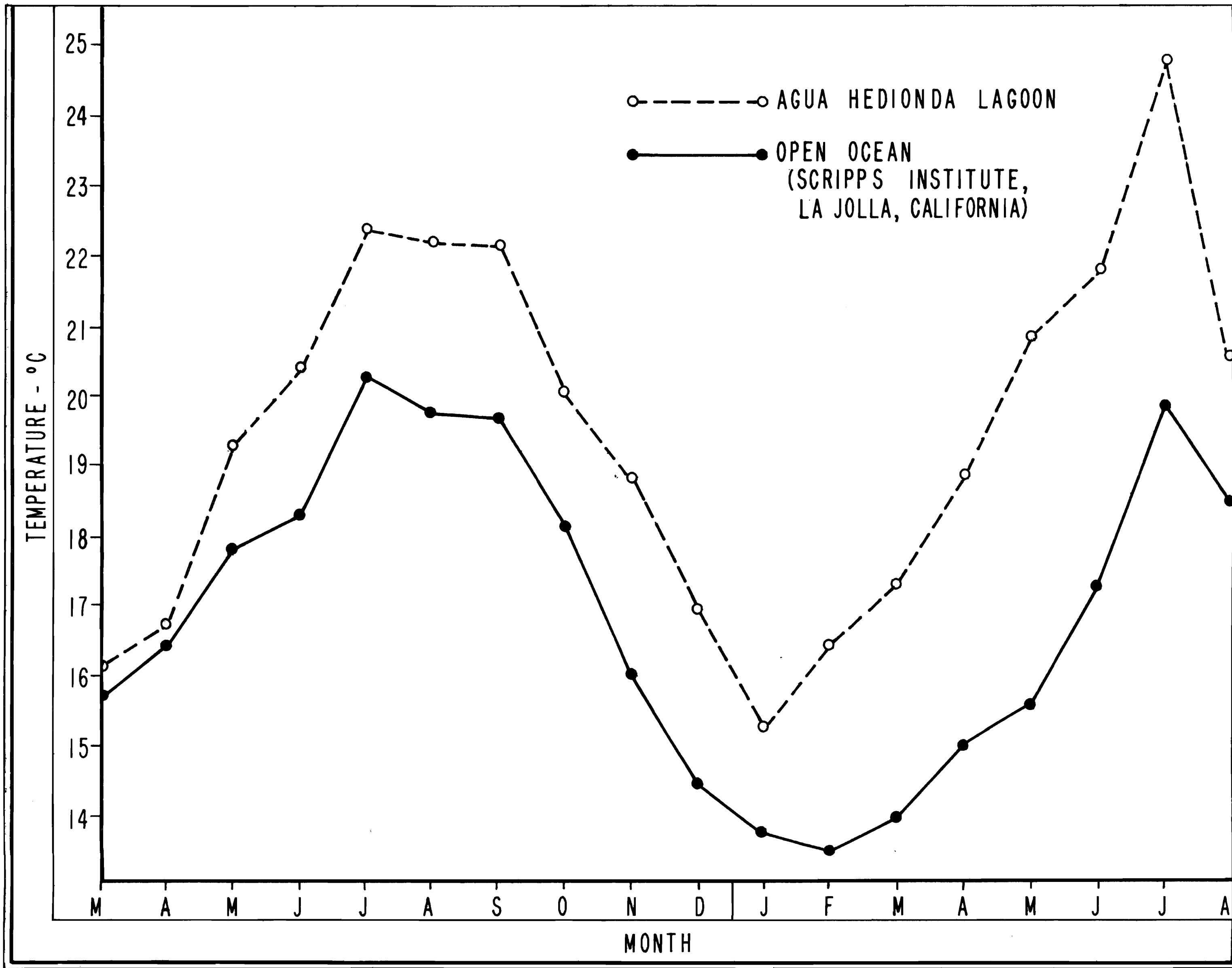
At extreme high tide (+7.7 feet MLLW) the entire lagoon has approximately 388 acres of water surface. At extreme low tide (-2.3 feet MLLW) the surface area is reduced to approximately 296 acres, forming an intertidal area of approximately 92 acres. The tidal prism (water volume between mean high water (MHW) and mean low water (MLW) flowing in and out with the tides) is estimated to be 1,265 acre feet.

<u>Water Characteristics</u>

The lagoon waters appear to be basically ocean water, only slightly modified by entrapment in the lagoon. The temperature pattern is

PLATE 4

SEASONAL VARIATIONS IN WATER TEMPERATURES AT AGUA HEDIONDA LAGOON, 1974-5



dynamic and complex, changing not only with the specific location and the state of the tide but also diurnally and seasonally. Plate 4 illustrates the seasonal variation in temperatures for the year 1974 recorded from the San Diego State University salt water intake facility in the outer lagoon. Surface water temperatures taken August 23, 1972, ranged from 21.0°C to 25.6°C (Bradshaw and Estberg, 1973). Minimum temperatures (21.0°C) noted on the incoming tide were found near the entrance jetty in the outer lagoon and extended as a tongue-shaped pattern along the deep channels through the middle and into the inner lagoon. Due to the warming effects of the sun, maximum open water temperatures (25.6°C) were recorded in the relatively shallow areas of the inner lagoon at low tide. Extreme temperatures (greater than 36°C) were recorded from shallow pools in the salt marsh.

As might be expected from the minor and seasonal fresh water input, the salinity of the lagoon waters is generally similar to that of the adjacent ocean water. In a salinity study carried out August 21-24, 1972, salinities varied from a minimum of 32.45°/oo (parts per thousand) to a maximum of 34.70°/oo. During the same period the salinity of the adjacent ocean water (Scripps Institution Pier) ranged from 33.54°/oo to 33.84°/oo. The dominant processes affecting the salinity are the addition of fresh water and evaporation. The minimum salinity noted (32.45°/oo) was found in the extreme southern portion of the outer lagoon near the slight freshwater drainage from the San Diego Gas and Electric facility. Elsewhere salinity values were either similar to those of the open ocean or slightly higher. The highest open water salinity (34.70°/oo) was recorded in the extreme eastern portion of the inner lagoon where the greatest amount of evaporation occurs.

Salinity conditions in the more isolated high channels and pools of the salt marsh were still more extreme. Here minimal values of 20^{o}/oo after periods of flooding and maximum values of 40^{o}/oo after periods of low spring tides are not uncommon. These values compare favorably with those obtained over a period of several years from a small channel in a mission Bay marsh (Bradshaw, 1968).

Dissolved oxygen values throughout the open waters of the lagoon are more variable than those from adjacent ocean water. A series of oxygen measurements taken throughout the lagoon on August 21-24, 1972, from both top and bottom water, ranged from a minimum of 3.9 ml/L (milliliters per liter) to a maximum of 5.80 ml/L.

Mixing of the water by wind action together with phytoplankton photosynthesis tends to increase dissolved oxygen content. On the other hand, respiration by plants, bacteria and animals tends to decrease the amount of oxygen present. As might be expected, because of this mixing and higher densities of phytoplankton, oxygen concentrations of the surface water were generally greater than those of the bottom water. Where the current action and resulting mixing is strong, as in the outer lagoon and in the major channels, oxygen concentration tends to be similar from top to bottom. In areas where circulation is more sluggish and mixing processes are weaker (for example in portions of the inner lagoon) higher oxygen concentrations occur at the surface (5.6 ml/L) than at the bottom (3.9 ml/L).

Climate

The coastal area of San Diego County, including Agua Hedionda Lagoon, is characterized by a subtropical, semiarid climate with a strong oceanic influence. Diurnal and seasonal temperature changes are slight and humidities normally high (50-80%). During the summer light fog is common, often occurring at night and dissipating in the early morning hours.

The mean annual temperature is about 60°F. The monthly mean temperatures range from a minimum of 43°F in January to a maximum of 74°F in August and September (U.S. Agricultural Extension Service, 1970). Temperature extremes range from a minimum of 25°F in January to a maximum of 105°F during September and October. Freezing temps, and hence frost damage, are rare. Unusually high maximums are associated with a weather pattern that creates what are known as "Santa Ana" winds. Fortunately, both of these extreme conditions are short-lived and only rarely affect the natural resources of the lagoon.

The mean annual rainfall is 10.7 inches, most of it occurring during the winter months. Less than one inch falls between the months of May and October. And soil moisture is usually exhausted by the end of May. The winter rain is primarily associated with cold fronts moving down the coast from the Gulf of Alaska. Because of the semi-permanent Pacific "high" often standing off the coast, however, most of these frontal storms are weakened or deflected inland.

Winds are predominantly westerly and are from light to moderate (winds less than 8 mph occur 64% of the time). Occasional strong winds are associated with winter storms and gales of 60-65 mph and occur on the average every 50 years. The Santa Ana winds blow from the east or northeast and tend to be less severe but locally gusty.

Agua Hedionda Lagoon receives approximately 3,200 hours of sunshine per year or about 70% of the total possible. There is actually slightly less sunshine during the summer than is found in winter because of the summer night and early morning cloudiness typical of the California coastal climate.

Bottom Sediment and Shore Soil Types

The bottom sediment of the lagoon is basically determined by the sources of supply and by the water circulation pattern. There is a net input of beach sand into the outer lagoon through the entrance due to the process of longshore drift (Inman and Frautschy, 1966; Ritter, 1972). There also is an input from minor stream drainage of finer sand, silts and clays into the inner lagoon from Agua Hedionda Creek and to a lesser extent into the middle lagoon.

Tidal currents during flood and ebb-tide attain high enough velocities to erode and transport finer sediments so that only the coarser particles remain on the bottom of the major channels connecting the various sections of the lagoon with the sea. The current velocities are highest between the jettys at the entrance and decrease away from the channels and toward the inner portions of the lagoon. The smaller sizes of sand, silt and clay as well as small particles of organic detritus drop out of the water whenever the current speed decreases below their individual critical transport velocities. Thus there are coarse gravels between the entrance jettys, medium-coarse sand along the main channels leading into the inner lagoon and finer sands, silts, clays, and organic detritus in areas away from the channels and especially in the far eastern lagoon section. A more detailed description of the bottom sediments is given by Bradshaw and Estberg (1973) and by Miller (1966).

Much of the intertidal area in the outer lagoon, and where channels between the lagoons are constricted, has been lined with granite boulders as rip-rap to prevent erosion at exposed points (Plate 5). Elsewhere the outer lagoon shoreline consists largely of fine sand with cobble patches. Most of the intertidal zone of the middle lagoon consists of mud containing many empty clam shells. Slightly more sandy sections occur along the west and east shores. Between the rip-rap under the bridges, the southern shoreline of the middle lagoon varies from coarse sand to patches of silty mud. The intertidal zone of the inner lagoon varies from narrow sandy beaches to mud-clay banks with the exception of the rip-rap under the highway bridge and on the banks of Bristol Cove. An extensive mudflat inundated only during tides greater than MHHW (-5.5 feet) extends east of the lagoon (Plate 5).

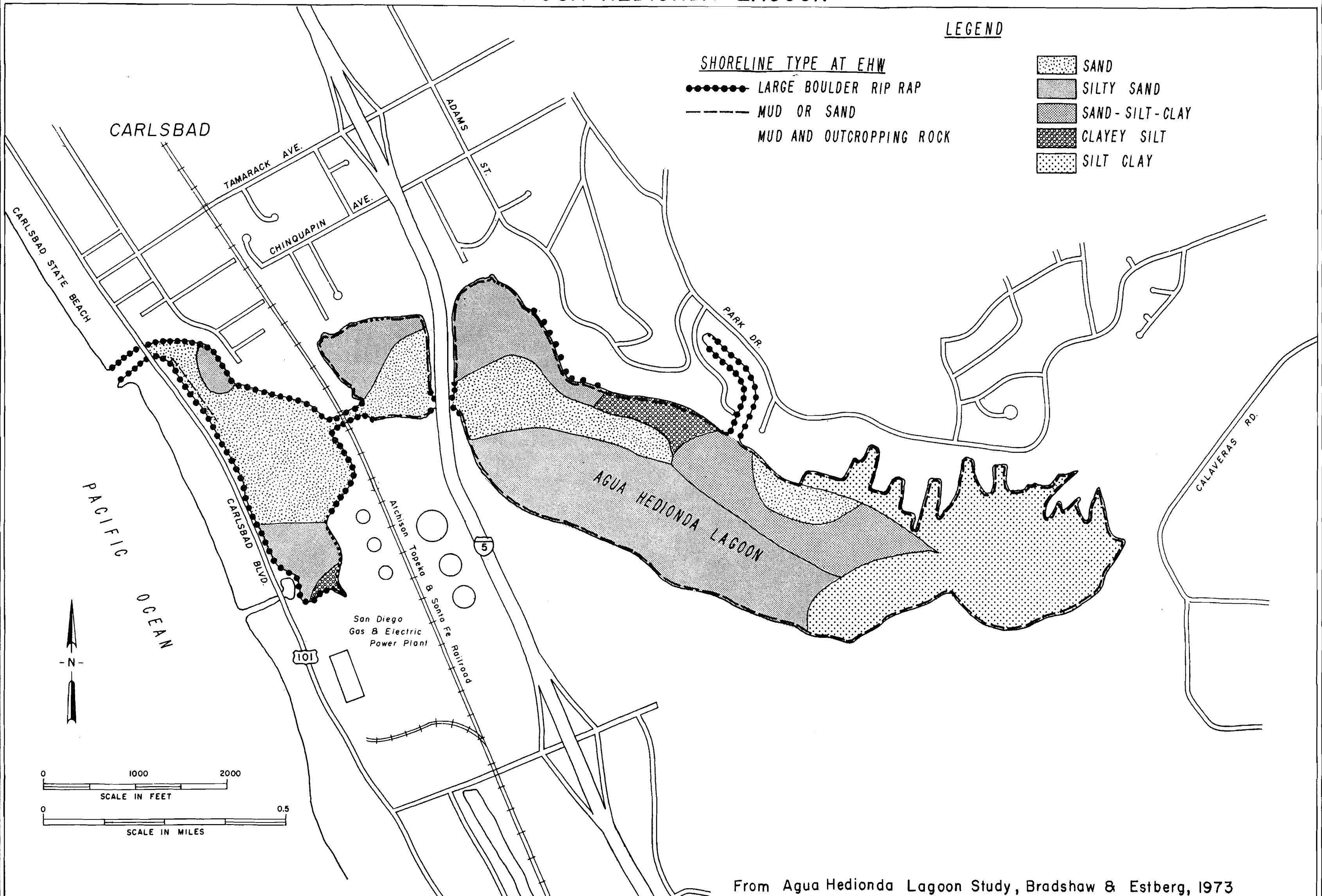
The soils of the maritime and upland areas of Agua Hedionda Lagoon are diverse, each soil type encouraging to a greater or lesser degree the development of different plant communities (U.S. Dept. of Agriculture, Soil Conservation Service, 1973).

The Marina loamy coarse sand on the marine terraces (ranging from near sea level to 300 feet) north and south of the lagoon, is an excessively drained, very deep, loamy coarse sand derived from the weakly consolidated marine terrace deposits. This material is well suited for avocados, citrus, tomatoes, flowers and truck crops but presently is being misappropriated for more and more housing developments.

The soil south of the eastern half of the inner lagoon is Las Flores loamy fine sand, is a deep, moderately well-drained, loamy, fine sand, having a sandy clay subsoil. In this soil that has low to medium fertility, rapid runoff creates considerable tendency for erosion.

PLATE 5

BOTTOM AND SHORE SUBSTRATE TYPES AT AGUA HEDIONDA LAGOON



From Agua Hedionda Lagoon Study, Bradshaw & Estberg, 1973

Good fertility and drainage makes good soil for citrus, flowers, tomatoes and truck crops, which can be found on terraces south of the lagoon.

Above the high tide line, the tidal flats grade upstream to Salinas clay loam, a well-drained to moderately well-drained clay loam that developed on sediments that had washed onto the flood plain. This soil has a moderately thick "A" horizon but a poorly developed "B" horizon. A slow runoff creates very slight erosion hazards. High fertility and good drainage make this soil suitable for citrus, tomatoes, flowers, truck crops and small pasture lots.

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Area Geology

Agua Hedionda Lagoon is the drowned mouth of a river cut valley, typical of the several estuaries that indent the southern California coast. This valley was cut into sedimentary rocks that deeply bury the older metamorphosed volcanic rocks (of the Santiago Peak Volcanics of Jurassic Age) which crop out approximately two miles east of the head of the lagoon. The volcanics and associated intrusive igneous rocks of the Southern California Batholith underlie most of the drainage basin of Agua Hedionda Creek (Calif. Div. of Mines and Geol., 1965).

This sequence of volcanic and intrusive rocks was deeply eroded and partially buried by sediments during the late Cretaceous Period. The climate of the time was tropical and more humid than at present and the resulting intensive weathering resulted in a thick layer of clay that has been mined in several places east of Evans Point near the head of the lagoon (Weber, 1963).

Marine waters covered the coastal area during the Eocene Epoch and a wedge of marine sediments thickening toward the west, buried the older topography (Wilson, 1972).

The Pleistocene, representing the last two million years, has been marked by world-wide fluctuations of sea level. During glacial periods the sea dropped below its present level, and during interglacial periods it often stood higher than today. During the high stands of sea level, wave action cut prominent marine terraces that are represented now as by the extensive rolling uplands that border the lagoon (Bell and Scott, 1975).

During low stands of sea level Agua Hedionda Creek eroded a deep valley into the Eocene sediments. As sea level began to rise 18,000 to 20,000 years ago, the advancing sea water filled the valley, forming a deep, open embayment. Gradually this embayment filled in with sediments from the creek and slope-wash from the sides of the valley. Wave deposition and longshore drift formed a partial sand barrier across the bay mouth. In this open lagoon shellfish flourished and were harvested by Indians until sometime in the last millenium when the lagoon became so filled with sediment that it no longer remained continuously open (Miller, 1966).

Geological mapping (Hannah, 1975) indicates that a broad zone of faulting passes across Agua Hedionda Creek about a mile east of the lagoon.

These faults are known to cut marine terraces, but it is not yet clear if they have been active in recent times.

History

Pre-Hispanic

Indian middens and campsites around Agua Hedionda have attracted considerable archaeological interest. They date back more than 9000 years and represent the best known example of the transition from a large game hunting economy (the pre-Desert, San Dieguito culture) to a shellfish and plant gathering economy (the La Jollan culture) (Moriarty, 1967). The transitional phase lasted for approximately 1,500 years followed by a 4,500 year occupation of the La Jollan culture, whose peoples gathered large quantities of shellfish from the large lagoon present at that time. The Yuman-Diegueno culture, which inhabited the area around the lagoon at the time of its European discovery, first occupied the area about 1000 B.C. and harvested many shellfish until sometime in the last millenium (Miller, 1966). Shellfish harvested by the Indians included oysters, cockles and bay scallops.

Hispanic

The first Europeans to view and describe the lagoon were the members of the Portola land expedition en route from San Diego to Monterey during the Spanish occupation of California in 1769. Since their route went inland from the coast to avoid the estuaries and lagoons, they viewed only the back part of the lagoon. Officially it was given the name of San Simon Lipnica, but the soldiers dubbed it Agua Hedionda ("stinking water") apparently due to the presence of stagnant water trapped behind the closed mouth of the lagoon. Following the establishment of the San Luis Rey Mission and until the late 1800's, salt was harvested from the lagoon and the surrounding land was used for cattle grazing. The lagoon, as part of the 13,311 acre Agua Hedionda land grant, was given to Juan Maria Marron in 1842. After Marron died in 1860, his family leased the ranch to Francis Hinton, while retaining the right to gather salt from the lagoon (Moyer, 1969). Hinton assumed ownership in 1865 and upon his death in 1870, the ownership passed to his majordomo, or ranch foreman, Robert Kelley. In 1881 the California Southern Railroad built across the lagoon on land given by Kelley.

Modern

In 1885, the California Southern Railroad was linked to the transcontinental railroad. This began the California land boom which was responsible for the founding in 1887 of the town of Carlsbad, then famous for its mineral water. Within a year there were 300 residents, and fruit trees flourished (Harmon, n.d.). The first accurate map of the area, made by the Coast & Geodetic Survey in 1887-88, shows the lagoon closed at the mouth. Subsequent historical maps by the U. S. Geological Survey in 1898 and the United States Department of Agriculture in 1915 also show the mouth of the lagoon as closed. Land adjacent to the lagoon was used for dry farming and later for vegetables. In 1909-10 the coast highway was constructed, traversing the spit and bridging the mouth of the lagoon for the first time. The highway and bridge were widened and paved in 1915-16, with a 75-foot wide concrete bridge replacing the wooden 25-foot bridge. In the early 1920's, bulb, flower and avocado production began to dominate agriculture around the lagoon, and has continued to do so to the present day. The Interstate Highway 5 was completed in 1967, finally dividing the lagoon into its present sections.

PLATE 6

CHANGES IN WETLAND HABITATS AT AGUA HEDIONDA LAGOON

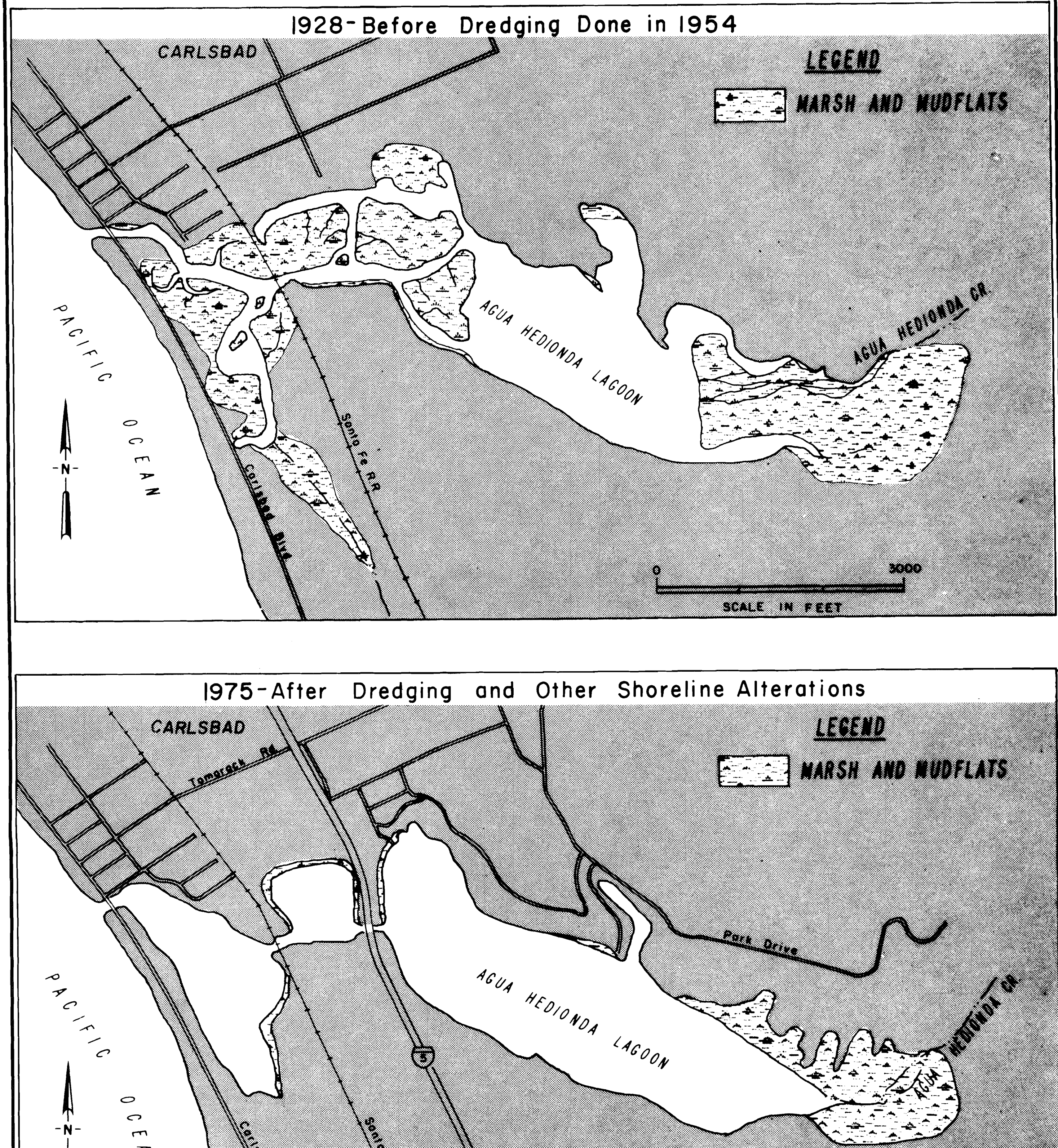
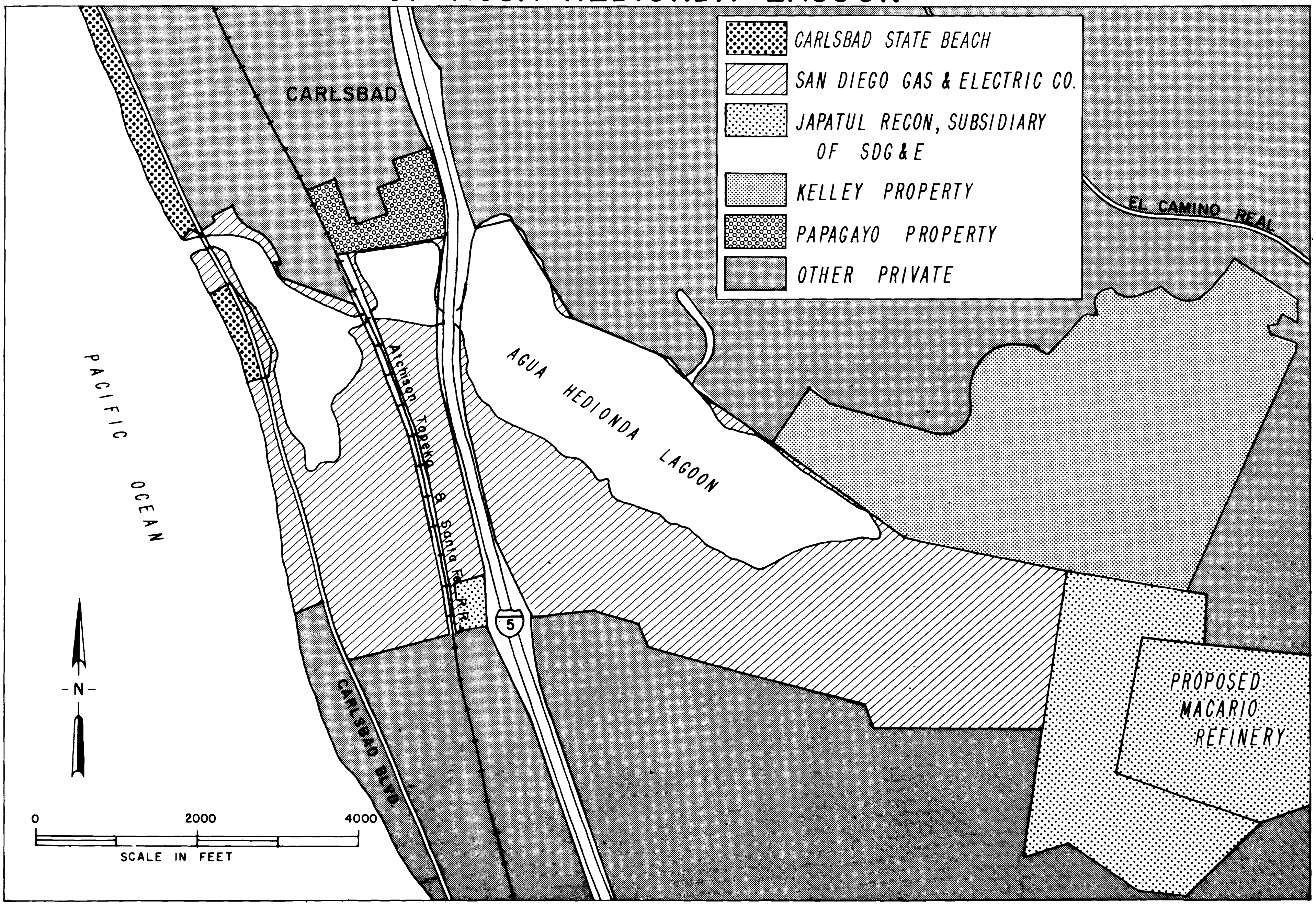


PLATE 7

LAND OWNERSHIP
OF AGUA HEDIONDA LAGOON



to prevent spillage and has been performed without accident to date. Currently 2 deliveries are made per month by vessels of 350,000 and 450,000 barrel capacities. Periodically fuel oil is loaded onto barges from the storage tanks and transported to the San Diego Gas and Electric South Bay Plant located in South San Diego Bay.

Sand has entered the lagoon at the rate of approximately 100,000-150,000 cubic yards per year (Ritter, 1972). To insure an adequate supply of cooling water for the power plant, it has been necessary to remove the sand deposits by dredging the lagoon at approximately two-year intervals.

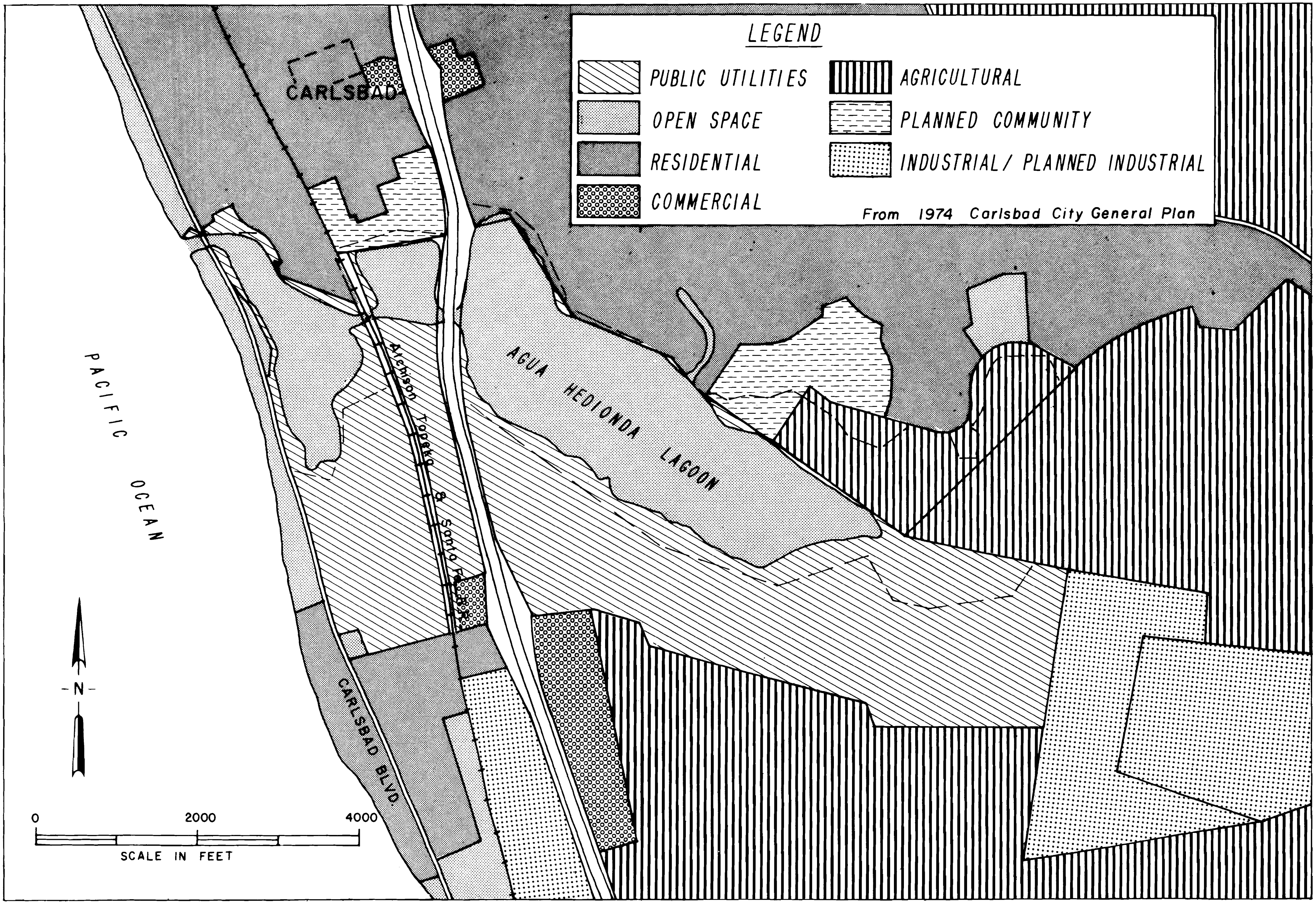
Land Ownership

The San Diego Gas & Electric Company is the owner of the land on the south side of the lagoon, and the land on the north and west sides of the outer lagoon (Plate 7). SDG&E is the record owner of the lagoon; however, there may be a public trust easement over the wetlands. The extent of this easement has not been determined to date.

The actual title of the bed of the lagoon is also in question. The State Lands Division is currently conducting research into the historic title of the lagoon. The State Lands Division has the responsibility for identification of State-owned lands and until their study is completed, it is not possible to state the exact nature and extent of public interest in the lagoon itself.

Of the remaining privately-owned land on the north side, most of it is in small parcels except for 44 acres on the north side of the middle lagoon owned by Papagayo properties and an 425-acre parcel at the north-east end of the inner lagoon owned by Allan Kelley. All of this land is within the city limits of Carlsbad, while the land just inland from

PLATE 8
LAND ZONING AND USE AT AGUA HEDIONDA LAGOON

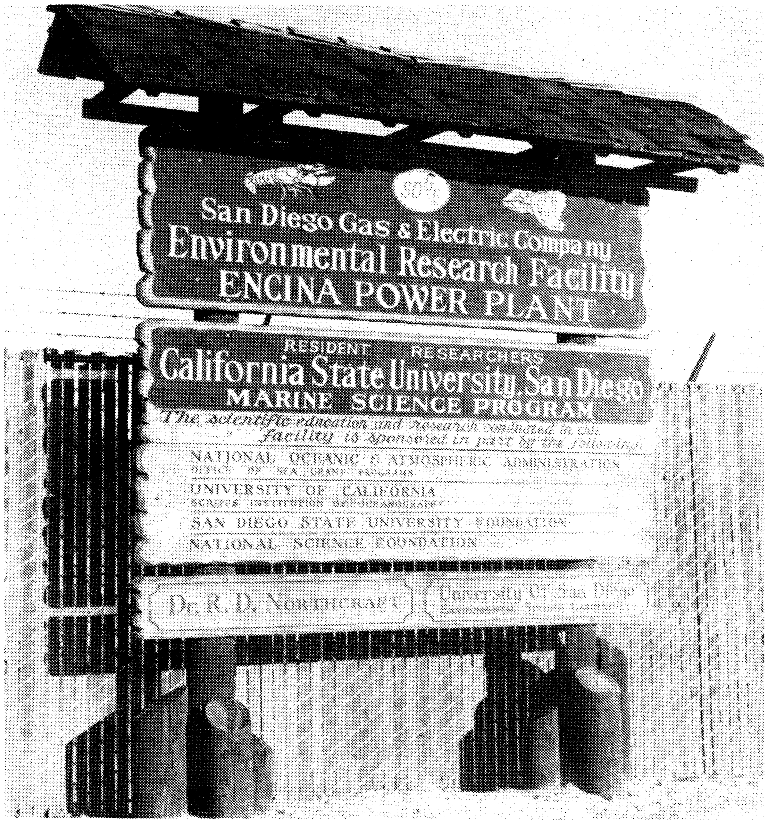


the lagoon is unincorporated land. The ocean-fronting Carlsbad State Beach, just north of the northern jetties is owned by the State of California.

Land Use

Most of the land and water in and around Agua Hedionda Lagoon lies within the city limits of Carlsbad. The zoning plan adopted when the City incorporated in 1952 indicates the lagoon as "open space," the property to the south of the lagoon for public utilities and the balance of the environs as residential, agricultural and industrial (Plate 8). In 1974 the City of Carlsbad adopted a general plan for all lands incorporated within its city limits and is now in the process of drawing up a specific Agua Hedionda area plan that will alter certain aspects of the General Plan, and that will conform with the environmental impact review process of the California Coastal Zone Conservation Commission regional plan (Prop. 20). This specific City plan for Agua Hedionda and its environs will call for rezoning the lands south and east of the inner lagoon to open space.

At present the utility company leases (for a token sum) the water area of the middle and inner lagoons to the City that allows several types of water-oriented recreational activities in those lagoon sections. Part of the middle lagoon is leased to the YMCA for an aquatic recreational camp, and limited recreational activities are allowed there also. Recreational opportunities are more restricted in the outer lagoon, because it is primarily used as a water intake basin for the power plant. However, scientific research, such as experimental mariculture, is permitted and public fishing has not only been allowed in the outer lagoon, but encouraged by public parking facilities provided by the San Diego Gas and Electric Company.

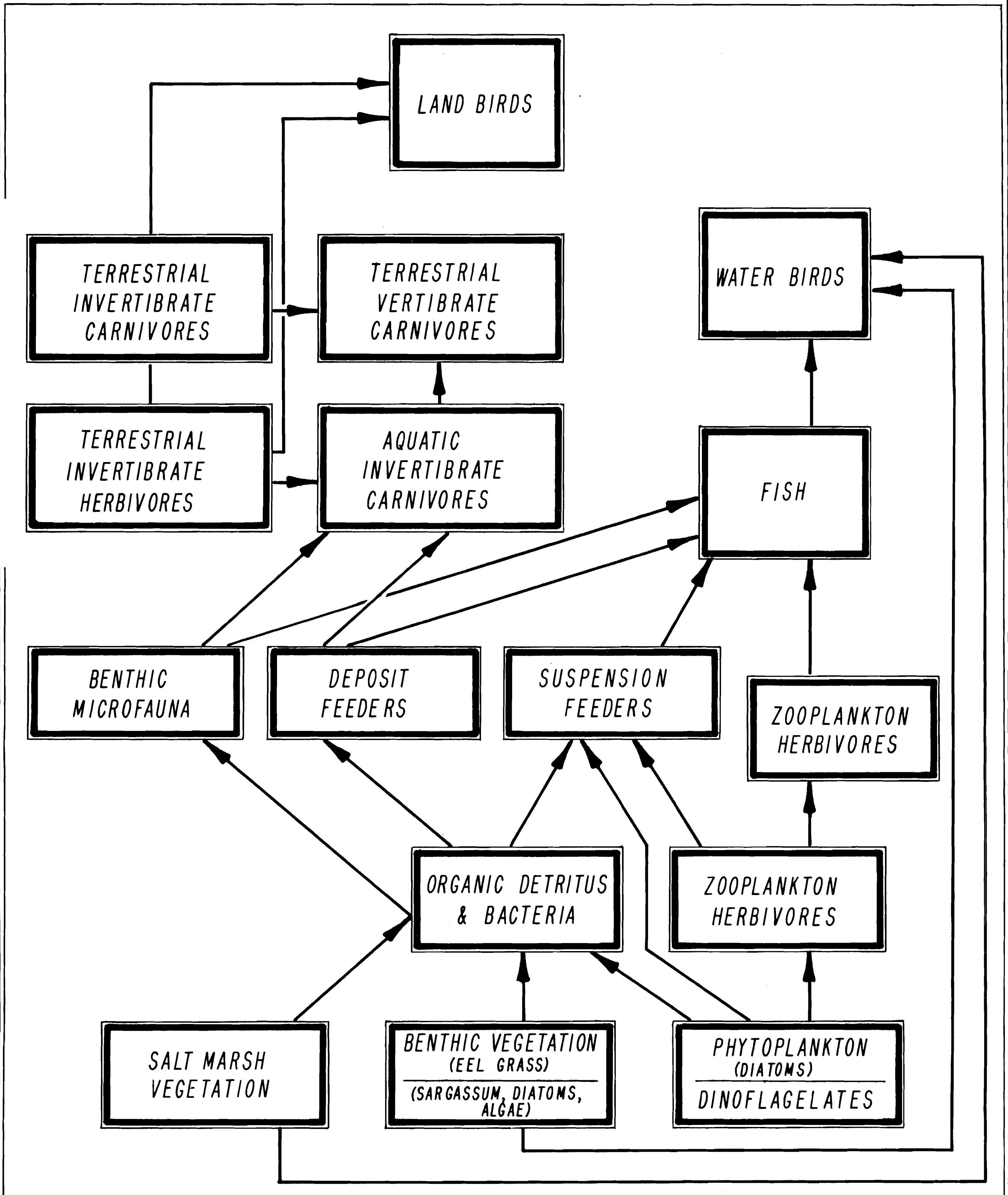


S.D.G.,&E. not only allows educational and scientific use of the outer lagoon, that serves as a cooling water basin for their power plant, but also provides a very popular fishing access.

Two private boating facilities are located on the north side of the inner lagoon, but primarily the north area is used as residential housing. Some agriculture exists to the east of the lagoon and on the table lands to the south.

PLATE 9

AGUA HEDIONDA LAGOON ECOSYSTEM



RESOURCES

Ecology and Habitats

The science of ecology is concerned with the relationships between organisms and their environments. One of the most fruitful methods of gaining an understanding of the often times bewildering complexity of these relationships is to introduce the concept of the ecosystem (Plate 9).

The abiotic (non-living) environment and the biotic communities (living organisms) occurring in that environment, together, make up the ecosystem. An ecosystem may be large or small, but to be considered a unit it must be able to be logically circumscribed. Very few ecosystems are entirely self contained. Typically, there are transfers of energy and/or materials both in and out of the systems, but these "inputs" and "out-puts" can be recognized and, ideally, quantified.

The commonly used term "habitat" referring to "where an organism lives" is but part of the ecosystem. A bed of eel grass, with producing plants, attached and associated animals and micro-organisms, and with energy and material interaction, is both a habitat and a small ecosystem. In a broader sense the entire lagoon is also an ecosystem with its circulating water and its contained plant and animal plankton recycling material from water to sediment and back again in complex biogeochemical cycles. Similarly the adjoining salt marsh and upland coastal sage scrub community are each subsystems with greater or lesser interaction with the larger lagoon ecosystem.

PLATE 10

A DIAGRAMATIC VIEW OF AGUA HEDIONDA LAGOON

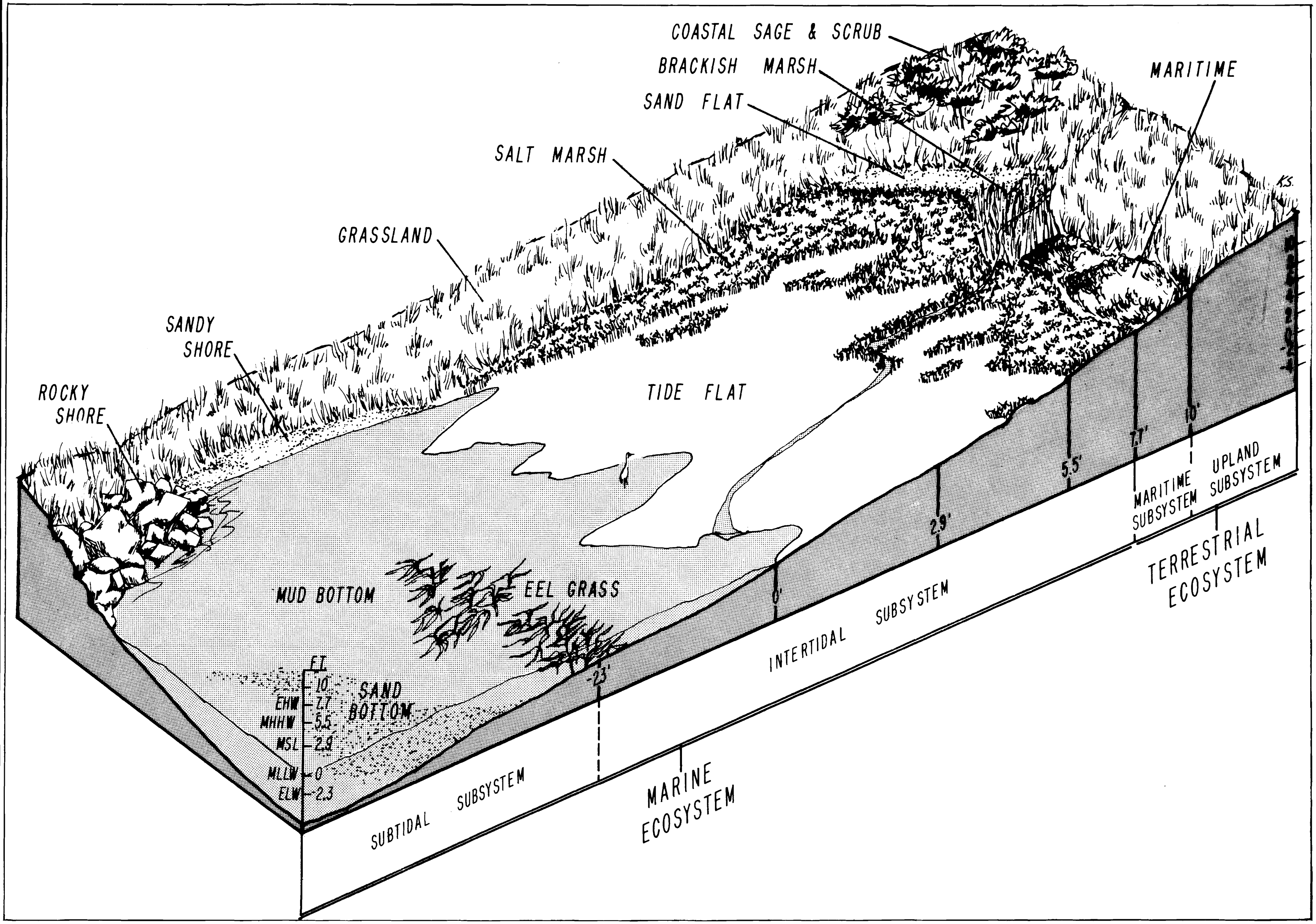
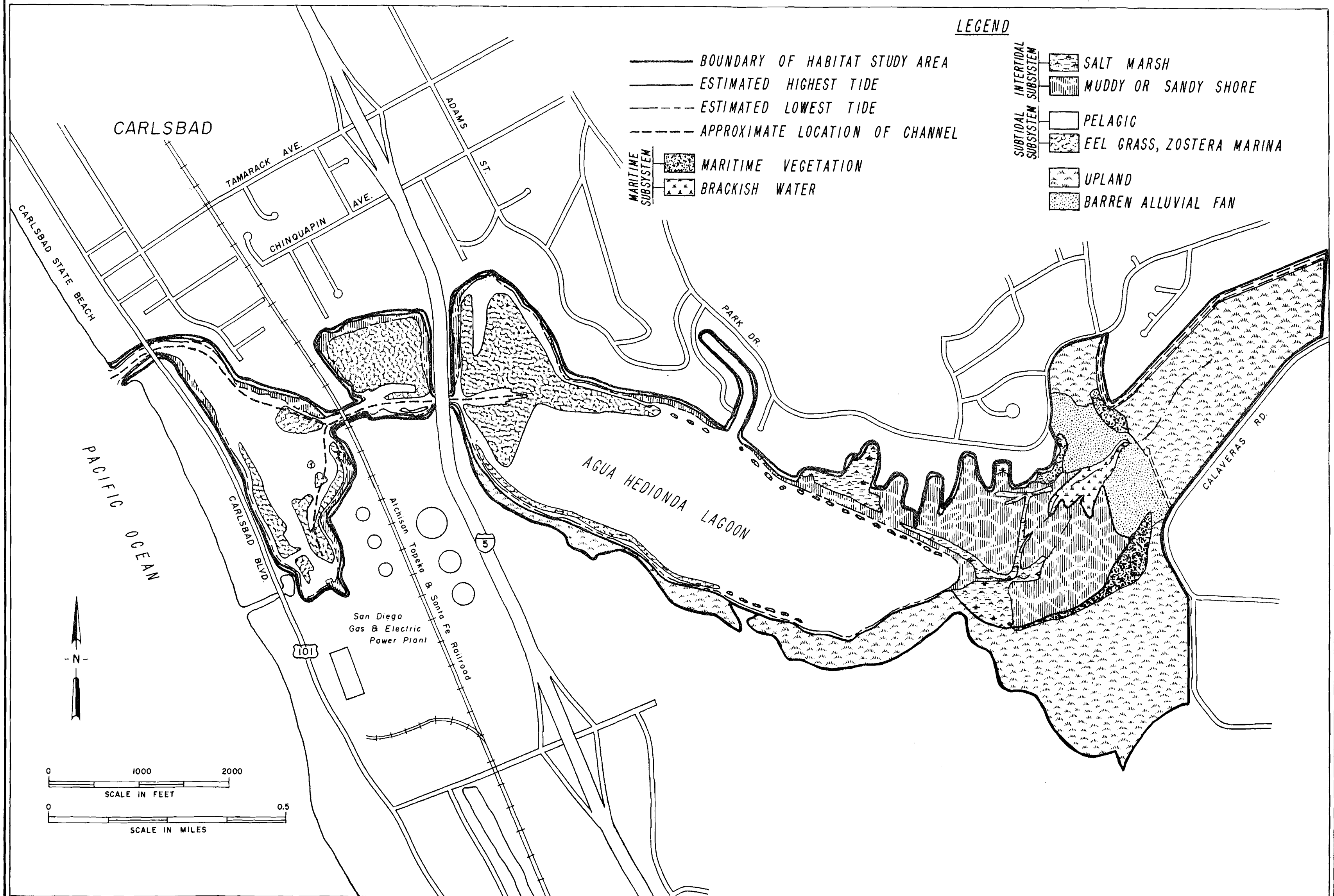


PLATE II

AGUA HEDIONDA LAGOON HABITAT TYPES



In order to better understand the ecological picture, Agua Hedionda Lagoon may be divided into two major ecosystems: marine and terrestrial. Each of these, in turn, may be divided into smaller eco-subsystems and habitats as follows (see Plates 10 and 11).

TABLE 1. Areal Extent of Lagoon Habitats

I.	Marine Ecosystem	388 acres total
	A. Subtidal Subsystem	
	1. Open Water	
	2. Rock Habitat	2 "
	3. Sand Habitat	169 "
	4. Mud Habitat	55 "
	5. Eel Grass Habitat	70 "
		296 acres
	B. Intertidal Subsystem	
	1. Rocky Shore Habitat	4 acres
	2. Sandy Shore Habitat	2 "
	3. Muddy Shore Habitat	70 "
	4. Salt Marsh Habitat	16 "
		92 acres
II.	Terrestrial Ecosystem	154 acres total
	A. Maritime Subsystem	
	1. Brackish Water Habitat	5 acres
	2. Maritime Habitat	19 "
	B. Upland Subsystem	130 acres total
	1. Grassland	
	2. Coastal Sage Scrub/Chaparral	
	Total Lagoon and Environs Studied	542 acres

Marine Ecosystem

The nearshore marine ecosystem can be divided into the following subsystems: subtidal and intertidal.

Subtidal Subsystem

The subtidal environment is that region continually underwater. In Agua Hedionda Lagoon this subsystem extends from a maximum water depth of 40 feet up to the lower boundary of the intertidal subsystem, *i.e.* extreme lower low water (ELLW) (-2.3 feet). This environment may be further divided on the basis of substrate type into the following habitats: 1) open water habitat, 2) rock habitat, 3) sand habitat, 4) mud habitat, and 5) eel grass habitat.

Open Water Habitat

There is 296 acres[1] of water surface area at extreme low water. This habitat is occupied by two ecologic groups separated on the basis of their ability to counteract large scale water movements. These are the plankton and nekton.

Plankton is made up of phytoplankton (plants) and zooplankton (animals), both drifting relatively helplessly in large scale flood and ebb currents flowing into and out of the lagoon. The phytoplankton are the principal producers (Plate 9) in this system and consist predominantly of diatoms and dino flagellates. Because of the high degree of turbulence and greater entrapment of water in the lagoon, most of the diatom species found in the plankton are not true planktonic species but instead are typical benthic, or bottom-dwelling, species that can function in either habitat. A preliminary list[2] of the diatom species found in the lagoon is included (Appendix A).

Zooplankton consists of those species (holoplankton) that spend their entire lives among the plankton and those larval stages (meroplankton) that eventually metamorphose into various adult benthic organisms,

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[1]Water, of course, covers the various substrates comprising the subtidal subsystem, hence surface acreage equals the sum of the substrate acreages (see Table 1).

[2]At present, studies are being conducted on the structure of the diatom communities at Agua Hedionda (Bradshaw, unpubl.).

such as worms, barnacles and clams, etc. A detailed study of Agua Hedionda Lagoon 200-plankton has been carried out (Bradshaw and Estberg, 1973) (Appendix B). The most abundant group throughout all sections of the lagoon were the copepods, especially the species *Acartia, clausi, Euterpina acutifrons* and*Oithona oculata.* The species composition and abundance were generally similar to those found in the shallow coastal waters of southern California, although numbers of worm and clam larvae were higher than usually found in the ocean. No species in the lagoon appeared to be more abundant at one location than any other; in fact, the zooplankton appear to be rather evenly distributed throughout the lagoon from the mouth to the inner-most portion. This well mixed condition presumably resulted from the large tidal incursions occurring at the time of the survey.

The relatively high concentrations of worm and clam larvae in the zooplankton correspond with the relative importance of the adults in the bottom sediments. Since reproduction and the subsequent development of larval forms is a seasonal phenomena in many regions, the mero plankton/ holoplankton ratio might be expected to show distinctive seasonal changes. However, since in this study only winter samples were analyzed, the presence or lack of seasonal periodicity is unknown. The high density of 29,400-56,800 individuals of all species per cubic meter provides a rich food source for many filter feeding organisms among the benth and nekton communities.

Another ecological component of the open water habitat is the nekton, represented in the lagoon by the fishes and larger free-swimming vertebrates. Twenty-two species in this classification have been caught by trawl, observed by divers or reported by fishermen (Bradshaw and Estberg, 1973). Occasional harbor seals have also been observed within the outer lagoon.

Rock Habitat

An estimated 2 acres of this habitat occur within the lagoon, most of it located on the underwater portions of the rock entrance jetty and the rip-rap lining much of the shore, particularly of the outer lagoon. Organisms occupying this environment include these normally found on rocky reef outcrops and other hard, underwater substrates such as boat bottoms, etc. Most are attached sessile organisms, e.g. attached macro algae and various suspension (filter) feeders (tunicates, sponges, hydroids, mussels, bryozoans, etc.). Other organisms are more mobile, e.g. grazers (chitons, limpets, abalones, snails, etc.) and associated fish such as garabaldi, senorita and black perch and larger scavenging or predatory animals (lobsters, crabs, whelks, starfish, etc.). The most abundant attached algae[1] is *Sargassum muticum*, an introduced species from Japan (a pseudoperennial brown algae) which, unlike eel grass, can attach directly to rock surfaces. During the summer this species dies back to its holdfast, but throughout the remainder of the year it is very conspicuous. *Sargassum* has many associated attached algae and animals. Juvenile individuals of giant kelp also are common in the outer lagoon but apparently the environment does not permit growth to maturity. Because many young giant kelp plants become established in the lagoon, there must be a continual recruitment from offshore.

A most interesting, unexpected colonist from the rocky subtidal habitat is a small surf grass,[2] a stand which is established at the channel entrance leading from the inner lagoon to the middle lagoon. These

[1]A check list of algae is found in Appendix C.

[2]Scientific names of flowering plants are found in Appendix D.

Dredging the lagoon to create an adequate tidal prism, ensures cooling waters for the power plant, and has also created a healthy marine ecosystem.

plants add to habitat heterogeneity and productivity and furnish valuable detritus to other subtidal habitats.

The rock habitat community composition varies from an open ocean type found on the submerged entrance jetties (Woodward Envicon, 1973) to a sheltered bay-lagoon assemblage on the underwater rip-rap in the lagoon. The factors causing this change in species composition are not well understood but presumably they involve greater stresses imposed by more extreme values of salinity, temperature, dissolved oxygen etc. in the lagoon.

Sand and Mud Habitats

Soft bottom sediments are made up of either sand (169 acres) or mud (55 acres) or various mixtures of each. Which of these substrate types prevails depends mostly on source material and physical sorting factors. The outside soft bottom (sand) habitat located adjacent to the entrance jetties has been studied by Woodward Envicon Inc. (1973). There, high wave action, intense bottom currents and surge, associated with the nearshore turbulent zone where only the heavier sand particles can accumulate, have resulted in the development of a distinctive ecological community of infauna such as Pismo clam and other burrowing invertebrates.[1]

Within the lagoon decreased wave action and a more complex current circulation pattern, with high tidal current velocities in some areas and slow water movement in other portions, have resulted in a complex mosaic of different soft bottom sediments. Where tidal currents are strong only coarse sand can remain and where currents are weaker the finer sediments (silt and clay) occur.

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[1] A checklist of invertebrates and the habitats in which they live may be found in Appendix I.

Within the inner lagoons, sand and mud habitats are generally found in those areas not covered by eel grass. In the outer lagoon near the ocean entrance the strong currents in the middle of the channel have not allowed eel grass to develop but instead have caused the formation of many large current ripples and depressions in the sand where considerable quantities of drift algae (giant kelp, feather boa kelp, etc.) and associated grazing organisms may be found. Nearby on the channel edges, where currents are less severe, dense accumulations of the olive shell, a marine snail, overlie extensive clam beds. In calm water further within the lagoon and below the lower distribution of eel grass, the sand surface is often covered with a fine diatom mat. Many detrital feeding worms, ghost shrimp, and clams are found in the sand (infauna). Larger organisms (occasionally in high concentrations) seen moving about on the sand surface (epifauna) include the spotted sand bass, the bubble shell snail, various starfishes, the sea pansy and the purple sea urchin.

A detailed community analysis (Bradshaw and Estberg, 1973) has revealed two fairly distinctive soft-bottom zooplankton communities within the lagoon, each named after the two most dominant members. These are: 1) the common littleneck clam-eggshell cockle (*Protochaca staminea-Laevicardium substriatum*) community occupying regions of relatively larger grain size, and 2) the snail-worm (*Cylichna alba-Haploscolopolis elongatus*) community inhabiting an environment of smaller grain sizes. Community composition appears to be related primarily to the feeding manner of the assemblage; the common littleneck-eggshell cockle community being principally suspension or filter feeders, and the snail-worm community consisting mostly of detritus feeders. This basic difference in feeding type appears to be, in turn, related to abiotic factors mentioned above. Where wave and current action are low, small sediment grains cannot be moved and sedimentation of silt particles together with small bits of detritus proceeds readily. The abundant detritus, together with associated bacteria, provides a rich source of food for detritivores. However, high turbidity of the water column readily clogs the straining devices of suspension feeders and tends to eliminate them from this habitat. The coarser sand, characteristic of the higher energy environments, indicates an area where fine-grained sediments and detritus particles cannot accumulate. Here detritus feeders are sparse and the predominant feeding mode is suspension feeding on the more abundant plankton.

Eel Grass Habitat

About 70 acres of eel grass are found in almost pure beds in the quiet waters of all three lagoon sections (Plate 11). The largest beds mostly occur in the outer and middle lagoons. Distribution of eel grass in Agua Hedionda appears to be principally controlled by the stability of the substrate and by the necessity of water clarity for efficient photosynthesis.

The eel grass community, once established, maintains stability of bottom and shorelines and provides large amounts of organic matter as direct food for grazing animals and indirectly as detritus for sediment feeders. In addition to its food value, eel grass provides shelter for many species of small fish and invertebrates, such as pipefish, crabs and shrimp, as well as an attachment substrate for a multitude of epiphytic algae and invertebrates (filamentous red algae, diatoms, coralline algae, bryozoa, serpulid worms and scallops). Red algae, sea lettuce and such drift plants as the feather boa kelp, giant kelp and other outer coast species are often entangled about the base of the eel grass.

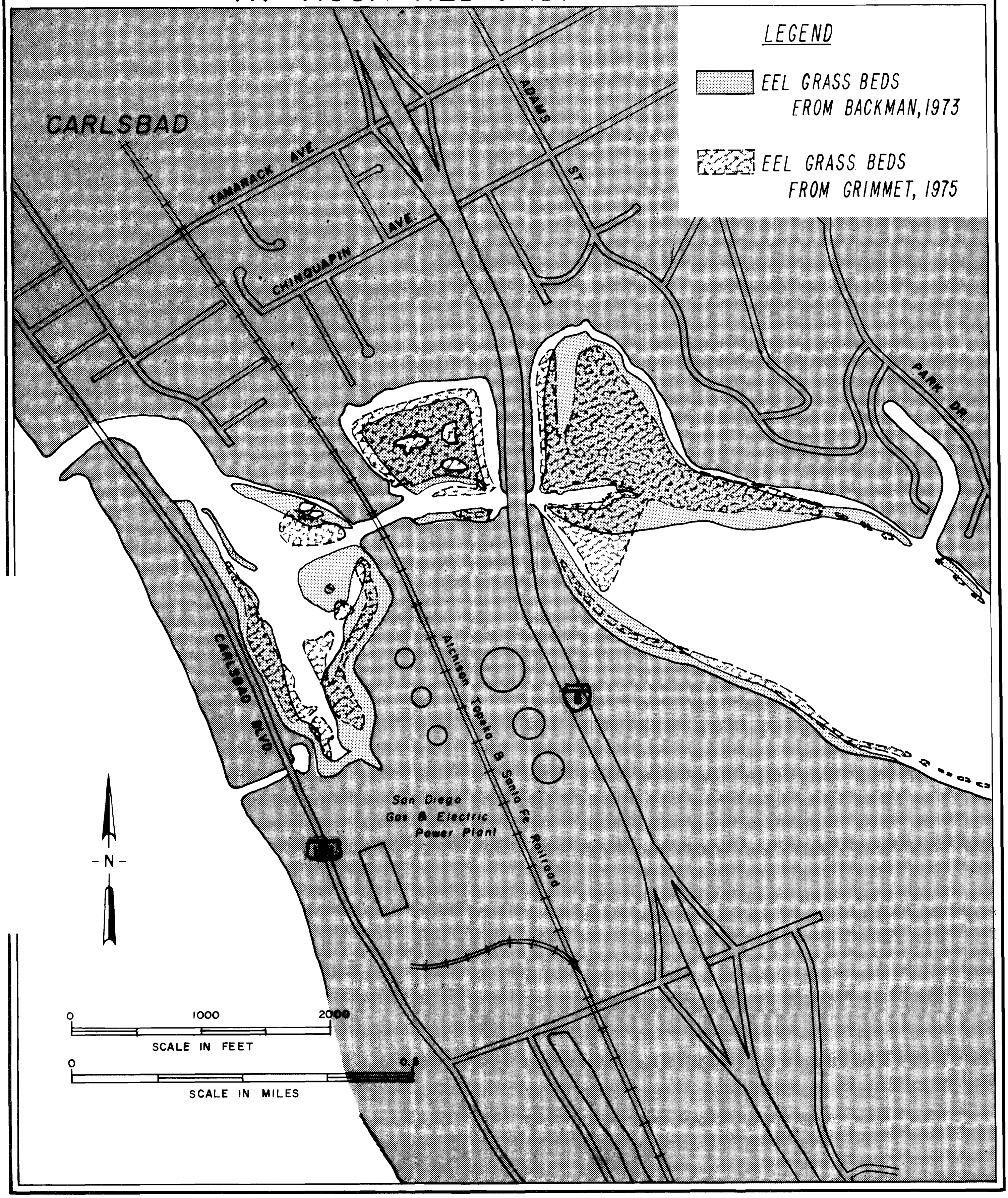
The infauna associated with eel grass includes various arthropods, clams, polychaete and nemertean worms, etc. Although some are detrital feeders (such as the polychaete worm *Haploscolopolis*) or predators (various nemertean worm apecies). Some suspension feeders, for example, littleneck clams, appear to be associated with eel grass habitat. Many species from these latter groups, however, may be found on the sand bottom outside of eel grass habitat.

Because of the prime importance of eel grass in the marine ecosystem, a brief discussion of its ecological requirements may be useful. The sediment in which eel grass grows is made up of a mixture of sand, silt and clay. In most eel grass areas of Agua Hedionda Lagoon sand makes up between 50-100% of the sediment. It has been suggested that the relative composition of these three-size fractions determines eel grass morphology. Short stocky plants are associated with type soils and longer, thinner plants, associated with more sandy sediment (Burkholder and Doheny, 1968).

The upper limit of eel grass in Agua Hedionda Lagoon is at a depth of slightly above 0 feet (MLLW): the lower limit lies at about 10 feet, with optimum biomass at about 3 feet (Bradshaw and Estberg, 1973). The upper limit appears to be related to the amount of dessication the plant can tolerate during low tide while the lower limit is related to the minimum amount of light necessary for efficient photosynthesis.

PLATE 12

CHANGES IN EEL GRASS BEDS AT AGUA HEDIONDA LAGOON



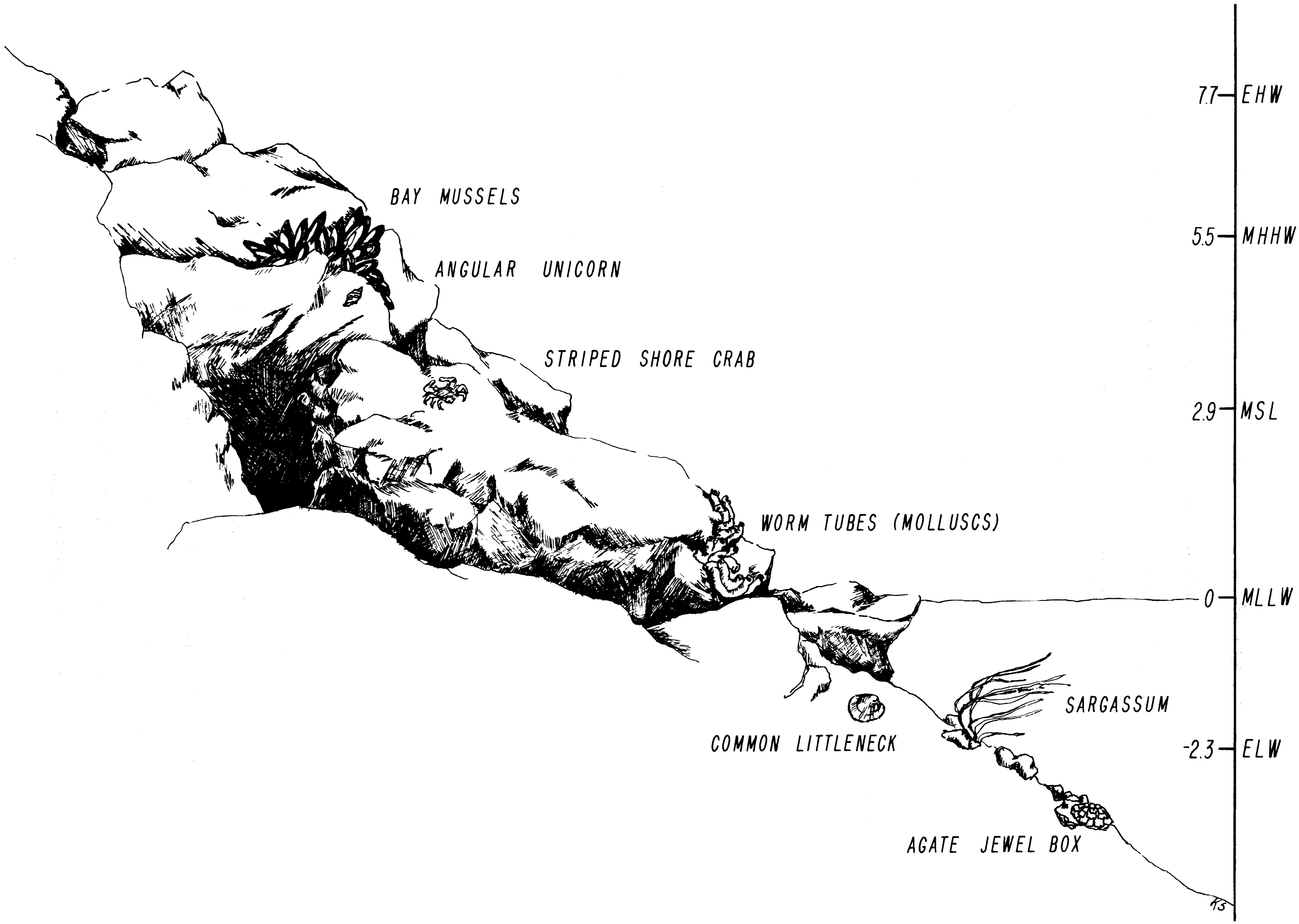
The areal coverage of the eel grass meadows as measured during the summer of 1975 has changed considerably from the last reported survey in the winter of 1972-73 (Bradshaw and Estberg, 1973) (Plate 12). The latest survey records a percentage coverage of 18.7% in the outer lagoon; 58.8% in the middle lagoon and 12.7% in the inner section. The change since the earlier survey in the proportionate area covered by eel grass is -41.2% for the outer section, +42.8% for the middle section and -16.8% for the inner section. By multiplying these changes in areal coverage by the total estimated biomass in 1972 (7.38 metric tons dry weight) (Bradshaw and Estberg, 1973) an estimated 6.26 total metric tons dry weight was obtained for the 1975 survey.

The changes in eel grass coverage in the lagoon sections appear significant. The decrease in coverage in the outer section may be due to maintenance dredging activities disrupting the beds while the increase reported in the middle section may be due to increased shoaling and the resulting formation of optimum conditions for the eel grass community.

Although eel grass supports a distinct faunal assemblage, it is still part of the total lagoon-nearshore ecosystem. Williams (1973) estimated that although eel grass covers only 17% of the bottom area in Beaufort Estuary, Louisiana, it contributes 64% of the combined total productivity of that estuary's ecosystem. In some cases, up to 45% of eel grass productivity may be carried to adjacent ocean ecosystems in the form of detritus (Theyer *et al.*, 1975). This degree of disproportionate, but positive, importance probably holds for Agua Hedionda Lagoon as well. As eel grass is broken down, detritus further increases in

PLATE 13

ROCKY HABITATS



food value as a result of bacterial action increasing the amino acid nutrients out of the sediments' diffusion into the water column and subsequent uptake by algal epiphytes.

Intertidal Subsystem

The intertidal environment of the marine ecosystem is that zone under tidal influence, being exposed at low tides and inundated during high tides. The intertidal area can be delineated at Agua Hedionda Lagoon between ELLW (-2.3 feet) and EHHW (+7.7 feet). This intertidal subsystem may, on the basis of degree of wave action, tidal exposure and substrate be divided into four habitats: 1) rocky shore, 2) sandy shore, 3) muddy shore and 4) salt marsh.

Rocky Shore Habitat

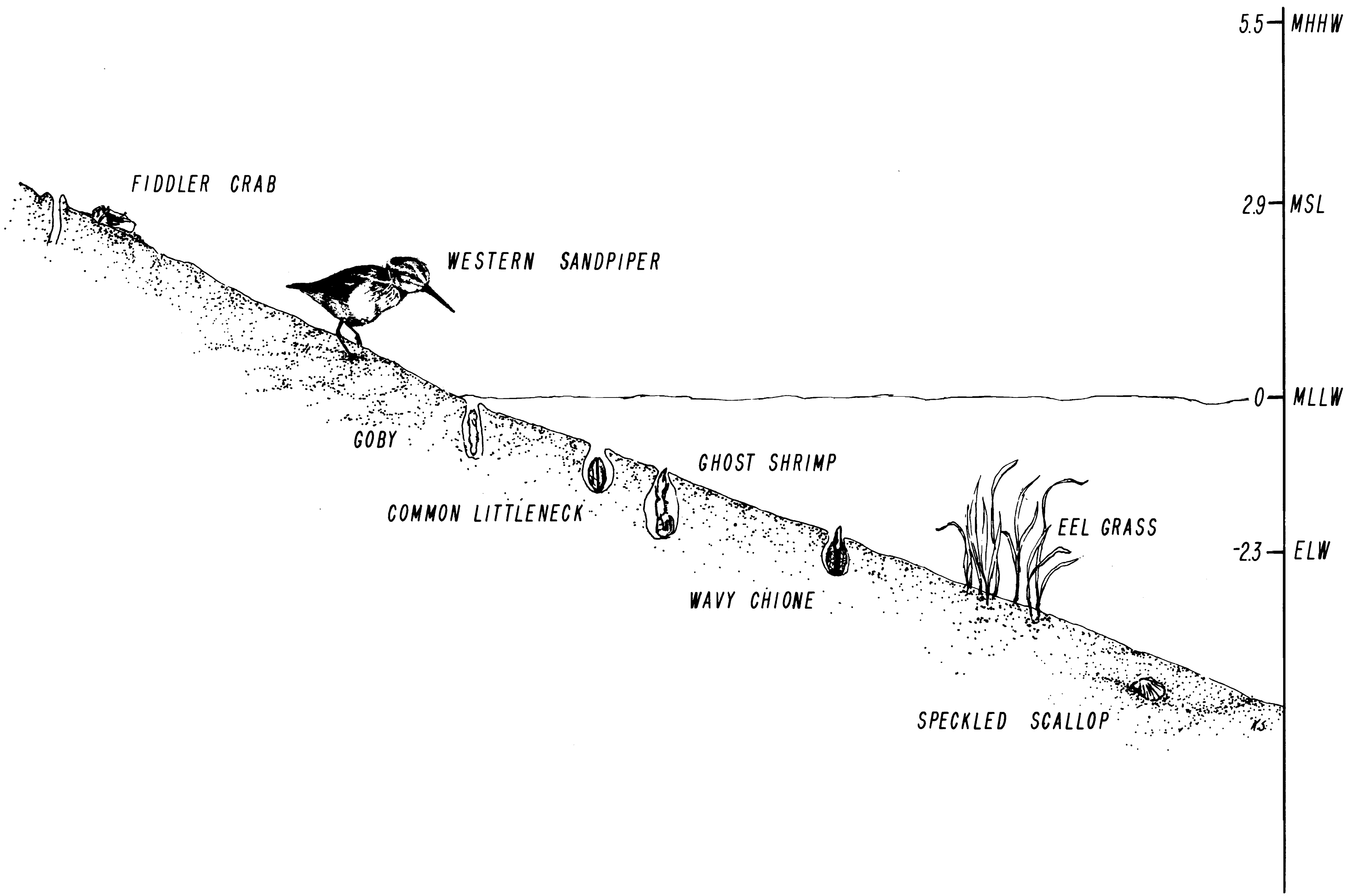
This habitat, comprising about 4 acres, is best developed on the rock jetties at the entrance, on the rock rip-rap lining the shore and on pilings at various locations throughout the lagoon. The hard substrate provides a good attachment surface for many of the same types of filter feeders, grazers and predators that are found in the subtidal hardbottom habitat. In addition, there occur many specialized forms in the high intertidal zone that are well adapted to long periods of dessication, that is, when the tide is out. This zone is populated by many forms seeking a refuge from the many predators (starfish, whelks and fish etc.) that abound in the subtidal subsystem below. Species distribution and the pattern of intertidal communities on rocky shores bring attention to the interesting and complex phenomenon of intertidal zonation (Ricketts and Calvin, 1968)(Plate 13). It is sufficient to say that various species appear to respond to various degrees of dessication and submergence resulting from the pattern of the tides in such a way that they form a vertical series or strata of communities. At Agua Hedionda, low tide, mid tide, high tide and splash zone communities may be recognized.

The rocky intertidal communities on the jetty differ from the rocky communities within the lagoon. Because of the greater wave action on the jetty, the intertidal zones there have a wider vertical range than those occurring within the lagoon. Although many of the open coast rocky intertidal zone organisms have extended their range into the outer lagoon, those that require a large splash zone, as do the limpets and periwinkles, are rare within the calmer lagoon waters. Other more subtle factors related to the relative influence of "open ocean" versus "lagoon" conditions appear to affect the species make-up of this community (Appendix I). For example, patches of California mussels are found interspersed with bay mussels on the jetty, but further inside the lagoon, only the bay mussel is found. Predation by the deeper dwelling angular unicorn and by the giant starfish appears to limit the lower extent of the bay mussel in this area. Other species, for example the tube snail, appear immune to this predation and grow abundantly on both intertidal and subtidal rocks within the outer lagoon section. The cardinate dovesnail (vegetarian) usually found on eel grass, lives on green algae that covers the low intertidal rocks.

The rocky intertidal community changes still further as the ocean influence is lost in passing toward the extreme inner lagoon sections. Diversity decreases, as many of the intertidal species common in the outer lagoon do not occur further inland; although more tolerant forms,

PLATE 14

SAND HABITATS



such as the striped shore crab, the bay mussel and the yellow bubble shell, are still abundant. In addition small numbers of clams (common littlenecks and smooth chiones) are found burrowing between the rocks.

Sandy Shore Habitat

Wave action exerts a major control over the distribution of sand dwelling animals because it influences many important substrate features, including stability, particle size, drainage, oxygenation and organic content. Along the outer ocean beach strong wave action limits the number of species that can occur. Survival is possible in the lower intertidal zones for burrowers, such as the sand crab and the bean clam, and in the upper levels for such air breathers as beach hoppers and pillbugs.

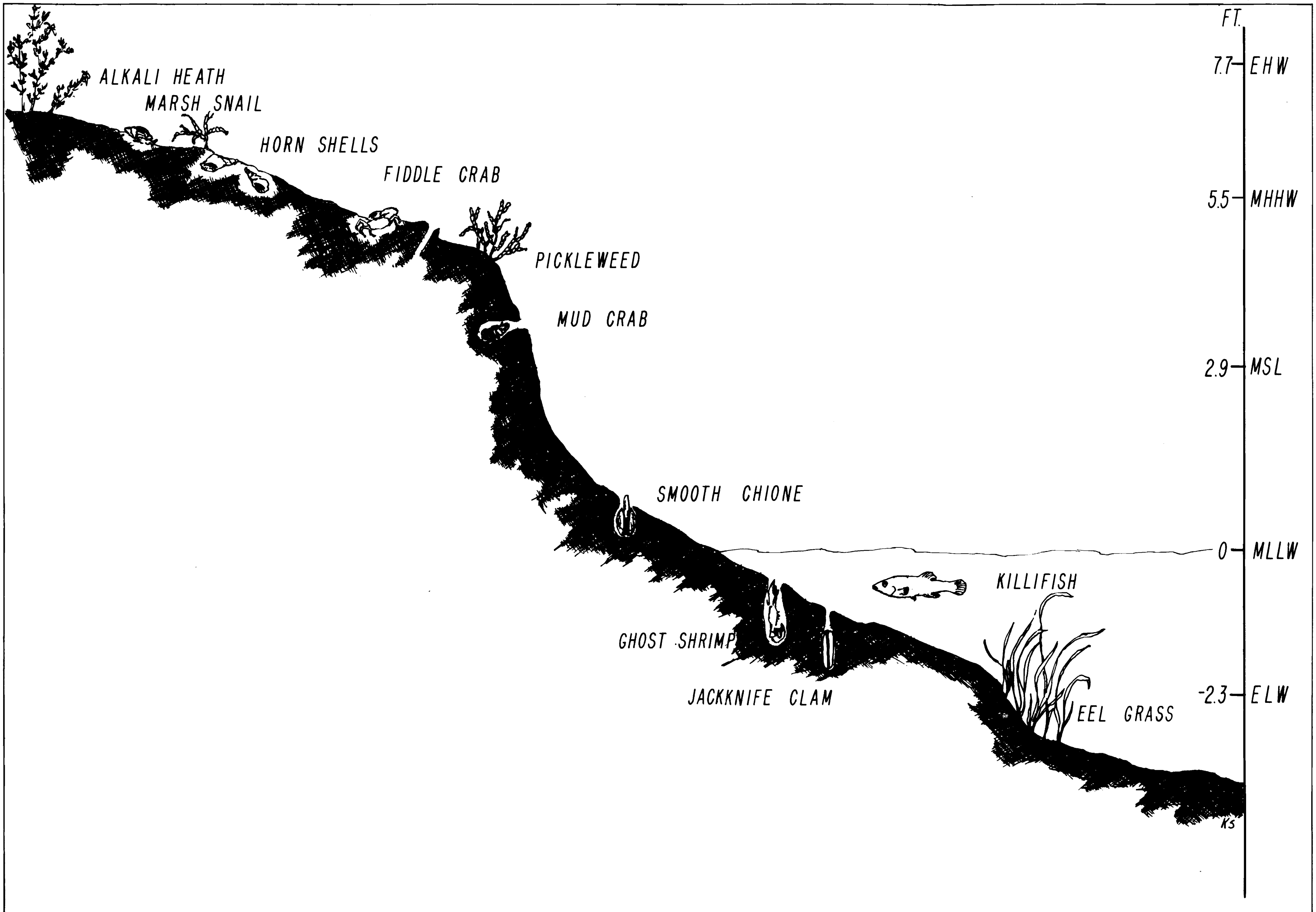
With decreasing wave action toward the inner reaches of the lagoon, smaller particles and organic matter are deposited and only a superficial layer is disturbed. Below this layer the sandy substrate is quite stable and blackening of lower layers indicates the presence of hydrogen sulfide which is produced by anaerobic sulfate reducing bacteria in a deoxygenated medium. The burrowers here are dependent upon dissolved oxygen being pumped through the burrow or upon extrusion of the gills above the sand surface. Organisms common to this sandy habitat are the common littleneck and Washington clams, polychaete worms, amphipods, sand and fiddler crabs. There are approximately 2 acres of this habitat (Plate 14).

Muddy Shore Habitat

"Mud" refers to sediments containing a high proportion of organic matter and silt or clay particles. Since the finest particles settle only from still water, mud shores are found away from wave action and swift currents. Muddy shores usually have little slope and extensive areas

PLATE 15

MUD HABITATS



of "mudflat," an integral part of this type of habitat, may be exposed as the tide recedes. Under these conditions organic debris readily settles and the organic content of the mud may reach 5%, with no oxygen and consequently a high proportion of sulfide. Burrowing is easy and burrows and tubes are stable for species such as the jacknife clam and ghost shrimp and gobies (Plate 15).

The tidal mudflats occur above the upper limit of the subtidal system (ELLW = 2.3') and extend to the lower limit of the salt marsh vegetation. Much of this habitat has been reduced due to the extensive dredging completed in 1954. However, sedimentation, particularly in the extreme eastern portion of the inner lagoon, and slumping and redeposition elsewhere have newly-produced localized sand or mudflats that emerge at extreme minus tides. At present, tidal flats extending from extreme low water to the lowest growing salt marsh vegetation make up approximately 70 acres. In most areas the lowest portion of the tidal flat up to MLLW (0') is covered by eel grass that extends upward from the subtidal region. On the mudflats above the eel grass and below the salt marsh, patches of green algae (*Enteromorpha* and sea lettuce) are seasonally abundant. Although the upper portion of this habitat may appear barren, in reality it is generally teeming with polychaete worms and other invertebrates. The fact that this habitat is one of the areas most frequented by vast numbers of probing shorebirds at low tide and small fish at high tide is an indication of its food value and importance to wildlife.

Salt Marsh

The exact lower level of the salt marsh varies depending upon the plant species and other environmental factors such as sediment type and amounts of freshwater drainage. In Agua Hedionda Lagoon, the lowest occurring salt marsh species is perennial pickleweed. This halophytic plant dominates the entire marsh between mean high water (MHW) or +4.8 feet and extends upward to the upper reaches of tidal influence or extreme high water (EHW +7.7 ft.) and in some cases, higher.

Floristic composition of the salt marsh also varies with elevation since different species are strongly influenced by tidal movements that determine the degree of submergence and exposure to which the shoreline is subjected. Detailed studies by Mudie (1970) in San Diego Bay, as well as by Stevenson and Emory (1958), Purer (1942), Vogel (1966) and MacDonald (1969) have provided much of the bases for the differentiation of plant communities in the southern California region.

Although at present the shoreline of most of the lagoon is too steep for development of extensive salt marsh, some salt marsh plants, such perennial pickleweed, sea blite, alkali heath, saltgrass and jaumea, occur as a thin fringe along the shore above MHW. More than 95% of the saltmarsh, however, consists of several small, remnant, "pocket" saltmarshes (less than 10 acres) along the northeast shore of the inner lagoon and a more extensive marsh at the extreme eastern end of the lagoon, making a total of about 16 acres of saltmarsh habitat at Agua Hedionda.

The pocket marshes are very limited in plant diversity. Perennial pickleweed is dominant with saltgrass present in areas with better drainage and some fresh water seepage. The upper margins of these small marshes have been land filled and the low diversity is possibly due to steep slopes and human interference (Mudie, 1974). Perennial pickleweed is by far the most dominant species throughout the salt marsh habitats, but small patches of alkali heath and jaumea occasionally occur together with the pickleweed, particularly along the creek banks where Agua Hedionda Creek empties into the lagoon, and inland from the mudflats at the eastern end of the inner lagoon.

The inlet of Agua Hedionda Creek, near its junction with the lagoon, is also dominated by perennial pickleweed; but the salt marsh there begins to grade into a fresh/brackish water marsh community approximately 1/4 mile upstream where tidal influence and salinity drop off rapidly. On either side of the watercourse is an extensive barren salt pan with occasional clumps of perennial pickleweed and glasswort interspersed with annual iceplant and sand spurrey.

Terrestrial Ecosystem

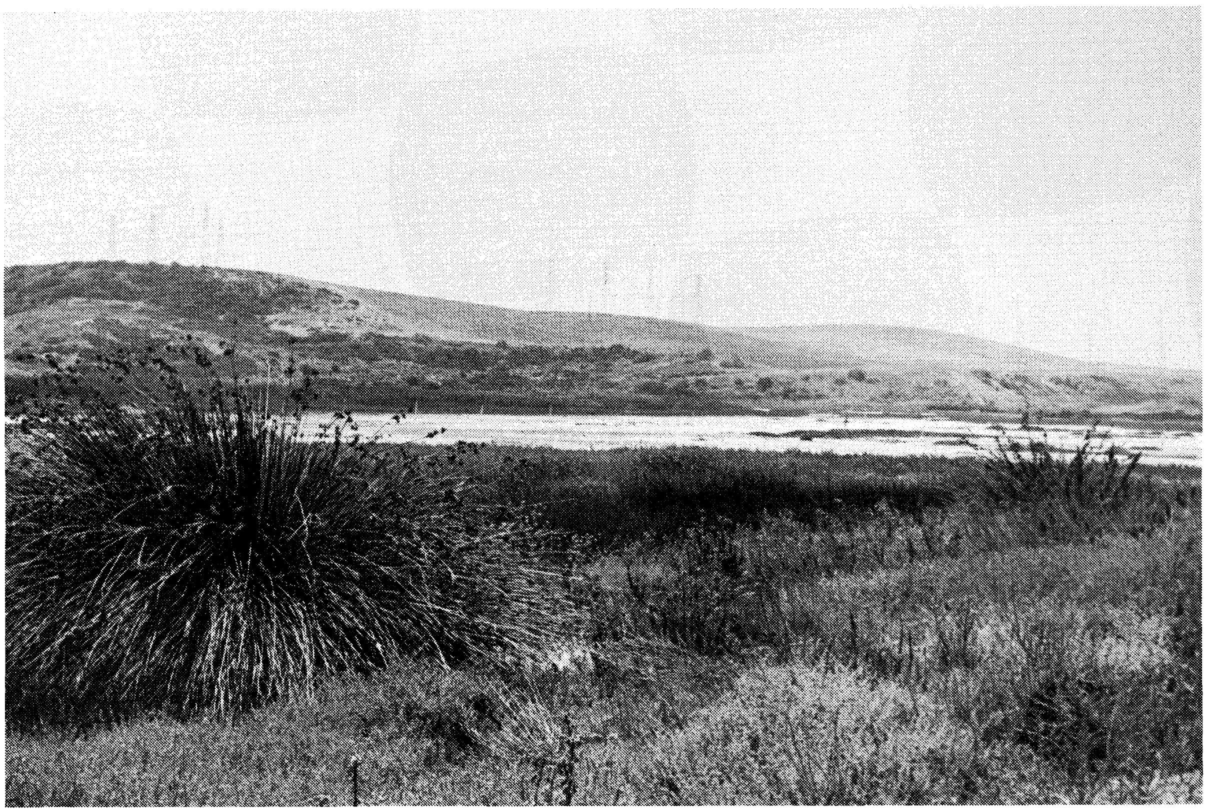
The second major ecosystem at Agua Hedionda includes that portion of the lagoon environs that lies above actual tidal influence. The terrestrial environment can be conveniently divided into two subsystems: maritime and upland.

Maritime Subsystem

The maritime zone is generally defined as that area indirectly affected by tidal influence, either by sub-irrigation, percolation or air transportation (spray, etc.). Brackish water habitat is included here because in some areas of the eastern lagoon, saline tidal water mixes with freshwater drainage to form distinct brackish water pools and vegetative communities.

Brackish Water Habitat

This habitat occurs in the eastern salt marsh at about the upper limit of tidal influence, where the brackish pools and sumps are fairly saline



Although in a somewhat degraded condition, there is a mixture of intertidal, maritime and upland habitats in the east end of the lagoon that support a typical, but rather depauperate flora and fauna.

and contain moderately salt-tolerant alkali bulrush and annual pickleweed. At a slightly higher elevation where salinity is lower, the pools are crowded with cat-tails and California bulrush and edged with spiney rush, brass buttons and annual grasses. These higher, "fresh water" pools provide habitat for frogs and crayfish and supply an important food source for several wildlife species.

Maritime Habitat

Above extreme high water, the salt marsh and the brackish water habitat gradually give way to maritime habitat. This habitat represents an ecotone, or transition zone, between the saltmarsh below and the coastal sage scrub or grassland communities above. The maritime habitat above the pocket marshes on the north side of the inner lagoon is very restricted due to the extensive filling, but contains alkali heath, Torrey sea blite, glasswort, goldenbush, tree tobacco, heliotrope, annual salt bush, annual iceplant and salt tolerant annual grasses. This paucity of plant species probably represents the disturbed nature of the terrain (*viz.*, vehicle tracks and refuse dumping) the youth of the environment and its distance from potentially colonizing sources located in other tidal lagoons. The species present appear to be ones present in the formerly non-tidal lagoon in addition to weedy species with moderate salt tolerance.

Upland Subsystem

Above the level of the maritime influence the salt-tolerant plants give way to species characteristic of the coastal sage scrub habitat and grassland habitat, which constitute the upland ecological subsystem of the lagoon environs.

Coastal Sage Scrub Habitat

The scrub is best developed on the slopes south of Agua Hedionda Creek. Common plants at lower levels include California sagebrush, black mustard and goldenbush and scattered stands of lemonade-berry. Less frequently encountered are species of Napa thistle, cudweed, seaside heliotrope, tarweed, red monkey flower, tree tobacco and nightshade. At higher elevations are found wartystem ceanothus, chamise, flat-topped buckwheat, scrub oak, white sage and black sage.

Grassland Habitat

The grassland is represented by a relatively disturbed community dominated by annual grasses, saltbush, black mustard, and goldenbush, with occasional specimens of coastal prickly pear and sow thistle.

Wildlife

The subtidal and intertidal habitats at Agua Hedionda Lagoon are well developed and support healthy populations of organisms adapted to those kinds of environments. However, the salt marsh and upland environs are generally in a disturbed and degraded condition and support a typical, but rather depauperate flora and fauna. The non-avian vertebrate fauna are not diverse and their populations low in number. The more abundant, and also more obvious, of the lagoon wildlife are the water-associated birds.

Water-associated Birds

Agua Hedionda Lagoon forms a part of the complex of coastal wetlands which are an integral part of the Pacific Flyway, the migration route that myriads of water birds, shorebirds and other water-associated birds follow from their breeding grounds in the north to their southern wintering grounds. Agua Hedionda is one of the larger of such wetlands in San Diego County. The lagoon's singular features of significance to birds are: a constant ocean connection producing extensive tidal flushing; relatively deep water, with steep slopes at the margins (rock-banked in several portions); and areas of mudflats, salt marsh and moderate amounts of freshwater marsh.

Fifty-five species of water-associated birds were identified during occasional observations between 1970 and 1975 (Appendix E). Six partial censuses from May-November 1975 recorded more than 1,100 individuals, ranging in number from 44 (2 August) to 539 (4 November) (Alice Fries, unpubl. data).

Although complete annual census data are lacking, it is probable that Agua Hedionda's water-bird populations follow an annual cycle typical of other coastal San Diego wetlands (Collier, 1975; Jurek, 1975). Fall-winter influxes of Pacific Flyway migrants produce population highs (already partly reflected in the August-November censuses) which are succeeded by spring-summer population lows, when small numbers of "summering" migrants and a modest number of nesting resident species remain after the northward return passage of most migratory birds (Collier, 1975).

Agua Hedionda Lagoon attracts moderate numbers of water-birds, divided almost equally between wading varieties and swimming-diving forms. The most common of the birds drawn to the deeper waters are the scaup,[1]

[1]Scientific names of birds are appended (Appendix E).

Shorebirds are among the most common of the water-associated birds attracted to the lagoon.

bufflehead, surf scoter and ruddy ducks; the red-breasted merganser; the horned, eared and western grebes; the California, western, ring-billed, Bonaparte's and Heermann's gulls, the Forster's and Caspian terns; double-crested cormorant; and the common coot.

Portions of the shoreline, mudflats and marshy sites, particularly at the eastern end of the lagoon, attract shorebirds in moderate numbers and wading birds in small numbers. The most abundant of the shorebirds observed at the lagoon are the snowy plover, killdeer, black-bellied plover, dunlin, dowitchers, godwits, sanderlings and sandpipers. The great blue heron, green heron and black-crowned night herons are the large wading birds seen in the area, but only in small numbers. Survey data show that the shorebirds, totalled 22 species and made up 59% of the birds censused in 1975. Gulls and terns were another 21%, waterfowl about another 7-1/2%. Coots and cormorants also were common but comprised only smaller percentages of the birds censused that year. Although Agua Hedionda compares favorably with nearby coastal wetlands such as Buena Vista Lagoon to the north and Batiquitos Lagoon to the south, in regard to species diversity (Collier, 1975; Jurek, 1974), it supports fewer numbers (over 50% fewer), probably due to greater disturbance, degradation and smaller amounts of required habitats.

Several species designated "endangered" or "rare" occur at Agua Hedionda Lagoon. The California least tern, classified as an endangered species by the federal government and the State of California, regularly nests on the sand flats at the east end of the lagoon. Nine pairs nested there in 1975 (Bender, 1974a, 1974b; Massey, 1975) (Plate 19).

A few California pelicans, also presently listed as endangered, visit the lagoon to loaf or forage for fish during quieter daylight hours. And, the endangered Belding's savannah sparrow breeds in the salt marshes of Agua Hedionda Lagoon; a census of this small sparrow, that virtually depends upon pickleweed marsh for its existence, conducted in March, 1973, recorded 37 singing males. Two other species, the black rail (classified as a rare species) and the light-footed clapper rail (en-dnagered), are found in other San Diego County wetlands, but no longer occur at Agua Hedionda due to disturbance, degradation and a lack of suitable habitat.

Populations of five water-associated birds commonly observed in the lagoon are in decline in the San Diego area: the western grebe, double-crested cormorant, black-crowned night heron, California least tern and snowy plover. In May 1975, the snowy plover was represented by at least 52 individuals and by 20 nests at the east end of the lagoon (Alice Fries, unpubl. data). This is one of the largest nesting populations of this plover in San Diego County.

Land Birds

Forty-seven land-bird species have been recorded in four partial censuses since September 1975 (Alice Fries, unpubl. data) (Appendix E). Land birds occur in portions of coastal sage scrub, salt marsh and fresh-water marsh habitats, grasslands and residential sites bordering the lagoon. In general, samplings of terrestrial birds from the lagoon environs resemble the typical terrestrial avifauna of coastal San Diego County habitats (Sams and Stott, 1959). Again, as compared with Buena Vista and Batiquitos lagoons, the Agua Hedionda environs shows about the same species diversity, but with less abundant populations, presumably due to less dense and less abundant brushland, more clearing and development, and other human disturbance. The census recorded 8 species of raptors (hawks, kites, falcons and owls), 2 gamebird species (mourning dove and California quail), 5 humming birds, 1 woodpecker (the common flicker), the kingfisher and 29 species of passerine birds, 25 of them songbirds, including the yellow warbler, a species that nests in riparian habitat and may be declining in San Diego County (McCaskie, 1976, pers. comm.). Conspicuous occurrences of rock dove, spotted dove, house sparrows and starlings, all introduced species, reflect the effect of human influence.

Mammals

The upland habitats surrounding Agua Hedionda Lagoon, although disturbed by man in many areas still support a relatively typical mammalian fauna. Approximately 27 mammalian species (Appendix F) are believed to occur at Agua Hedionda and in the immediately adjacent habitats. Most of them are distributed throughout the county. Ten of the twenty-seven species were verified as present, either by live-trap capture, sighting, tracks or droppings identification (Dingham, unpubl. data). Fresh water from Agua Hedionda Creek and intermittent brackish water ponds in the southern canyon near the head of the lagoon are breeding sites for amphibians and invertebrates. Frogs, toads, salamanders and crayfish provide food for mammals such as the raccoon and coyote. Agricultural practices on the southern mesas above the lagoon have eliminated some of the coastal sage chaparral, which also provides food and cover for several animals. But, the erosional gulleys leading from the mesa top to the lagoon edge have stands of native vegetation that support many mammals like the dusty-footed wood rat and California mouse. Drier areas at the edge of the chaparral and grasslands favor mammals, like the desert wood rat and cactus mouse, more adapted to mere mesic conditions. The intertidal habitats of the lagoon also are explored and exploited for foods by more adventuresome mammals such as the coyote and raccoons.

Several of the mammals, such as the coyote, fox, bobcat and rabbits range over the entire area. And, an occasional deer has been observed in the vicinity, probably using the area as a migration corridor. Although many of the smaller mammals are generally secretive and/or nocturnal, and many considered pests by farmers, these animals are an essential part of the Agua Hedionda ecosystem as they often provide food for the larger avian raptors and mammalian carnivores.

Amphibians and Reptiles

Although coastal lagoons and salt marshes are not optimum habitat for amphibians, one species of salamander, two frogs and one toad probably occur at Agua Hedionda (Appendix G). The distinctive call of the Pacific tree frog has been heard in the moist areas along the southern edge of the inner lagoon and one was captured in a brackish pond near the upper edge of the salt marsh. The California slender salamander, western spadefood frog and western toad are ubiquitous in similar habitats throughout San Diego County (Sloan, 1964), hence their presence at Agua Hedionda is most likely.

Habitats in San Diego County similar to the varied habitats found at Agua Hedionda Lagoon contain at least 5 species of lizards and 8 species of snakes, hence it is expected that all or most of them (Appendix G) occur here. Only two species have been verified to date: the side-blotch lizard and western aquatic garter snake. However, survey of this category of the local fauna was conducted at a time of year past the activity peak of reptilian fauna.

Fishes

A definitive study has not been made of the fish at Agua Hedionda Lagoon. Perfunctory surveys of both the lagoon, and fish caught in the ocean from the beaches opposite the lagoon, in addition to fish taken off of the Encina power plant, cooling water, intake screens, yield a total of 42 species from the lagoon and 23 from the adjacent ocean waters (Appendix H).

The leopard shark and smoothhounds, shovelnose guitarfish, bat ray and round stingrays are the most common of the elasmobranchs found in the lagoon waters. Anchovies are seasonally abundant as are the croakers, corbina and some of the flatfish, sea basses, and surfperch. The greater abundance of some of these fish during the spring and summer appears to be related to the utilization of the lagoon as a nursery area by some of the species, like the elasmobranchs and flatfish.

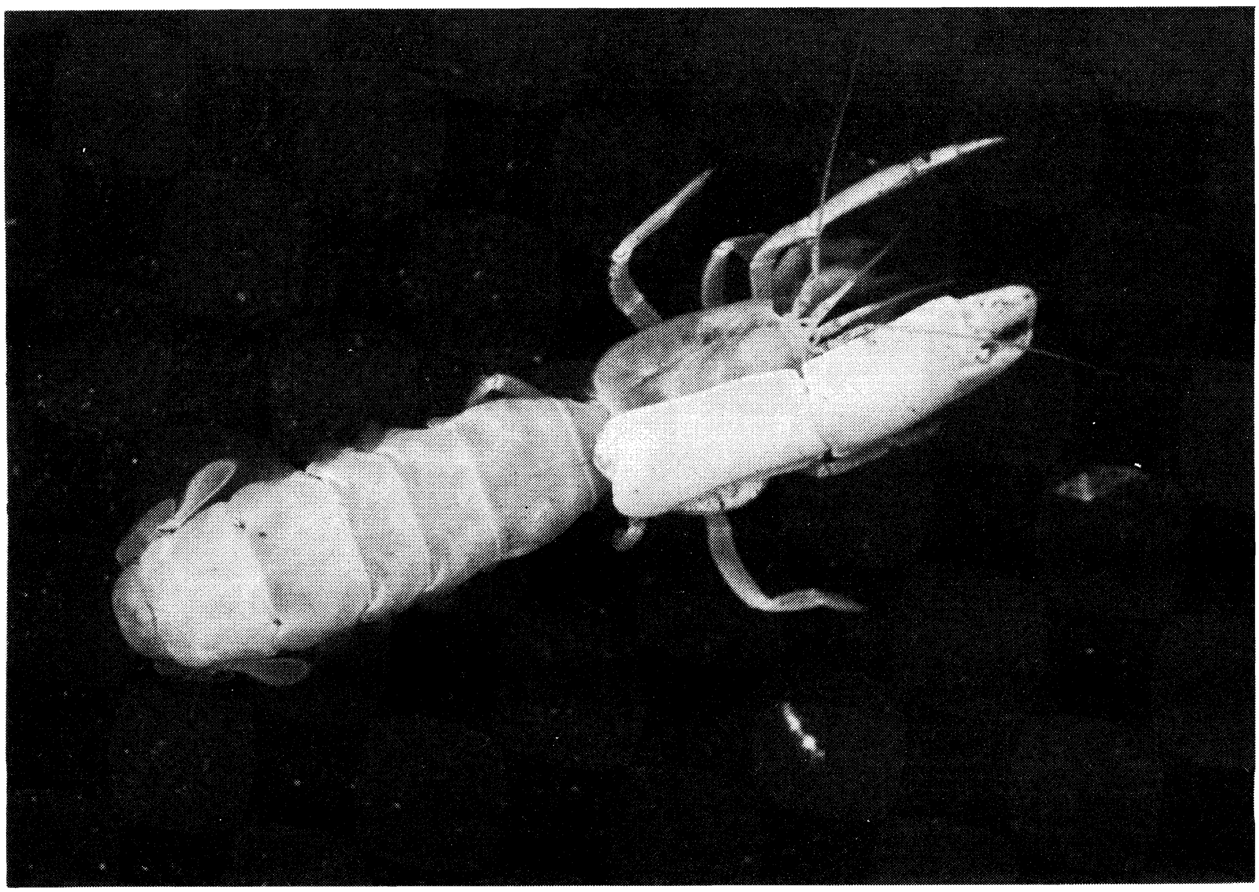
San Diego Gas and Electric Company maintains a record of fish caught on its cooling water intake screens. Sixteen species were so recorded (Appendix H), including some oddities like the barracuda, normally an ocean-running predator.

Invertebrates

Due to the diversity of subtidal and intertidal habitats, a large tidal prism and the effective and healthful tidal flushing, the invertebrate population is very impressive. Over 200 invertebrate species have been recorded from the lagoon and environs (Appendix I), over 150 from the lagoon, and another 45 from the adjacent ocean shore habitats. The list includes corals, anenomes; 32 species of bivalves, including clams, cockles, mussels, oysters and scallops; 39 species of snails, 25 species of amphipods, 8 isopods, 11 crabs, shrimp, barnacles, starfish, sand and brittle stars, sea urchins, sand dollars, bryazoa; 54 species of polychaete worms, as well as numbers of flat worms, ribbon worms, and insects.

The most obvious and common of the invertebrates are the larger shellfish, some of which are commercially important. For example, the bay and California mussels, both grow in the rocky intertidal habitat, on pilings or on other hard substrates (highest density in the mid-tide zone), and also extend in certain situations well into the subtidal zone. The most densely-populated areas are along the jetty at the mouth of the lagoon and near the intake channel of the S.D.G.&E. power station. The relative proportion of the two species of mussels changes, depending upon the relative degree of open ocean influence. Along the outer jetty, only the California mussel is found; on the inner jetty, both occur in roughly equal numbers; and being very tolerant of more sluggish currents, only the bay mussel is seen within the lagoon (and even in the eastern section). Also found attached to hard substrates along with the two mussel species, but relatively rare in the lagoon, are the black abalone and California ("rock") oyster.

The most common intertidal and subtidal shellfish in the sand habitat within the lagoon is the common littleneck, found throughout the lagoon, but with highest populations (120 individuals per square meter, 13-52 mm in size) occurring among rocks and sand near the railroad trestle between the outer and middle sections. Other clams found in this habitat are rough-sided littlenecks (ranging between 34 and 79 millimeters in length), Washington clams (14-107 mm), gapers (30-119 mm), wavy chione (34-43 mm), yellow apolymetis (52 mm) and the clipped semele (46-55 mm) (Duffey, 1975). Relatively high populations of the protected bay scallop occur subtidally in the outer lagoon section. Within the eel grass beds, juveniles of kelp/scallop occur in large numbers. The California jacknife clam, California ghost shrimp, false mya, bent nose clam and the burrowing crab occur most frequently in the inner lagoon, particularly in the muddy substrate in the far northeastern portion. The most conspicuous shellfish in the salt marsh and mudflats of the inner lagoon are the California hornshell, with populations up to 1,600 individuals per square meter. Relatively low numbers of smooth chione and yellow shore ("mud") crab occur in the same habitats with the hornshells. Extensive intertidal populations of the fiddler crab occur wherever the substrate is firm enough for their burrows. Especially large numbers (up to 30 burrows per square meter) are found in mudflats on the north side of the middle lagoon and in the more extensive mudflats at the east end of the inner lagoon. Less conspicuous, but just as interesting and important to the subtidal and intertidal ecosystems, are the small shelled invertebrates, such as the numerous marine snails, the free swimming amphipods, isopods, insects and ubiquitous marine worms. These smaller invertebrates occupy critical niches in the various tidal and subtidal habitats and function as important links in the food webs of the ecosystems, transferring the the sun's energy that is trapped in the plants to fish, mammals, birds and even to man.



Because of good tidal flushing and a diversity of inter and subtidal habitats. The lagoon has abundant and diverse populations of invertebrate organisms.

Fishing, clamming and harvesting of other invertebrates are two of the most popular appropriative recreational uses of the lagoon's resources.

RESOURCE USE

Hunting

Due to the heavy recreational use of the lagoon and the residential development on the north shore, hunting within the lagoon and in the surrounding uplands is prohibited by Carlsbad City ordinance. Although harvestable populations of rabbits and several covies of quail occur on the edge of the flats and adjoining chaparral at the east end of the inner lagoon, hunting probably will never be a compatible use of the lagoon's resources.

Clamming and Harvesting of Other Invertebrates

Clams, mussels and ghost shrimp are harvested from the lagoon for human consumption and for bait. The most intensively used area for the collection of clams is in the sand-rock habitats of the outer lagoon. Here littleneck clams, cockles, clipped semele and Washington clams are collected in season. Clammers have been observed obtaining their limit of common littlenecks in half an hour (John Duffey, unpubl. data). Ghost shrimp are collected from the sand and mud bottoms and mussels from the jetties and rock habitats and used for bait. Gaper clams also are collected in the middle and inner lagoons for human consumption and, together with ghost shrimp and jacknife clams, taken for bait.

Invertebrate populations appear to be sufficient to support the harvesting pressure at this time. Some, like the bay mussel, however, can be easily over-exploited, and resource use should be monitored.

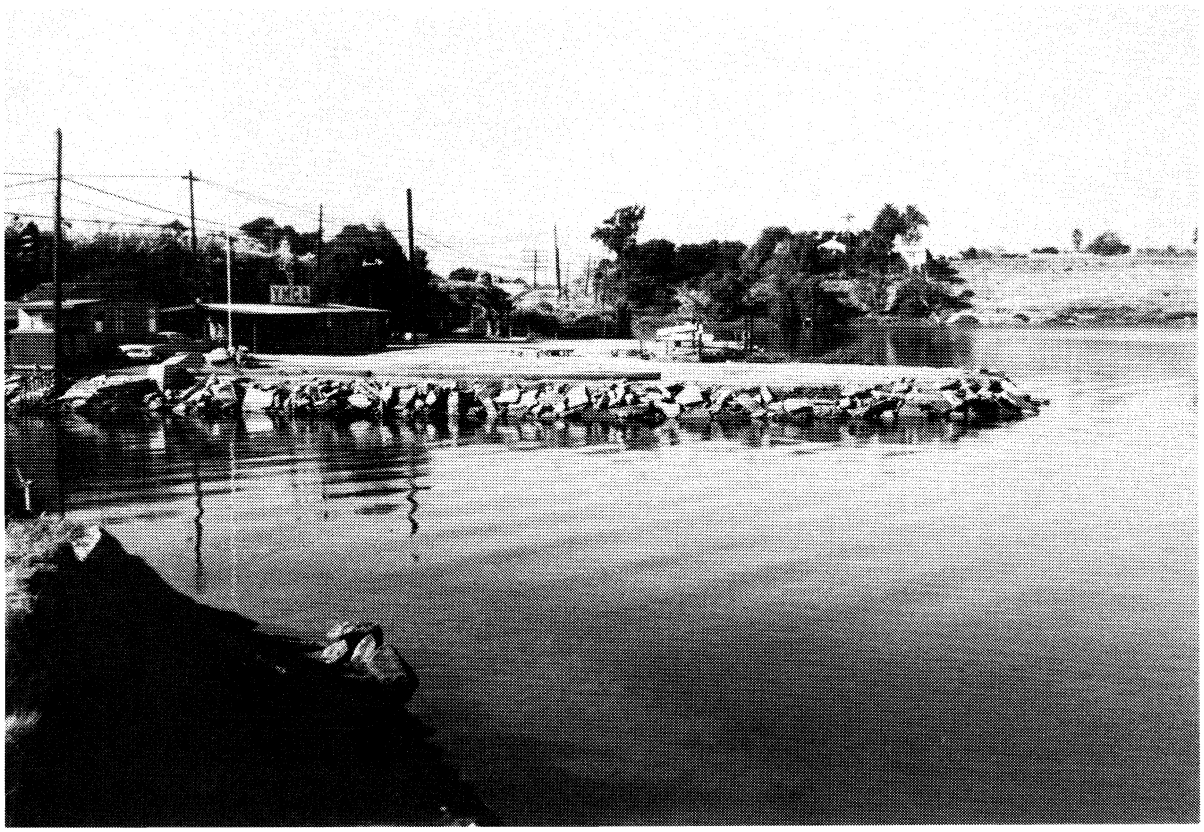
Lagoon Fishing

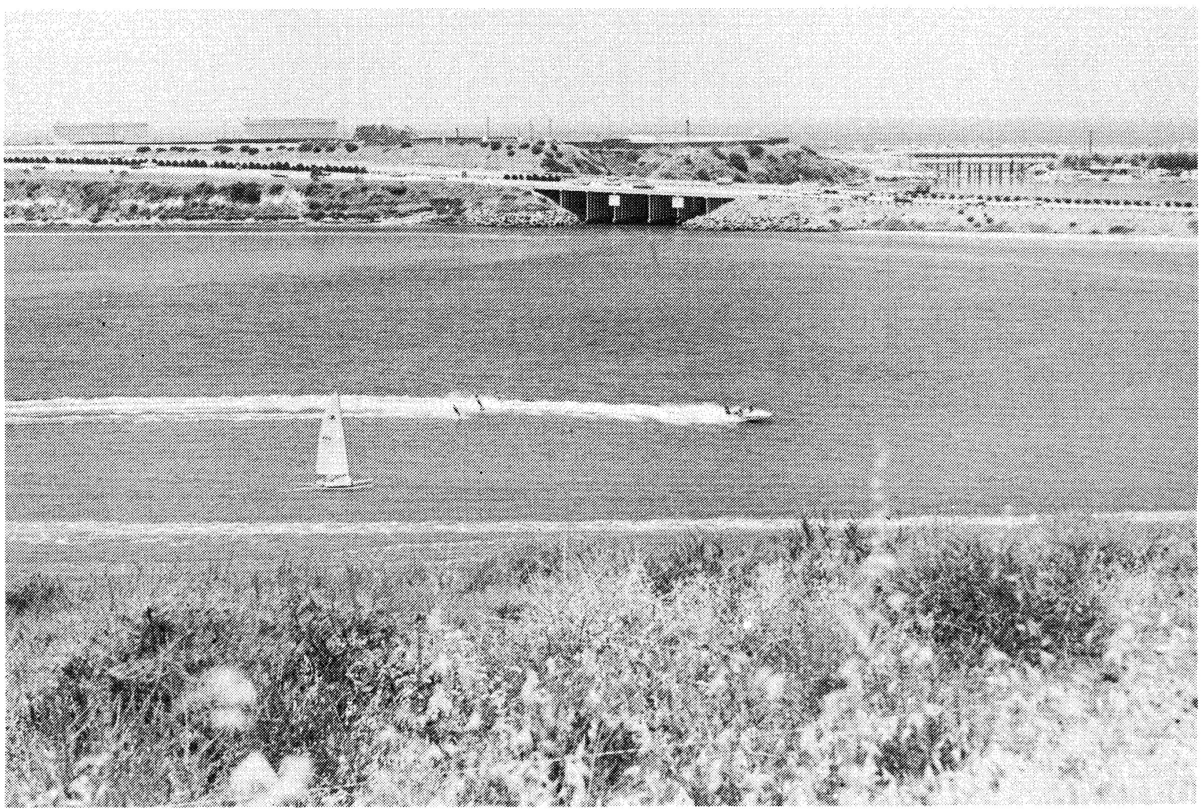
The San Diego Gas and Electric Company does not allow commercial fishing or fishing from boats in the outer lagoon, but has provided an improved fishing access on the western shore. This access area, called the "Encina Fishing Area," provides free parking, trash receptacles and fire pits, as well as direct access to the outer lagoon waters; it is a very popular fishing spot.

In a limited survey at the Encina Fishing Area in 1973, 5 fish were verified in the catch: the California guitarfish, leopard shark, queenfish, rubber-lipped perch and sargo. Other important sport fish available to the Agua Hedionda fishermen include barred surf perch, bigmouth sole, calico bass, California corbina, California halibut, giant kelp fish, opaleye, barred sandbass, shiner perch, spot fin croaker, yellowfin croaker, spotted sandbass and spotted turbot (Bradshaw and Estberg, 1973; John Rutherford, 1975, pers. comm.). Fishermen report significant variations in their catch of spotfin croaker, sargo and surfperch, presumably due to seasonal differences in abundance and feeding behavior. A gradual decline in the catch of all bass species has been noted over the past few years. Many large specimens (up to 30 pounds) of several species of sharks and rays have been reported by fishermen; most of these caught at night.

Non-appropriative Recreation

The use of the outer lagoon is controlled by the S.D.G.&E., which prohibits swimming and boating. Booms placed across the entrance channel, the channel to the middle lagoon, and the southern end, prevent access by boat. The use of the inner and middle lagoons is regulated by the City of Carlsbad which leases the water area from the S.D.G.&E. for one dollar per year. Boating in the middle lagoon is restricted to speeds below five mph. The YMCA leases a portion of the west shore for a





Recreational use of the lagoon is probably the highest and best use of the natural resources of the area and with a few restrictions can be accomplished without destroying or degrading those resources.

regional aquatic day use facility. Passage between the inner and middle lagoons is impaired by the Interstate-5 bridge and the strong tidal currents that develop in the channel beneath it, make the middle lagoon relatively isolated and ideal for the day-use facility.

Water skiing, boating, sailing and fishing are the major uses of the inner lagoon. On the north shore there are two private boat launching and day-use facilities available to the general public. Private docking facilities are found at Bristol Cove, a residential-marina development on the north shore of the lagoon. Land access to the south shore is restricted by S.D.G.&E., although trash receptacles are provided for boaters at pocket beaches located on that shore. Swimming is permitted in areas of both inner and middle lagoons where it does not conflict with boating and water skiing, although the lack of well developed beaches limits this use.

Carlsbad State Beach, located just north of the entrance channel, provides additional day-use facilities. There are no over-night camping facilities near the lagoon.

Numerous tracks across the mudflats and salt marshes east of the lagoon indicate that off-road vehicles and motorcycles have been operating there.

Scientific and Educational Use

The lagoon serves as a natural field laboratory for numerous scientific studies being carried out by various educational institutions, governmental agencies and interested individuals. San Diego State University maintains a well-equipped running sea water laboratory located on the southwestern shore of the outer lagoon for experimental aquaculture (mariculture) studies and related marine biological projects. Studies include the culture of various commercially important shellfish species and experiments involving accelerated growth of lobsters using heated effluent from the adjacent Encina Power Plant (Dexter, 1972; Krekorian *et al.*, 1974). Although attempts were made to rear the native west coast spiny lobster (*Panulirus interruptus*) in this laboratory, it was eventually eliminated as a subject for domestication due to its extended and complicated larval stage (6 months and 12 molts to attain the miniature 7/8-inch form of an adult). Of much more commercial interest are successful studies of the American lobster (*Homarus americanus*) which has been grown from the egg to one pound size in 18 months, a size that required 5 to 7 years in New England habitat (Kloftenstein, no date). Eleven graduate theses from San Diego State University have been prepared on these aquaculture projects.

From 1968-1974 an independent aquaculture study to determine the feasibility of culturing oysters in the outer lagoon was carried on by Dr. Richard Northcraft under S.D.G.&E. auspices. Pacific oyster spat from Japan was encouraged to colonize on empty oyster shells and the resulting "clutch" was held in rafts or suspended from ropes in the outer lagoon. Growth was rapid in the warmer water; and after several months, the young oysters were transported in special tank trucks to northern Washington for growth to maturity. The growth period in southern waters apparently allowed the oysters to attain harvestable size, months sooner than if grown continuously in the colder northern waters. In another aquaculture project, which was recently discontinued, mature chione clams (*Chione fluctifraga*) were imported from the Gulf of California and "sanitized" in large batches in the inner lagoon prior to sale to local markets.

Scientific and educational use is a compatible use of the lagoon's resources. Additional studies at Agua Hedionda can serve as a basis for the development of future wetlands management tools.

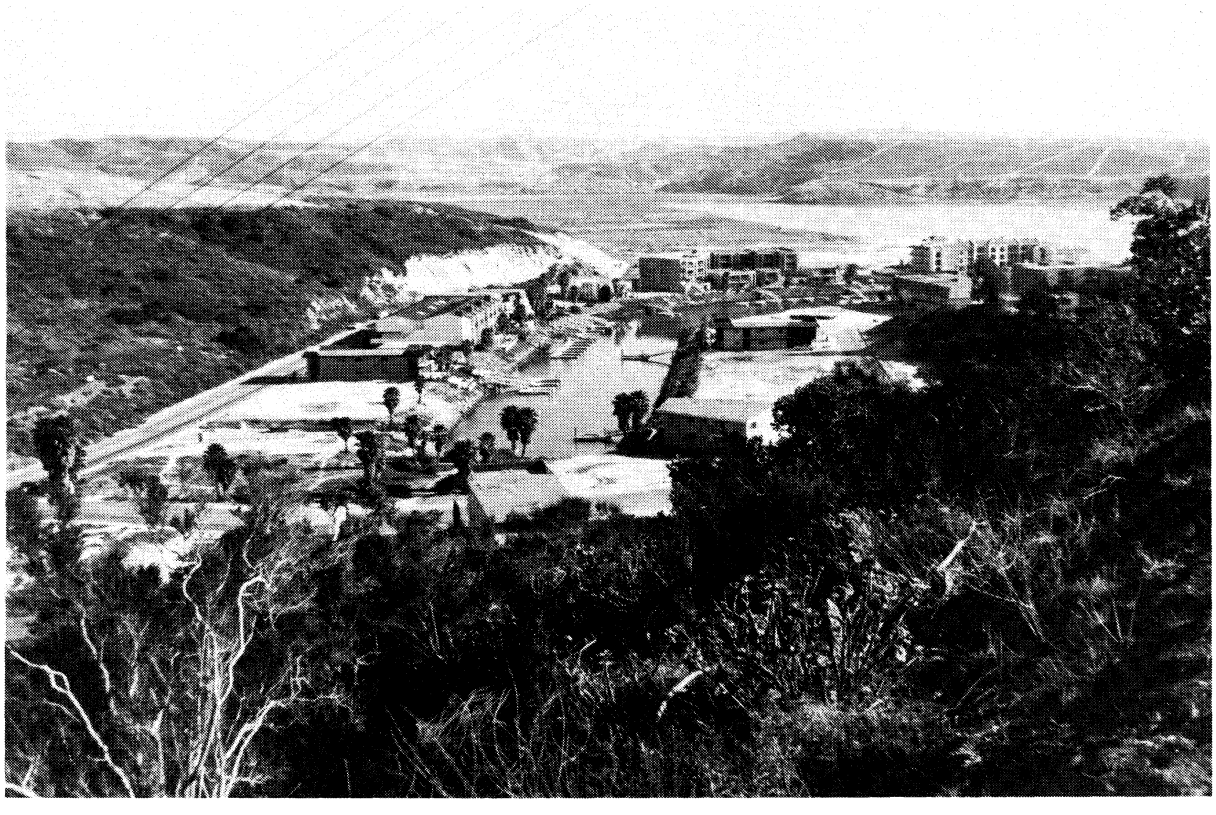
The Environmental Studies Laboratory of the University of San Diego has carried out continuing studies of the lagoon since 1973. Much of this work has been incorporated in a comprehensive report on the subtidal marine life (Bradshaw and Estberg, 1973). Published papers and doctoral theses concerned with related scientific aspects of the lagoon include studies of the eel grass (Backman, 1975) and investigations of the Indian middens (Moriarty, 1967 and Miller, 1966). Several local and secondary schools also make field trips to the lagoon area.

There is a need and opportunity for further scientific study at Agua Hedionda. Long-range resource management in the southern California lagoons and estuaries must be based on an understanding of the interactions of ecological factors involved, including human use. Details of the food web and energy flow within and between the various habitats are poorly understood. Research should be directed toward a knowledge of the relative importance of communities, elements within the ecosystems, so that the effect of changing the environment can be predicted. For instance, there is no good way to evaluate elimination of the remaining salt marsh on the productivity and abundance of desirable resource species.

The California Coastal Zone Conservation Commission has requested studies to determine the importance of natural cycles and man-induced stresses upon wetland ecosystems. Additional studies and monitoring programs at Agua Hedionda Lagoon can serve as basis for the development of descriptive and mathematical models for future wetlands management tools.

Nature Study

Naturalists, both unattached and organized, also use the lagoon for birdwatching and nature study. But the area does not appear to be used as heavily for this purpose as are other lagoons to the north and south, probably due to the lack of public access and the relative sparseness and degradation of salt marsh vegetation and adjacent upland habitats.



The greatest threat to the status of the natural resources of Agua Hedionda is the continuing pressure for recreational, residential and industrial development of the lagoon and its watershed.

PROBLEMS AND CONFLICTS OF USE

Development

The greatest threat to the present status of Agua Hedionda Lagoon and its environs is the continuing pressure for development of the lagoon and its watershed. The demand is for three principal types of development: 1) recreational, 2) residential and 3) industrial.

Small Craft Harbor Plan

Of the eight estuarine lagoons on the northern San Diego County coastline, Batiquitos and Agua Hedionda offer the greatest potential for development of small craft harbors and related on-shore recreational facilities. The concept of a harbor of refuge in Agua Hedionda has been considered for some time. In 1947, the U.S. Army Corps of Engineers made a preliminary survey of the southern California coast and reported Agua Hedionda Lagoon as a site worthy of further consideration in the proposed chain of refuge harbors on the California coast (U.S. Army Corps of Engineers, 1947). In 1956, San Diego County authorized a preliminary feasibility study for the development of Agua Hedionda Lagoon into a small craft harbor (Patterson, 1957). This report concluded that the site, " . . . when developed into a harbor, would provide for a larger capacity for boats and recreational advantages than any other site in the area."

In 1962, Carlsbad applied to the Division of Small Craft Harbors, State of California, for a loan to prepare a small craft harbor feasibility study. This study (Daniel, Mann, Johnson and Mendenhall, 1965), suggested the creation of a harbor which would be the focal point of the

community, and become " . . . the Carlsbad image and the magnet which attracts new residents, new industry and additional tourism to Carlsbad . . . ." And, because of the development of the large expanse of undeveloped land surrounding the harbor site, such a harbor could " . . . result in greatly indreased economic benefit, not only the City of Carlsbad, but also to southern California as a whole."

The 1965 Carlsbad Small Crafts Harbor Plan (Plate 16) called for the removal of the 250-foot wide entrance channel and construction of a new 400-foot wide, jetty-protected, entrance channel immediately north of the Encina Power Plant outfall. The entrance channel was to open directly into the outer lagoon and continue through a narrow 150-foot wide channel, under an enlarged railroad bridge to the middle lagoon; and from there, continue through another 150-foot wide channel under a new Interstate 5 Freeway bridge into the inner lagoon. All of the harbor development would occur on the northerly side of this channel. The outer lagoon, conceived as the major focal point of the entire harbor, would feature a spacious marine view restaurant with harbor administrative office on top and could accommodate approximately 450 boats. Larger craft and higher-masted sailboats would be limited to the outer lagoon because of the height-limiting factor of the bridges at the entrance to the middle and inner lagoons. The middle lagoon was to provide approximately 360 supplementary berths and a large parking area for approximately 530 cars and boat trailers. The inner lagoon was to be divided into two separate berthing areas for approximately 410 boats each, to encourage development and access from both westerly and easterly directions.

This plan is now considered obsolete, due to financial considerations; a proposal to expand the Oceanside Harbor (five miles to the north) from 700 to 2,000 berth capacity; the threat of the "energy crisis" precluding gasoline for pleasure craft use, etc.

The 1965 Small Craft Harbor Plan has been included in this report to document the scope of plans derived in response to overwhelming demands by the public for specific recreational opportunity.

Regional Park Development

Plans prepared in 1972 by the San Diego County Park Department called for the purchase and development of a 400-acre parcel at the southeast end of the lagoon as a regional park (Cornell, Bridgers and Troller, 1972). It is felt that Agua Hedionda is suitabily located in the north county beach area to serve as a possible Amtrak stop and to relieve projected deficiences in camping and parking accommodations at the state beach parks along the San Diego coast. Recreation activities and amounts of land that would be required and developed are as follows: Picnicking - 9.71 acres, Field Games - 9.88 acres, Bicycling - 5.41 acres, Swimming - 2.00 acres, Boating - 79.31 acres, Fishing - 10.27 acres, Hiking - 0.89 acres, Water Ski Support - 20.00 acres, Family Camping - 34.42 acres and Support Facilities - 171.89.

Because of the ownership and jurisdictional complexities, implementation of this plan would call for participation by several interests--the City of Carlsbad, San Diego County, private interests, and possibly the U.S. Army Corps of Engineers--to fully utilize the lagoon under a multiple-use concept. The land considered for purchase is located along Agua Hedionda Creek and eastward almost to El Camino Real and would provide

usable activity acreage in acticipation of further lagoon expansion (Plate 17). It would be necessary that a portion of the south shore and lagoon area be made available by the San Diego Gas and Electric Company (Cornell, Bridgers and Troller, 1972).

Because of more pressing priorities (Batiquitos Lagoon and Lake Calavera, the latter in the Agua Hedionda watershed), the County has dropped the lagoon from its priority list (extending to 1985) for acquisition and development. Other reasons affecting this priority change are the present level of recreational use at the lagoonand the fact that the City of Carlsbad is working on special plans for the Agua Hedionda area.

Agua Hedionda Specific Plan

The City of Carlsbad, the California Coastal Zone Conservation Commission and a group of property owners have entered into a cooperative agreement to prepare a specific land use plan for Agua Hedionda Lagoon and its immediate environs. The purpose of this plan is to reconcile the City's General Plan, adopted in 1973, with the State Coastal Plan, as it affects the Agua Hedionda area. Basically the specific plan calls for rezoning of the lagoon and its environs to open space, recreational, residential, industrial and other land uses (Plate 18); and, the creation of a 90-acre community park (to be leased from S.D.G.&E.) at the southeast corner of the lagoon.

The City has prepared a very good and quite complete environmental impact report (EIR) that defines land uses in light of the environmental information available on not only the natural resources of the lagoon, but also on water and air quality, agriculture, aquaculture, archeological sites, energy conservation measures, as well as noise, traffic, visual resources, utilities, community services and recreation facilities. The EIR on the specific plan also speaks well to the relationship

between local, short-term uses of the resources as opposed to preservation, maintenance and enhancement of the long-term productivity of the environment of the lagoon area.

The specific plan EIR also enumerates the environmental effects which cannot be avoided if the project is implemented. These include: 1) a decrease in the amount of open space, 2) alteration of natural land forms, 3) removal of a small portion of the remaining natural vegetation, 4) displacement of some of the resident animal populations and partial destruction of their habitat, 5) an increase in erosion potential through vegetation cover removal, an increase in demand for recreational facilities, etc., 6) some problems in water quality maintenance and 7) increased human encroachment on sensitive natural and scenic areas.

The EIR reflects the City of Carlsbad planning department's awareness of and concern for the area's natural resources. For the EIR also contains many sound mitigation measures for the impacts on the environment identified in the report. The EIR went into the review process in June 1976, and will be reviewed by several appropriate agencies, including the Department of Fish and Game and the U.S. Fish and Wildlife Service.

Agua Hedionda Acquisition Proposal

Part of the EIR on the Specific Plan for Agua Hedionda Lagoon and its environs outlines alternatives to project proposals. One such alternative is a proposed recreational vehicle park (RVP) on the north shore of the eastern end of the inner lagoon (Plate 19). This alternative is of special note, since the landowner has engaged private environmental consultants to prepare a mitigative measure called the Agua Hedionda Lagoon Acquisition Proposal, for the development of the RVP. The

Private Marina Development

Two marinas in private ownership occur on the north shore of the inner lagoon. One, called Whitey's Landing, gives access to the middle of the lagoon and is currently zoned "residential tourist" and is designated as an "medium density" area. However, because of the steep slope at the property edge, it is less desirable as a boat launching site than other locations around the lagoon. The City's Specific Plan indicates a recreation-commercial use (restaurant, motel) may be more suitable for this site.

The Carlsbad General Plan for "Snug Harbor," the area and private marina located in a cove at the northwestern corner of the inner lagoon shows the existing marina and launching facilities as "recreation-commercial," surrounded by "medium and medium high" density residential zoning. The Specific Plan suggests alternatives for some expansion and/or development at this site. That plan also calls for public access and facilities in the same vicinity. The Department recognizes that boating and allied recreational activities such as water skiing, etc., are a compatible use of the natural resources of the lagoon. Unfortunately the western end of the lagoon and particularly the Snug Harbor area is excellent eel grass habitat, which suggests that some simple restrictions may be necessary in the use of this area. Critical areas and channels to the central portion of the inner lagoon can be delineated by a system of buoys.

Residential Development

During the past few years, construction of water-oriented condominiums along the northern shoreline of the lagoon has resulted in the encroachment of landfill into the salt marsh and mudflat habitats. Over 70% of the remaining, healthy marshland has been filled.

Although present zoning would permit 421 residential units, as well as private docks, the most recent city plan (1974) suggests 242 units and 178

The refinery, whose design has been approved by the Environmental Protection Agency, would receive crude oil through the S.D.G.&E. offshore terminal and produce low sulfur residual fuel oil for use by S.D.G.&E. All runoff from the refinery site would be collected to prevent sedimentation and pollution of the lagoon. An EIR has not been prepared to date. The refinery plan has caused considerable local controversy, prompting the formation of an opposition citizens' group, "Community Cause," consisting of 500-600 local residents.

Sedimentation

The erosion characteristics of the Agua Hedionda Creek drainage are such that serious sedimentation does not seem to occur. However, some degree of sedimentation is a normal process throughout the life span of most estuarine systems since some silt is deposited even under conditions of normal rainfall. Periods of excessive rainfall and floods, however, can cause serious erosion in the Agua Hedionda watershed, resulting in transport of excessive quantities of clay, silt and sand into the lagoon. During these periods sediments clog the respiratory structures of many marine organisms, adversely affect egg development, deprive algae and eel grass of necessary sunlight and adversely affect other marine habitats.

Because of the extensive dredging carried out during 1954, it is difficult to accurately assess (from earlier maps and aerial photos) the amount of natural sedimentation in the lagoon. However, comparison of relative changes in extent of the salt marsh and mudflat since the 1954 dredging, indicates some increase of mudflat and decrease of water area.

Another index of the amount of recent sedimentation is the comparison of depths at the present with the depths that existed after the dredging. In 1954, the entire lagoon (including a 17-foot deep sump to allow for

TABLE 2

Record of Dredging in Agua Hedionda Lagoon

Date	Amount of Spoils (10^3 cubic yards)	Comments
2/54 to 10/54	4,279	Initial dredging
8/55 to 9/55	90	Maintenance dredging
9/54 to 12/57	226	Maintenance dredging
10/59 to 3/60	370	Maintenance dredging
1/61 to 4/61	227	Maintenance dredging
9/62 to 3/63	307	Maintenance dredging
9/64 to 2/65	222	Maintenance dredging
11/66 to 3/67	159	Maintenance dredging
1/69 to 3/69	97	Maintenance dredging
1/72 to 2/72	209	Maintenance dredging

The sediment removed (predominantly sand) is pumped through a permanently installed pipe under the highway to the ocean beach where it replenishes the beach sand as part of the coastal sand transport system.

An analysis of monthly bathymetric data for the period of 1955-57 showed that the average annual rate of sand accumulation in the outer lagoon was 168,000 cubic yards per year with the highest rates in March and September (periods of lower tidal range) (Ritter, 1972). Since the depths of most of the outer lagoon at present are considerably deeper than the original dredged depth of minus 5 feet MLLW, the S.D.G.&E. has successfully deepened this lagoon over a period of years. The company dredge "La Encina," stationed in the outer lagoon, however, is too large to move into the middle and inner lagoon areas; therefore, these waters represent the original dredged condition, modified by 21 years of scouring, shoaling and sedimentation.

nutrients as well as some pesticide residues. However, since the curtailment of the use of chlorinated hydrocarbons as pesticides, the levels of those chemicals in the lagoon waters have dropped dramatically (EPA, 1973). And, in contrast with the other north county lagoons, relatively little pesticide spraying for mosquitoes is carried out in the upper Agua Hedionda marsh areas. Therefore, because of the large amount of tidal flushing in the lagoon, both pesticides and eutrophication (as a result of excess nitrogen and phosphorous nutrients) are considered minimal (Bradshaw and Estberg, 1973; Bradshaw and Mudie, 1972).

The Department recognizes the needs and demands for residential, industrial and, of course, recreational development in the vicinity of areas as aesthetically attractive as the coastal wetlands. In the case of Agua Hedionda Lagoon, specifically, the Department recognizes the possibilities of a multiple-use concept for this wetland. Surely, the compatible industrial and recreational uses of the outer lagoon are an obvious success (just ask any of the fishermen that frequent the Encina fishing access area provided by the utility company!). Could there be a better use of the middle lagoon, isolated and secluded by two major transportation thoroughfares, than it receives by the young people attracted to the YMCA recreation center there? Even the inner lagoon, with one side developing into a marine-oriented residential community together with private marina and facilities, provides a variety of recreational uses, without any great threat to the natural resources. Multiple-use seems to be the highest and best use policy for the Agua Hedionda Lagoon. This report, then, offers a descriptive inventory of the natural resources of the Agua Hedionda and some quidelines for the multiple-use, management, preservation and enhancement of those resources.

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APPENDIX A

DIATOMS

(Identified by Stephanie Perrin, University of San Diego)

Actinoptychus sp.
Amphiprora sp.
Amphora arcus
Amphora exigua
Amphora sp.
Biddulphia sp.
Cocconeis dirupta
Cocconeis scutellum
Coscinodiscus spp.
Diploneis prob. *D. litoralis*
Eunotogramma laeve
Fragilaria pinnata
Gyrosigma simili
Navicula cancellata
Navicula clavata
Navicula directa
Navicula finnmarchica
Navicula granulata
Navicula pavillurdi
Navicula sp.
Pleurosigma sp.
Rhaphoneis amphiceros
Rhaphoneis amphiceros var.
Rhaphoneis grossepunctata
Rhaphoneis surirella var. *australis*
Synedra tabulata

ZOOPLANKTON (cont.)

Oithona oculata adults

Oithona similis adults

Oithona oculata and *similis* copepodids

Oithona nauplii

Oncaea spp. adults

Paracalanus parvus adults

Paracalanus parvus copopodids

Paracalanus parvus nauplii

Unidentified calanoid adult

Unidentified calanoid copepodids

Unidentified cyclopoid #1

Unidentified harpacticoids

Unidentified nauplii

Cirripedia

Balanus spp. nauplii

Unidentified cirriped nauplii

Cumacea

Isopoda

Amphipoda

Mysidacea

Decapoda

Caridean adults

Caridean larvae

Brachyuran zoea larvae

CHAETOGNATHA

Sagitta euneritica adults and juveniles

ECHINODERMATA

Echinopleuteus larvae

CHORDATA - UROCHORDATA

Larvacea

Oikopleura spp.

CHORDATA - VERTEBRATA

Fish larvae

EGGS

Unidentified egg #1

Unidentified eggs

APPENDIX D
FLOWERING PLANTS

Legend: R = Rare C = Common A = Abundant

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
DICOTS														
Lizard-tail Family														
Yerba mansa, *Anemopsis californica*											C			
Mallow Family (Malvaceae)														
Alkali mallow, *Sida hederacea*											C			
Tamarisk Family (Tamaricaceae)														
Tamarisk, *Tamarix gallica*											R			
Frankenia Family (Frankeniaceae)														
Alkali heath, *Frankenia grandiflora*									C		C			
Mustard Family (Brassicaceae)														
Black mustard, *Brassica nigra*											C	R	A	
Pink Family (Caryophyllaceae)														
Sand spurrey, *Spergularia marina*									R		A			
Carpet-weed Family (Aizoaceae)														
Little ice plant, *Gasoul nodiflorum*											A			
Sea-fig, *Carpobrotus aequilaterus*											C	R	R	
Hottentot-fig, *Carpobrotus edula*											R	R	R	
Cactus Family (Cactaceae)														
Prickly pear, *Opuntia occidentalis*											R	C	R	
Coastal cholla, *Opuntia prolifera*											R	C	R	
Buckwheat Family (Polygonaceae)														
Flat topped buckwheat, *Eriogonum fasciculatum*												A		
Curly dock, *Rumex crispus*									R	C				
Goosefoot Family (Chenopodiaceae)														
Saltbush, *Atriplex californica*											R			
Fat-hen, *Atriplex patula*											C			
Perennial pickleweed, *Salicornia virginica*									A	C	A			
Glasswort, *Salicornia subterminalis*									R		A			
California sea-blite, *Suaeda californica*									C		C			
Primrose Family (Primulaceae)														
Scarlet pimpernel, *Anagallis arvensis*											R			

APPENDIX D
FLOWERING PLANTS

Legend: R = Rare C = Common A = Abundant

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
Sunflower Family (Asteraceae) (cont.)														
Sow thistle, *Sonchus* spp.											C		C	
Cocklebur, *Xanthium strumarium*											C		C	
MONOCOTS														
Eel-grass Family (Zosteraceae)														
Eel-grass, *Zostera marina*					A									
Surf-grass, *Phyllospadix* sp.		R												
Cat-tail Family (Typhaceae)														
Narrow-leaved cat-tail, *Typha angustifolia*										A				
Hybrid cat-tail, *Typha glauca*										A				
Common cat-tail, *Typha latifolia*										A				
Rush Family (Juncaceae)														
Spiny rush, *Juncus acutus*										C				
Rush, *Juncus effusus*										R				
Sedge Family (Cyperaceae)														
Red rooted cyperus, *Cyperus erythrorhizos*										R				
California bulrush, *Scirpus californicus*										C				
Alkali bulrush, *Scirpus robustus*										A				
Grass Family (Poaceae)														
Saltgrass, *Distichlis spicata*									C	A	C			
Salt cedar, *Monanthochloe littoralis*									C		R			
Ditch polypogon, *Polypogon interruptus*										A	C			
Rabbitfootgrass, *Polypogon monspeliensis*										R				

APPENDIX D (continued)

SUPPLEMENTAL FLORAL CHECKLIST (continued)
(City of Carlsbad, 1976)

Eleocharis acicularis Slender spike-rush

Eleocharis macrostachya Pale spike-rush

Elymus condensatus Giant rye-grass

Epilobium adenocaulon var. *parishii* Sticky willowweed

Eucalyptus camaldulensis Eucalyptus

Gasoul crystallinum Ice-plant

Ganphalium beneolens Fragrant everlasting

Gnaphalium californicum Green everlasting flower

Hemizonia paniculata Tarweed

Heteromeles arbutifolia Toyon

Heterotheca grandifolia Telegraph weed

Hordeum jubatum Barley

Isomeris arborea Bladderpod

Lampranthus sp. Fig marigold

Lepidium dictyotum var. *dictyotum* Alakli peppergrass

Malacothamnus fasciculatus var. *fasciculatus* Mesa malvastrum

Malva parviflora Cheeseweed

Marrubium vulgare Horehound

Medicago polymorpha Bur-clover

Myoporum laetum Myoporum

Phragmites australis Reed

Picris echioides Ox-tongue

APPENDIX E

BIRDS

Legend: R = Rare C = Common A = Abundant
r = resident m = migrant
b = breeding

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
LOONS														
Common loon, *Gavia immer*	C													m
GREBES														
Horned grebe, *Podiceps auritus*	A													m
Eared grebe, *Podiceps nigricollis*	A													m
Western grebe, *Aechmophorus occidentalis*	A													m
Pied-billed grebe, *Podilymbus podiceps*	C													rmb
PELICANS AND CORMORANTS														
White pelican, *Pelecanus erythrorhynchos*	R													m
Brown pelican, *Pelecanus occidentalis*	C													rm
Double-crested cormorant, *Phalacrocorax auritus*	A													rm
WADING BIRDS														
Great blue heron, *Ardea herodius*	C					C	C	C	C					rm
Green heron, *Butorides virescens*								C	C	C				rmb
White-faced ibis, *Plegadis chihi*									R	R				m
Black-crowned night heron, *Nycticorax nycticorax*						C	C	C	C	C				rm
Great egret, *Casmerodius albus*									R	R				m
Snowy egret, *Egretta thula*									R	R				m
SURFACE FEEDING DUCKS														
Cinnamon teal, *Anas cyanoptera*	C						C	C	C	C				rmb
BAY AND SEA DUCKS														
Canvasback, *Aythya valisineria*	R													m
Lesser scaup, *Aythya affinis*	A													m
Bufflehead, *Bucephala albeola*	A													m
Surf scoter, *Melanitta perspicillata*	A													m
Black scoter, *Melanitta nigra*	R													m
STIFF-TAILED DUCKS														
Ruddy duck, *Oxyura jamaicensis*	A													rmb
MERGANSERS														
Common merganser, *Mergus merganser*	R													m
Red-breasted merganser, *Mergus serrator*	A													m

APPENDIX E (continued)

BIRDS

Legend: R = Rare C = Common A = Abundant
r = resident m = migrant
b = breeding

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
Long-billed dowitcher, *Limnodromus scolopaceus*							C	C	C	A				m
Western sandpiper, *Calidris mauri*							A	A	A	A				m
Marbled godwit, *Limosa fedoa*							A	A	A	A				m
Sanderling, *Calidris alba*						C	A	A	C					m
American avocet, *Recurvirostra americana*	R						C	C	C					rmb
Black-necked stilt, *Himantopus mexicanus*	R						C	C	C					rmb
Northern phalarope, *Lobipes lobatus*	A						C	C	C					m
GULLS														
Western gull, *Larus occidentalis*	A					A	A	A	A					rm
Herring gull, *L. argentatus*	C					C	C	C	C					m
California gull, *L. californicus*	A					C	C	C	C					m
Ring-billed gull, *L. delawarensis*	A					A	A	A	A					m
Bonaparte's gull, *L. philadelphia*	A					A	A	A	A					m
Heermann's gull, *L. heermanni*	A					A	A	A						m
TERNS														
Forster's tern, *Sterna forsteri*	A					C	C	C						rm
Common tern, *S. hirundo*	C					R	R	R						m
Least tern, *S. albifrons*	A					A	A	C						mb
Royal tern, *Thalasseus maximus*	R					R	R	R						m
Caspian tern, *Hydroprogne caspia*	A					A	A	A						rm
DOVES														
Rock dove, *Columba livia*									R			C	C	r
Mourning dove, *Zenaida macroura*										A	A	A	A	rmb
Spotted dove, *Streptopelia chinensis*											R	R	R	r
OWLS														
Burrowing owl, *Speotyto cunicularia*								R	R				C	rb
HUMMINGBIRDS														
Black-chinned hummingbird, *Archilochus alexondri*									R	C	C	R	R	mb
Costa's hummingbird, *Calypte costae*									R	C	C	R	R	rmb
Anna's hummingbird, *C. anna*										C	C	C	C	rmb
Rufous hummingbird, *Selasphorus rufus*										R	R	C	R	m

APPENDIX E (continued)

BIRDS

Legend: R = Rare C = Common A = Abundant
r = resident m = migrant
b = breeding

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
House finch, *Carpodaus mexicanus*									C	A	A	A	A	rm
Lesser goldfinch, *Spinus psaltria*									R	C	R	A	A	rb
Brown towhee, *Pipilo fuscus*										C	C	A	C	rb
Savannah sparrow, *Passerculus sandwichensis*								R	C	R	R	A	A	rb
White-crowned sparrow, *Zonotrichia leucophrys*									R	C	A	A	A	m

APPENDIX F

MAMMALS

Legend: R = Rare C = Common A = Abundant

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
Opossum, *Didelphis marsupialis*									R	R	R	C	C	
Ornate shrew, *Sorex ornatus*									C	C	C	C	C	
Broad-handed mole, *Scapanus latimanus*												R	C	
Brush rabbit, *Sylvilagus bachmani*									R	R	R	C	R	
Desert cottontail, *Sylvilagus audubonii*									R	R	R	C	C	
Black-tailed jackrabbit, *Lepus californicus*									R	R	R	C	C	
California ground squirrel, *Otospermophilus beecheyi*									R	R	R	C	C	
Botta pocket gopher, *Thomomys bottae*												C	C	
Little pocket mouse, *Perognathus longimembris*												R		
San Diego pocket mouse, *Perognathus fallax*									R		R	C		
Pacific kangaroo rat, *Dipodomys agilis*												C	C	
Western harvest mouse, *Reithrodontomys megalotis*									C		R	R	C	
California mouse, *Peromyscus californicus*												C	R	
Cactus mouse, *P. eremicus*												C	R	
Deer mouse, *P. maniculatus*									R		R	C	C	
Southern grasshopper mouse, *Onychomys torridus*												R	R	
Desert wood rat, *Neotoma lepida*												C	R	
Dusky-footed wood rat, *Neotoma fuscipes*												C		
California meadow mouse, *Microtus californicus*									C				C	
Coyote, *Canis latrans*									C	C	C	C	C	
Gray fox, *Urocyon cinereoargenteus*									R	R	R	C	C	
Raccoon, *Procyon lotor*									R	R	R			
Long-tailed weasel, *Mustela frenata*									R	R	R	R	R	
Badger, *Taxidea taxus*												R	R	
Striped skunk, *Mephitis mephitis*									R	R	R	C	C	
Spotted skunk, *Spilogale putorius*									R	R	R	C	C	
Bobcat, *Lynx rufus*									R	R	R	R	R	

APPENDIX H

FISHES

Legend: R = Rare C = Common A = Abundant

X = Fish collected from S.D.G. & E. intake screens. (S.D.G.&E., 1976, Pers. Comm.)

L = Lagoon O = Ocean

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
SHARKS AND RAYS														
Bullhead shark family (Heterodontidae)														
Horn shark, *Heterodontus francisci*														X
Requeim shark family (Carcharhinidae)														
Leopard shark, *Triakis semifasciata*			C	C										L,O
Gray smoothhound, *Mustelus californicus*			C	C	R									L,O
Brown smoothhound, *Mustelus henlei*			C	C	C									L,O
Thornback family (Platyrhinidae)														
Thornback ray, *Platyrhinoidis triseriata*														X
Guitarfish family (Rhinobatidae)														
Shovelnose guitarfish, *Rhinobotas productus*			C	C	C									L,O
Bat ray family (Myliobatididae)														
Bat ray, *Myliobatis californica*			C	C	A									L,O
Butterfly ray family (Gymnuridae)														
California butterfly ray, *Gymnura marmorata*														X
Sting ray family (Dasyatididae)														
Round stingray, *Urolophus halleri*			C	C	A									L
Diamond stingray, *Dasyatis dipterura*														X
BONY FISHES														
Herring family (Clupeidae)														
Pacific sardine, *Sardinops sagax caeruleus*														X
Anchovy family (Engraulidiae)														
Northern anchovy, *Engraulis mordax*	C													L,O
Slough anchovy, *Anchoa delicatissima*	C													L
Toadfish family (Batrachoididae)														
Specklefin midshipman, *Porichthys myriaster*														X
Plainfin midshipman, *P. notatus*			R	R										L,O
Needlefish family (Belonidae)														
California needlefish, *Strongylura exillis*	C													O
Halfbeak family (hemiramphidae)														
Genus unidentified														X

APPENDIX H (continued)

FISHES

Legend: R = Rare C = Common A = Abundant

X = Fish collected from S.D.G.&E. intake screens. (S.D.G.&E., 1976, Pers. Comm.)

L = Lagoon O = Ocean

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
Nibbler family (Girellidae)														
Opaleye, *Girella nigricans*		A	R		C									L,O
Zebraperch family (Kyphosidae)														
Zebraperch, *Hermosilla azurea*														X
Surfperch family (Embiotocidae)														
Rubberlip surfperch, *Rhacochilus toxotes*		A			R									O
Barred surfperch, *Amphistichus argenteus*			A											O
Pile surfperch, *Damalichthys vacca*		A			C									O
Walleye surfperch, *Hyperprosopon argenteum*														X
Shiner surfperch, *Cymatogaster aggregata*		A			C									O
Damselfish family (Pomacentridae)														
Garbaldi, *Hypsypops rubicundus*		R												O
Blacksmith, *Chromis punctipinnus*														X
Mullet family (Mugilidae)														
Striped mullet, *Mugil cephalus*	A													L
Barracuda family (Sphyraenidae)														
Barracuda, *Sphyraena argentea*														X
Wrass family (Labridae)														
California sheephead, *Pimelometopon pulchrum*		C												O
Senorita, *Oxyjulis californica*			A											O
Blenny family (Blennidae)														
Bay blenny, *Hysoblennius gentili*		C												L,O
Clinid family (Clinidae)														
Giant kelpfish, *Heterostichus rostratus*		C			R									O
Spotted kelpfish, *Gibbonsia elegans*		C			R									O
Goby family (Gobiidae)														
Arrow goby, *Clevelandia ios*			A	C	R		C	C						L
Blind goby, *Typhlogobius californiensis*		C	C											O
Longjaw mudsucker, *Gillichthys mirabilis*				A	C									L
Tonguefish family (Cynoglossidae)														
California tonguefish, *Symphurus atricauda*			R		C									L

APPENDIX I

INVERTEBRATES

Legend: R = Rare C = Common A = Abundant
L = Lagoon O = Ocean

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
CNIDARIANS (Coelenterata)														
Anenomes and corals (Anthozoa)														
Soft coral family (Muriceidae)														
Brown sea fan, *Nuricea californica*		C												L
Sea anemone family (Anthopleuridae)														
Aggregate sea anemone, *Anthopleura elegantissima*						C								L,O
Giant green anemone, *A. xanthogrammica*						C								L,O
FLAT WORMS (Platyhelminthes)					C		R							L
RIBBON WORMS (Nemertea)				C	C									L,O
MOLLUSCS (Mollusca)														
Bivalves (Bivalvia)														
Mussel family (Mytilidae)														
Straight horsemussel, *Modiolus rectus*							R							O
California mussel, *Mytilis californianus*						A								O
Bay mussel, *Mytilis edulis*		A				A								L
Oyster family (Ostreidae)														
Native oyster, *Ostrea lurida*						R								L,O
Scallop family (Pectinidae)														
Speckled scallop, *Aequipecten aequisulcatus*			C											L
Kelp weed scallop, *Leptopecten latiauratus*				A	A									L
Chama family (Chamidae)														
Agate chama, *Chama pellucida*		R												O
Heart shell family (Cardiidae)														
Egg cockle, *Laevicardium substriatum*			A											L
Cockle family (Veneridae)														
Smooth chione, *Chione fluctifraga*								R	C					L
Wavy chione, *Chione undatella*					C			R						L
Rough-sided littleneck, *Protothaca laciniata*				A	C		C							L
Common littleneck, *P, staminea*		R	A				A							L,O
Washington clam, *Saxidomus nuttalli*			C				C							L
Japanese littleneck, *Tapes japonica*					R									L

APPENDIX I (continued)

INVERTEBRATES

Legend: R = Rare C = Common A = Abundant
L = Lagoon O = Ocean

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
Limpet family (Acmaeidae)														
Test's limpet, *Acmaea conus*		R				C								L,O
Finger limpet, *Collisella digitalis*						C								O
File limpet, *Collisella limatula*						C								L,O
Limpet, *Collisella strigatella*						C								O
Owl limpet, *Lottia gigantea*						C								O
Fenestrate limpet, *Notoacmaea fenestrata*						R								O
Top shell family (Trochidae)														
Banded top, *Tegula eiseni*						R								O
Black top, *T. funebralis*			R			A								L,O
Speckled top, *T. gallina*						C								O
Pheasant shell family (Phasianellidae)														
Small pheasant, *Tricolia pulloides*					R									L
Periwinkle family (Littorinidae)														
Eroded periwinkle, *Littorina planaxis*						A								O
Checkered periwinkle, *L. scutulata*						C								O
Chink shell family (Lacunidae)														
One-banded lacuna, *Lacuna unifasciata*					C									L
Vitrinellid family (Vitrinellidae)														
Trinostomia, *Trinostoma supravallatum*		C	R											L
Caecid family (Caecidae)														
Caecum snail, *Caecum californicum*		C	C											L
Worm shell family (Vermetidae)														
Scaled worm shells, *Serpulorbis squanigenus*						A								
Horned shell family (Potamididae)														
California horn shell, *Cerithidea californica*									A					L
Slipper shell family (Calyptraeidae)														
Norris slipper, *Crepidula norrisiarum*		R												L
Onyx slipper shell, *Crepidula onyx*		C												L
Half slipper shell, *Crepipatella lingulata*		C			R									L
Moon shell family (Naticidae)														

APPENDIX I (continued)

INVERTEBRATES

Legend: R = Rare C = Common A = Abundant
L = Lagoon O = Ocean

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
SEGMENTED WORMS (Annelida)														
Polychaete worms (Polychaeta)														
"<u>Errantiate</u>"														
Polynoidae family														
Halosydna tuberculifer						R								L
Lagisca lamellifer		R			R									L
Amphinomidae family														
Eurythoe complanata								R						L
Phyllodoridae family														
Eulalia aviculiseta					R									L
E. quadrioculata					C									L
Hesionidae family														
Ophiodromus pugettensis				R										L
Syllidae family														
Pionosyllis sp.					R									L
P. gigantea					C									L
Typosyllis sp.			R				R							L,O
Nereidae family														
Nereis latescens			C				R							L,O
Platynereis bicanaliculata					C									L
Nephtyidae family														
Nephtys californiensis			A				C							L,O
Glyceridae family														
Glycera sp.			C											L
G. convoluta					R									L
G. tenuis							R							O
Hemipodus borealis					R		C							L,O
Goniadidae family														
Goniada littorea					C									L
Lumbrineridae family														
Lumbrineris sp.							R							O

APPENDIX I (continued)

INVERTEBRATES

Legend: R = Rare C = Common A = Abundant
L = Lagoon O = Ocean

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
Opheliidae family														
Armandia bioculata		R		C	R									L
Euzonus dillonensis							R							O
E. mucronata							A							O
Capitellidae family														
Anotomastus gordiodes							R							L
Capitita ambiseta				A	C			R						L
Heteromastus filiformis			C			R								L
Notomastus tenuis						C	C							L
Oweniidae family														
Owenia collaris				R										L
Sabellariidae family														
Phragmatopoma californica		R				C								L,O
Terebellidae family														
Artacamella hancocki				R										L
Sabellidae family														
Chone mollis							R							O
Euchone limnicola				C										L
Serpulidae family														
Spirorbis borealis					A									L
Protodrilidae family														
Saccocirrus papillocercus							R							O
ARTHROPODS (Arthropoda)														
Amphipods (Amphipoda)														
Amphithoidae family														
Amphithoe longimana					R		C							L
A. plumulosa		R												L
A. pollex					A									L
Aoridae family														
Amphideutopus sp.								R						L
Rudilemboides stenopropodus					C									L

APPENDIX I (continued)

INVERTEBRATES

Legend: R = Rare C = Common A = Abundant
L = Lagoon O = Ocean

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
Talitridae family (continued)														
Orchestoidea californiana							C							L,O
O. corniculata							A							O
Isopods (Isopoda)														
Aegidae family														
Rocinela aries							C							L
Bopyridae family														
Phyllodurus abdominalis								R						L
Cirolanidae family														
Excirolana chiltoni							C							O
Jaeropsidae family														
Jaeropsis concava		R												L
Ligiidae family														
Ligia occidentalis						A	R							L,O
Sphaeromatidae family														
Ancinus granulosus							R							O
Gnorimosphaerma sp.							R							L,O
Paracerceis sculpta					C									L
Decapods (Decapoda)														
Grass Shrimp family, Hippolytidae														
Broken-back shrimp, *Spirontocaris palpator*							R							O
Snapping Shrimp family, Crangonidae														
Long fingered shrimp, *Betaeus longidactylus*						C								L
Ghost shrimp family, Callianassidae														
Red ghost shrimp, *Callianassa californiensis*		C	C		R			A						L
Hermit crab family, Paguridae														
Blue-clawed hermit crab, *Pagurus samuelis*						C								O
Sand crab family, Albuneidae														
Common sand crab, *Emerita analoga*							A							O
Porcelain sand crab, *Lepidopa myops*							R							O

APPENDIX I (continued)

INVERTEBRATES

Legend: R = Rare C = Common A = Abundant
L = Lagoon O = Ocean

	MARINE									TERRESTRIAL				
	SUBTIDAL					INTERTIDAL				MARITIME		UPLAND		
	Open Water	Rock	Sand	Mud	Eel Grass	Rocky Shore	Sandy Shore	Muddy Shore	Salt Marsh	Brackish Water	Maritime	Coastal Sage Scrub	Grassland	Status
Insects (Insecta)														
Beetle pupae, Coleoptera							C							O
Kelp fly, Diptera							A							O
Silverfish, *Lepisma saccharina*							R							O
ECHINODERMS (Echinodermata)														
Sea stars (Asteroidea)														
Sea star family, Asteriidae														
Soft sea star, *Astrometis sertulifera*														L,O
Giant sea star, *Pisaster giganteus capitus*						R								L,O
Ochre sea star, *P. ochraceous*						C								L,O
Sand star family, Astropectinidae														
Spiny sand star, *Astropecten armatus*							C							L
Brittle stars (Ophiuroidea)														
Brittle star family, Amphiuridae														
Amphipholis squamatus					R									L
Annulated brittle star, *Ophionereis annulata*		C												L
Urchins (Echinoidea)														
Short-spined urchin family, Echinidae														
Painted sea urchin, *Lytechinus pictus*					R									L
Long-spined urchin family, Strongylocentrotidae														
Purple sea urchin, *Strongylocentrotus purpuratus*		R												L,O
Sand dollar family, Scutellidae														
Common sand dollar, *Dendraster excentricus*							R							L
Heart urchin family, Spatangidae														
Sea porcupine, *Lovenia cordiformis*			R											L
ECTOPROCTA (Bryozoa)														
Gymnolaemata														
Network bryozoa, *Hippothoa hyalina*					C									L,O
Colonial bryozoa, *Lichenopora sp.*					A									L,O
Jack frost bryozoa, *Membranipora membranacea*					C	R								L,O
Chambered bryozoa, *Thalamoporella californicus*			R		R									L,O