ESTUARINE FISH COMMUNITIES OF BALLONA

Camm C. Swift and Gretchen D. Frantz

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INTRODUCTION

Ballona Marsh is a highly modified remnant marsh on the western edge of the Los Angeles Basin bordering on Santa Monica Bay. Most of the original marsh has been channelized and developed into marinas and condominiums. Ballona Creek is enclosed in a concrete-lined channel and 140 hectares remain separated from the creek by two sets of tide gates (Fig. 1). Although the fish faunas of several coastal estuarine areas of southern California are well studied (Allen and Horn, 1975; Lane and Hill, 1977; Horn, 1981) and some work has been done on Ballona Marsh (Reish, 1980) and the nearby Marina del Rey Harbor (Soule and Oguri, 1977, 1980), the fish community of the marsh was poorly known. Only in Lane and Hill's (1977) study on Anaheim Bay were small upper slough habitats regularly sampled, the only kind of habitat present in Ballona. Lane and Hill did not calculate diversity indices, nor did they discuss the upper marsh as a distinct unit. Thus, this is the first detailed study of an upper marsh fish community in southern California, and provides interesting comparisons with other local marshes and with estuarine areas in other parts of the world. A baseline of information is also provided for assessing future changes in the fish fauna.

METHODS AND MATERIALS

We sampled fourteen stations monthly, from July 1980 through June 1981, among the tribu... y channels of the marsh (Fig. 1): three (Nos. 3, 4, 7) with a large seine, 5 x 1.8 m, with 3.2 mm mesh, and the remaining ten (1-2, 5-6, 8-13) with a 1.8 x 1.2 mm, 6.3 mm mesh seine. We collected plankton with a one-meter diameter plankton net with 0.505 mm mesh. Each seine station consisted of two hauls along the center of the channel at relatively low tides (-0.1 to +0.5 m), when the net swept all or most of the channel. Numerous, relatively short, repetitive sampling drags such as these increases sampling effectiveness, and the level of replicability can be predicted (Livingston, 1976). Stations 3 and 7 were deep holes, in contrast to the typically shallow sloughs of the 11 remaining localities as well as most of the marsh. Collections in Unit 1 fell within 2 hours of low tide. Since Unit 2 was only affected at high tides, collections were always during constant low-tide levels of a few hours' duration.

Fishes were counted, standard length was measured and most fish were released to prevent decimation of the populations. Occasionally, aliquots were taken of large samples, and numbers and biomass were partially estimated, particularly with large samples of postlarval gobies (Gobiidae) in spring. Occasional representative samples were preserved in 5% formalin.

At the low tides, about 3,730 square meters of water surface existed, and our samples covered 9.5% of this (355.12 sq. m) (Table 1). From July through December, we did not collect station 13, or it was dry and 9% of the area was sampled. Dates of collections appear on Table 2. Salinity and temperature were taken from the surface usually before collecting, occasionally after. Salinities were determined by refractometer. A study of top and bottom salinities during a tidal cycle on 15 August 1980 showed these to be identical at low tide in the marsh. Dimensions and bottom type remained stable through the study, and variation in aquatic vegetation is also noted (Table 1). Plankton samples were taken in the main channel (vicinity of Station 4) on incoming tide 2-3 hours after low tide. We estimated the volume strained when the opening of the net was not completely submerged. On 15

August 1980, we set a series of eight minnow traps (baited with frozen squid and anchovy) during the incoming and high tide: four in the channel at Stations 2, 3, 4 and 7, and four on the *Salicornia* flats in the high intertidal north of Station 7, north of Station 5, and east and west of Station 2. The traps on the flats were submerged only for 1 to 2 hours of highest tide, and the one east of Station 2 was only 3/5 inundated.

Diversity (H') was calculated with the method of Shannon-Weaver (1963):

$$H' = -\sum_{i=1}^{s} P_i \log P_i$$

where Pi is the proportion of individual fish (or their biomass) in the ith species. We used natural logarithms in our calculations. The measure of the difference between samples used was the percentage similarity index of Whittaker and Fairbanks (1958).

$$PS = 100(1.0 - 0.5\Sigma[P_{ia} - P_{ib}])$$

where Pia is the proportion of individuals (biomass) in the ith species of sample a and Pib for sample b. We used these measures to compare our samples by area and season and also to compare them with other southern California estuaries. Livingston (1966) has shown a high degree of correlation among the several most common measures of diversity including H', when applied to collections of estuarine fishes.

Common and scientific names follow Robins et al. (1980) and are listed on Table 2 for Station collections and Table 3 for larval (plankton) collections. Diversity calculations are based on the regular seine stations (Table 1) only, and both larvae and incidental juveniles and adults are listed for the plankton samples (Table 2). Other collections appear in text discussion but not in the tables.

DESCRIPTION OF THE AREA

The area studied consists of two Units (Fig. 1) traversed by tidal channels or sloughs of about 1.5 ha of surface water at mean tide levels. The area is part of the Marina del Rey Harbor-Ballona Channel estuarine area, which together have about 200 ha of surface water. The channels are mostly quite straight, and the two largest pass through culverts under Culver Boulevard and empty into Ballona Creek channel through larger culverts with tide gates. Channels in Unit 1 fluctuated with the tide, but the channels in Unit 2, being about one meter higher, fluctuated only during the upper 1/4 to 1/3 of the high tide. During the remainder of the tide cycle, little or no fluctuation occurred in Unit 2. During minus tides, water in Ballona Creek Channel falls below the levels in Unit 1, and 30 minutes to 1.5 hours of static low tide occur in the marsh (i.e. Stations 3 and 4) depending on the height of the tide. Broad areas of shallow flats adjacent to channels mostly drained at low tide. A few hypersaline pools on the west edge of Unit 1 were fishless during this study.

onal fluctuation in low-tide salinity and temperature occur (Fig. 2). Salinities were generally high (15-34 ^{o}/oo) and were full strength only occasionally at the entrance to Ballona Channel (Stations 1 and 3) and were fresh only at the uppermost Stations (9, 11, 12, 13). At Station 3, above the tide gates, the salinity would usually be in the high twenties at low tides. As the tide started to come in, fresh water that extended down Ballona Flood Control Chanel would push in on top of the saline water. As the tide rose, the fresh water would be pushed farther up Ballona Channel and the surface water at Station 3 got progressively saltier until high tide, when full-strength seawater existed from top to bottom. As the tide went out, surface salinity would initially decline faster than the bottom. By low tide, mixing of the outflowing water equalized top and bottom salinities to similar values. Stratification also occurred on incoming and high tide at Stations 1, 2, 3, 5, 6 and 7, with the surface salinity 3 $^{o}/oo$ (Station 1) to 9 $^{o}/oo$ (Station 2) lower at the surface than at the bottom. High salinities were maintained in the warm months in Unit 1 by evaporation on shallow flats inundated only at high tides. This water was often hypersaline and was recorded up to 52 $^{o}/oo$ just northeast and upstream of Station 4. During the cool months, the salinity of water on the flats was comparable to nearby channels, and increased fresh-water inflow caused a general decrease in values. Water temperature fluctuated in a bimodal pattern, lower in mid-summer, increasing in late summer-early fall, decreasing again in late fall to low levels in winter. Water temperature rose regularly into April, declined in May, and rose again in June. The mid-summer decrease is probably due to the increased fog near the coast, allowing the shallow marsh water to cool, and the fall increase is caused by the lack of fog, allowing the sun to warm the water considerably. Later in winter, cold air, increased cloud cover, and cold ocean temperature combined to cool the water again. The May reduction was not as strong as the previous July, but indicates that often the highest water temperatures may occur in spring and fall with a mid-summer depression due to fog cover. This would only occur in upper shallow marshes where solar radiation can significantly alter temperatures and substantial mixing with local marine waters does not take place. Coastal ocean temperatures regularly fluctuate from winter lows to late summer highs as do other connecting well-mixed bays, but the two sets of culverts restrict flow in the marsh and probably enable solar effects to predominate, as they would have in the original shallow marsh closed or only narrowly open, to the ocean.

The culverts opening to Ballona Channel were open through fall 1980, but those of the main channel at Station 3 were covered with plywood from late December to June 1981. These were placed to divert a large sewage spill down Ballona Channel, 12-18 December, and apparently protect adjacent farm land and business from high spring tides. Intermittently the gates were removed, or moved from the marsh side to the flood control channel side of the culverts. Considerable water flowed around the gates, and tides rose and fell in the marsh with little visible difference. Tides were probably delayed slightly and did not reach the highest levels possible, but were otherwise normal. The gates served as a partial barrier to waterflow only.

FISHES

Engraulidae

Engraulis mordax. The northern anchovy was only taken as two eggs in March and one larva in plankton hauls in March. It is common in larger bays [illegible]bors in California (Allen and Horn, 1975; Horn, 1981), but rarely [illegible] in shallow, upper slough areas.

Cyprinodontidae

Fundulus parvipinnis. California killifish were the fourth most abundant fish and were common throughout the year. Greatest abundance was in the summer months, and there was a shift in abundance from Unit 1 to Unit 2 during the winter. Adult tuberculated males in breeding color occurred from April to September. The first young of the year were observed in June. California killifish were taken or observed in water ranging from fresh to 38.4 $^{o}/oo$, well within the tolerance range of this species (Barlow, 1963). Trapping on 15 August 1980 took three fish in the channels and 24 on the flats during incoming and high tides, demonstrating movement onto the flats at this time. Fritz (1977) studied the biology of this species in Anaheim Bay.

Poeciliidae

Gambusia affinis. Mosquitofish, a non-native species, widely introduced to control mosquitos, entered California in 1922 and were established in the Los Angeles Basin by 1930 (Miller, 1961). They were the second most abundant fish but were abundant only in Unit 2. Summer collections in Unit 1 (Stations 6 and 7) took occasional individuals, and mosquitofish were most abundant at the stations with low salinities (Station 9) and in the fall. They occurred in shallow, flat Salicornia-choked pools and channels between the main channels of Units 1 and 2, and our data are for the main channels only. Newly spawned young were first taken in April, and individuals 15 mm or less were taken as late as November. We took mosquitofish in water up to 52.8 $^{o}/oo$ at Station 12 in August. Fifty to sixty dead and dying mosquitofish were observed 70-100 m upstream of Station 9 on 9 July 1980.

Atherinidae

Atherinops affinis. Topsmelt were the third most abundant species and were absent during the winter (late December to February), apparently moving seaward into Marina del Rey or Santa Monica Bay. They were almost entirely confined to Unit 1, and two size classes were apparent in the fall. The first young of the year appeared in March. Horn (1981) reviewed the information available on life history of this species in southern California and showed that topsmelt are commonly one of the dominant species in southern California bays and estuaries. They feed largely on zooplankton.

Leuresthes tenuis. Four grunion larvae were taken in the plankton hauls in September and May. Grunion are common in southern California but rare in bays and marshes (Walker, 1952).

Atherinopsis californiensis. Eight jacksmelt larvae were taken, five in the December plankton haul, two in March and one in April, coinciding with the winter spawning peak of this common coastal fish (Feder, Turner, and Limbaugh, 1974) that is rare in coastal marshes.

Cottidae

Leptocottus armatus. Staghorn sculpin were taken in small numbers in Unit 1 and were the seventh most abundant species. Small juveniles appeared in winter and early spring collections, indicating a late fall and winter spawning as documented for other southern California populations (Tasto, 1977; Horn, 1981). Usually this species invades brackish and freshwater portions of estuaries, but we did not collect it in Unit 2. It was taken at salinities of 15.6 ^{o}/oo to 36.0 ^{o}/oo.

Gobiidae

Acanthogobius flavimanus. The yellowfin goby was introduced to the Pacific coast from Japan in the late 1950's and was first observed in southern California in 1977 (Haaker, 1979). Both juveniles and adults were collected in the marsh with juveniles predominating in spring collections. Our collections are the first southern California records north of Palos Verdes Peninsula. This goby was taken only in the higher salinity of Unit 1 (at salinities of 20.4 ^{o}/oo to 36.0 ^{o}/oo) despite its propensity for brackish and freshwater elsewhere. Populations of this species should be watched to document its spread in southern California.

Clevelandia ios. The arrow goby was numerically the most abundant species. Arrow gobies were present throughout the year and were most abundant from late winter through spring when large numbers of young of the year were present. Almost all records are for Unit 1 with small numbers taken at Station 10 (Unit 2) in the fall. Because of their burrowing habitat, adult arrow gobies, were probably undersampled in general. Our collections indicate a late winter spawning time, and the young of the year dominated the collections in Unit 1 in March and April. Horn (1980) emphasized the probable great importance of gobies in the food web of bays and marshes in transferring energy from low trophic levels to the higher ones (i.e., shorebirds, that prey on gobies).

Quietula y-cauda. The shadow goby was taken only three times in the spring and apparently occurs in very low numbers in the marsh. Brothers (1975) extensively studied the biology of this species, the arrow goby and the cheek-spot goby in the San Diego area.

Gillichthys mirabilis. Mudsuckers were mostly taken in Unit 1 and were the fifth most abundant species. Sixteen fish were taken in Unit 2, and one of these (March) was taken in fresh water. Young-of-the-year were common in the spring and coincided with the spawning season documented by Weisel (1947), Barlow (1963), Barlow and de Vlaming (1972). One series of eight traps set during high tide on 15 August 1980 demonstrates a greater abundance of mudsucker than our seine collections indicate. Channel traps caught 18, and traps on the flats took 28 fish. Twelve of the channel fish were taken in the exceptionally deep hole at Station 7. Gillichthys, like Fundulus, moves onto the flats at high tides. Its scarcity in our low-tide station collections indicates that it retreats into slough-side crab burrows (Barlow, 1963), rather than into the slough channels as do Fundulus.

Ilypnus gilberti. Three larval cheekspot gobies were taken in the plankton in July, and two juveniles were seined in April; they are apparently very rare.

Goby A. Fifteen small larval gobies are Ilypnus gilberti or Quietula y-cauda, three in December, one in April and eleven in June; they cannot be distinguished further.

Goby C. Five small larval gobies taken in March are Clevelandia ios, Lethops connectens or Lepidogobius lepidus and cannot be distinguished further.

Mugilidae

Mugil cephalus. Striped mullet were taken only in Unit 1 and probably represent one year class that grew successively larger (July to April) and then left the marsh, since no mullet were collected in May and June. The mullet collected in July ranged form 91-110 mm SL ($\bar{x}$ = 108 mm SL); those taken in March ranged from 93 to 212 mm SL ($\bar{x}$ = 166 mm SL). Mullet were taken at salinities of 12.6 $^{o}/oo$ to 36.0 $^{o}/oo$. Young-of-the-year are occasionally taken in the lower portions of coastal streams in mid- and late winter (LACM records). Many of the mullet showed fin deformities that have been associated with high pollution levels in other areas (Sindermann, 1978). Nineteen of 41 mullet we actually measured (41%) showed eroded fins or anatomical deformities. Out of 76 fish tallied in Ballona Marsh (some jumped over our net or otherwise escaped), these represent 26%. Some of these fish may have been caught on successive months, and deformed fish could have been more vulnerable to capture. However, even a considerably lower (<2-3%) incidence would indicate abnormal conditions. Sindermann (1978) documents that in brackish pond (12 $^{o}/oo$), 4-5 ppm of crude oil caused fin erosion in most of the mullet exposed in 6-8 days. He notes a wide variety of other pollution related effects on a variety of fish species, and only a detailed study of Ballona Marsh would disclose the conditions existing.

Bothidae

Paralichthys californicus. One juvenile California halibut (103 mm SL) was collected at Station 4 in August at a salinity of 36.0 $^{o}/oo$. Haaker (1977) has extensively documented the life history of this species in Anaheim Bay, where juveniles (under 300 mm in length) were common inhabitants. He found the youngest fish appeared in April and May and remained in the marsh about one year after which they departed to deeper coastal water. This is a valuable sport species that relies on shallow bays for nursery areas elsewhere in southern California and would become more common in Ballona Marsh if conditions improved.

Pleuronectidae

Hypsopsetta guttulata. The diamond turbot was the most commonly caught species of flatfish and was taken primarily at Station 5, where the greatest amount of shelly substrate occurred. All but one fish seined were young-of-the-year taken in November, December, March, April and May at salinities of 30.0 $^{o}/oo$ to 40.8 $^{o}/oo$. Two diamond turbot eggs were taken in March, and two non-metamorphosed larvae were taken in May. Diamond turbot are common bay and estuary inhabitants (Lane, 1977) that should be more common in Ballona Marsh.

Pleuronichthys verticalis. Nine eggs of the horny head turbot were in the March plankton haul. This species is common in California coastal waters but rare in upper marshes (Fitch, 1963).

Pleuronichthys ritteri. Three eggs of the spotted turbot were taken in the March plankton haul. This species is common in California coastal waters but is rare in upper marshes (Fitch, 1963).

Embiotocidae

Embiotoca jacksoni. A large adult black perch was taken at Station 3 in March, obviously a straggler from the outer marina area. Black perch are common game fish around shallow southern California reefs, jetties and kelp beds (Feder, Turner and Limbaugh, 1974).

Cymatogaster aggregata. One young-of-the-year shiner perch, 32 mm SL, was taken at Station 3 in April. The shiner perch is a common sport species in bays and marshes in southern California (Odenweller, 1977) and would become more common if conditions improved in Ballona Marsh.

Blenniidae

<u>Hypsoblennius gentilis</u>. The bay blenny is represented by one transforming "ophioblennius" larvae taken in the August plankton haul. This species is undoubtedly common on the hard substrate in protected areas just outside the marsh, as it is in many southern California localities (Stephens et al., 1970).

Clinidae

<u>Heterostichus rostratus</u>. The giant kelp fish is represented by three larvae taken in the March plankton haul. This species is common around shallow reefs, jetties and kelp beds in southern California and spawns from March to July (Feder, Turner and Limbaugh, 1974).

Clinid A. Two larvae in the December plankton haul are clinids and represent either <u>Gibbonsia</u> or <u>Neoclinus</u>, each with three southern California species. Several of these species undoubtedly occur in Marina del Rey but are rare in upper marsh habitats (Feder et al., 1974).

Sciaenidae

<u>Seriphus politus</u>. The queenfish is represented by nine postlarvae taken at Station 3 in May. It is a common schooling species in shallow coastal marine waters (Feder, Turner and Limbaugh, 1974) and spawns April to August in southern California (Goldberg, 1974). Only juveniles occasionally occur in back bays and estuaries (Klingbeil, Sandell and Wells, 1977).

<u>Genyonemus lineatus</u>. One white croaker larvae was taken in April; this is a common croaker in larger bays and along the southern California coast (Feder et al., 1974).

DISCUSSION

The Ballona marsh and tributary creek undoubtedly was once similar to many others along coastal southern California. Its extent under unimpacted conditions is shown on an early map of the southwestern Los Angeles Basin (Redondo Sheet, U. S. Geological Survey, 1896 edition, based on surveys done in 1894) (Fig. 3). Typically a broad marsh area existed behind a long sand spit with only a narrow opening to the sea. This opening probably often closed to the ocean during the summer and fall, leaving a brackish lagoon until high winter inflows opened it again. When open, build-up of sand at the mouth would prevent the tide in the marsh from fluctuating fully. Without full daily flushing, the water in the marsh would stay relatively fresh and temperature would fluctuate more widely as it still does in relatively pristine coastal lagoons elsewhere in California.

Today the marsh has been heavily modified. Channelization of the harbor and creek established and maintained full, regular tidal flow to most of the area. Both this increased mixing with sea water and reduced freshwater inflows brought higher salinity, which along with temperature vary in parallel with nearby open coastal areas. Regular tidal cycles also maintain deeper more well-defined channels in the actual marsh than under original conditions. The Culver Boulevard barrier artifically maintains a low-tidal fluctation in Unit 2 and consequently shallower channels exist there. Below in Unit 1, almost complete tidal fluctuation occurs, channels are much deeper, and at least two tributaries are actively eroding headward. In Unit 2 temperatures are generally higher, reflecting the influence of solar radiation in warming shallow water. Unit 1 values, particularly Stations 1 and 3 near the inlet of the marsh are more in parallel with the sea. Man's activities have fortuitously created somewhat original physical conditions in Unit 2 and highly modified conditions in Unit 1. The restricted water flow through culverts and/or flapgate at Ballona Creek channel and through Culver Boulevard has restricted the movement of fishes and has caused faunal differences between the two areas.

Twenty-five species of fish were collected in the marsh (Tables 2 and 3), comprised of 13,389 juveniles and adults, 278 larvae and 439 eggs. Fourteen eggs were identified to species, and the rest fall into about ten categories and are not identified further. Ten species were only taken as eggs, larvae or postlarvae, *Engraulis mordax*, *Atherinopsis californiensis*, *Leuresthes tenuis*, *Hypsoblennius gentilis*, *Heterostichus rostratus*, *Seriphus politus*, Clinid A, *Genyonemus lineatus*, *Pleuronichthys verticalis* and *P. ritteri*. Three were taken only once, *Embiotoca jacksoni*, *Cymatogaster aggregata* and *Paralichthys californicus*, and one was taken only twice, *Ilypnus gilberti*. Two are introduced species, not native to California, *Gambusia affinis* and *Acanthogobius flavimanus*. The remaining nine species are common inhabitants of coastal bays and estuaries from Morro Bay to northern Baja California. We did not find a large number of species that have been recorded from other southern California bays and marshes such as Anaheim Bay (Lane and Hill, 1977), Colorado Lagoon (Allen and Horn, 1975) and Mugu Lagoon (MacDonald, 1976 [from Horn]), for two reasons: First, our collections represented uppermost tidal channel habitats only, since the larger, deeper open lagoonal areas were not present at Ballona. Second, flap gates and the shallow Ballona Creek Flood Control Channel separate the marsh from deeper water, interrupting the habitat continuum from shallow marsh to deeper bay, and thus preventing species invasion.

Most of the additional species are not typical of deeper water or are only occasional invaders of the shallow marsh. Three species, Paralichthys californica, Cymatogaster aggregata and Hypsopsetta guttulata would be more common under natural conditions. Three species not recorded, Syngnathus leptorhynchus (bay pipefish), Platichthys stellatus (starry flounder) and Eucyclogobius newberryi (tidewater goby), should occur. Bay pipefish are usually restricted to grass beds that were largely absent at Ballona. Tidewater gobies are found in the upper, freshwater portions of coastal lagoons and are sensitive to habitat modification. They probably occurred at Ballona in the past but have been eliminated. Starry flounders are not as common in southern California as they are in cooler estuaries north of Point Conception. Flatfishes were rare in our study in general, and some unknown factor is causing this.

The fish community diversity H' fluctuated relatively regularly with the season in each area, for a variety of reasons. Unit 1 had high diversities in summer and low diversities in winter. Unit 2 had the opposite with both areas having roughly equal diversities in the winter (Fig. 4). Unit 1 decreased in diversity in the fall because topsmelt left the area, and California killifish and goby species became less abundant. Topsmelt left the marsh, but some California killifish and gobies (Clevelandia and Gillichthys) moved into Unit 2 increasing the diveristy there. The tendency for Fundulus parvipinnis to invade fresher water in fall and winter has been documented elsewhere (Miller, 1939, 1943, LACM unpublished records). In the spring, killifish and gobies moved back out of Unit 2 causing the diversity to decline again. The concomitant increase of these in Unit 1 along with 1) increasing large numbers of young-of-the-year gobies (Quietula, Gillichthys, Acanthogobius and, predominantly, Clevelandia) and later 2) return of Atherinops affinis, caused the diversity here to rise again. Our H' was calculated from numbers of specimens rather than biomass, and since the vast majority of our fish fell between 20 and 120 mm SL and were slender or elongate fusiform in shape, the diversity trends would not be altered significantly by using biomass.

The diversity measure, H', ranges from .55 to 1.57 in Unit 1 and .07 to .67 in Unit 2. Haedrich (1975), Livingston (1976) and Horn (1981) discussed the general increase of the value of this measure with lack of disturbance to the habitat, and Horn (1981) discussed values for several southern California lagoons. Often values up to .75 or .80 represent highly impacted, modified estuaries, whereas values of 1.5-1.7 are calculated from data on relatively pristine systems in southern California. Values from sampling stations in a relatively pristine tropical estuary in the southern Gulf of Mexico ranged from 0.5-2.50 (Yanez-A., Amezcua and Day, 1980), and Livingston (1976) found wide variation in diversity due to salinity and temperature fluctuations in a relatively unpolluted south temperate estuary in Florida. Ballona Creek

an estimated 4 to 5 million gallons of untreated sewage from an accidental leak on 12 December 1980. This occurred after the diversity in Unit 2 had risen to winter levels, but before a significant decrease occurred in Unit 1. If the sewage reduced fish populations and/or forced them from Unit 1 into Unit 2, lower than normal diversity in Unit 1 would result.

The increase in numbers of fish-eating birds during the winter migratory period probably also accounts for some reduction in number and diversity of fishes in Unit 1. Horn (1981) noted that California estuarine gobies probably are a significant food source for shorebirds, and Swift et al. (1977) noted that cyprinodont fishes (Fundulus and Gambusia in this study) are often heavily preyed upon by fish-eating birds, particularly herons and egrets. Definite increases in the populations of such birds during the winter are documented elsewhere (Dock and Schreiber, this study), but quantitative data on their predation on fishes is lacking. Diversity values in the summer fall in the range of those for other relatively unimpacted estuaries in southern California. Fall, winter and spring values are lower, mostly because of seasonal movements of the few dominant species (Atherinops affinis, Fundulus parvipinnis and Clevelandia ios) and because Ballona is an upper marsh where the fauna is expected to be smaller and less diverse than in a larger bay (Horn and Allen, 1976; this paper). Bird predation, the restricted openings to the marsh and occasional pollution certainly affected the magnitude of these fluctuations, but to an as-yet-undetermined extent, and clearly diversity values reflect the interaction of natural and manmade influences on composition of the fish community.

The generally low-diversity figures for Ballona are due to a combination of location in the upper marsh, small marsh area, and impact of human modification. Estuarine biologists long ago noted the decrease in diversity at the upper end of estuarine systems (Hedgpeth, 1957) based on the numbers of species. Diversity is usually lowest in the 5 to 8 $^{o}/oo$ range (Khlebovich, 1969) and increases again as one proceeds into strictly freshwater habitats. Without comparative data on lower, middle, upper and strictly freshwater portions of comparable estuaries, we cannot separate these three factors. Data presented by Horn and Allen (1976) predict that the Ballona marsh, with an area of only about 1.5 hectares of water surface at mean tide (Units 1 and 2), should have a fish fauna of only a few species. The smallest estuaries studied by them, Los Pensaquitos Lagoon (22 ha) and Tijuana Estuary (59 ha) had 22 and 29 species, respectively. Obviously the Ballona marsh fauna is only a small part of the larger Marina del Rey-Ballona Creek estuarine area, and its large species list is due to association with this larger area. These areas combined have about 200 ha of water surface at mean tide, close to Alamitos Bay (166 ha) and Elkhorn Slough (216 ha) that have 43 and 69 species, respectively. Forty-four species (not including two non-natives) have been reported from Marina del Rey estuarine areas (Soule and Oguri, 1980; this study) and about 50 would be expected from an estuary of this size. In Unit 1, summer diversity values are within the range of relatively unmodified estuaries elsewhere. In Unit 2 the human encroachment is greatest, and the low diversity values reflect this effect. One of the two dominant fish in Unit 2 (Gambusia affinis) is not native, and removal of it would lower the values even more. Our data indicate a relatively normal fish fauna in Unit 1, and a highly impacted and depauperate one in Unit 2. Removal or amelioration of the barrier between them (Culver Boulevard) would result in Unit 2 converging towards the condition found in Unit 1. If the barrier between Unit 1 and Ballona Creek were also removed, a salt marsh would be established that would resemble those present in upper Newport Bay, Anaheim Bay and Mugu Lagoon, and the number of [illegible] biomass and diversity of fishes would all increase.

Ballona Marsh would not return to its original condition, which was a large, mostly fresh and brackish, marsh open to the ocean only seasonally. Such localities remaining today in southern California have only a few fish species, usually Fundulus parvipinnis, Eucyclogobius newberryi and Gasterosteus aculeatus, and occasionally Atherinops affinis, Cymatogaster aggregata, Hypsopsetta guttulata, Leptocottus armatus and a few other species. They also have very low diversity as is predicted from the typically low salinity of this habitat. A fish species unique to the brackish and freshwater lagoon habitat (Eucyclogobius newberryi) was probably eliminated in the middle of this century, and several other species of organisms typical of this habitat remain under altered conditions.

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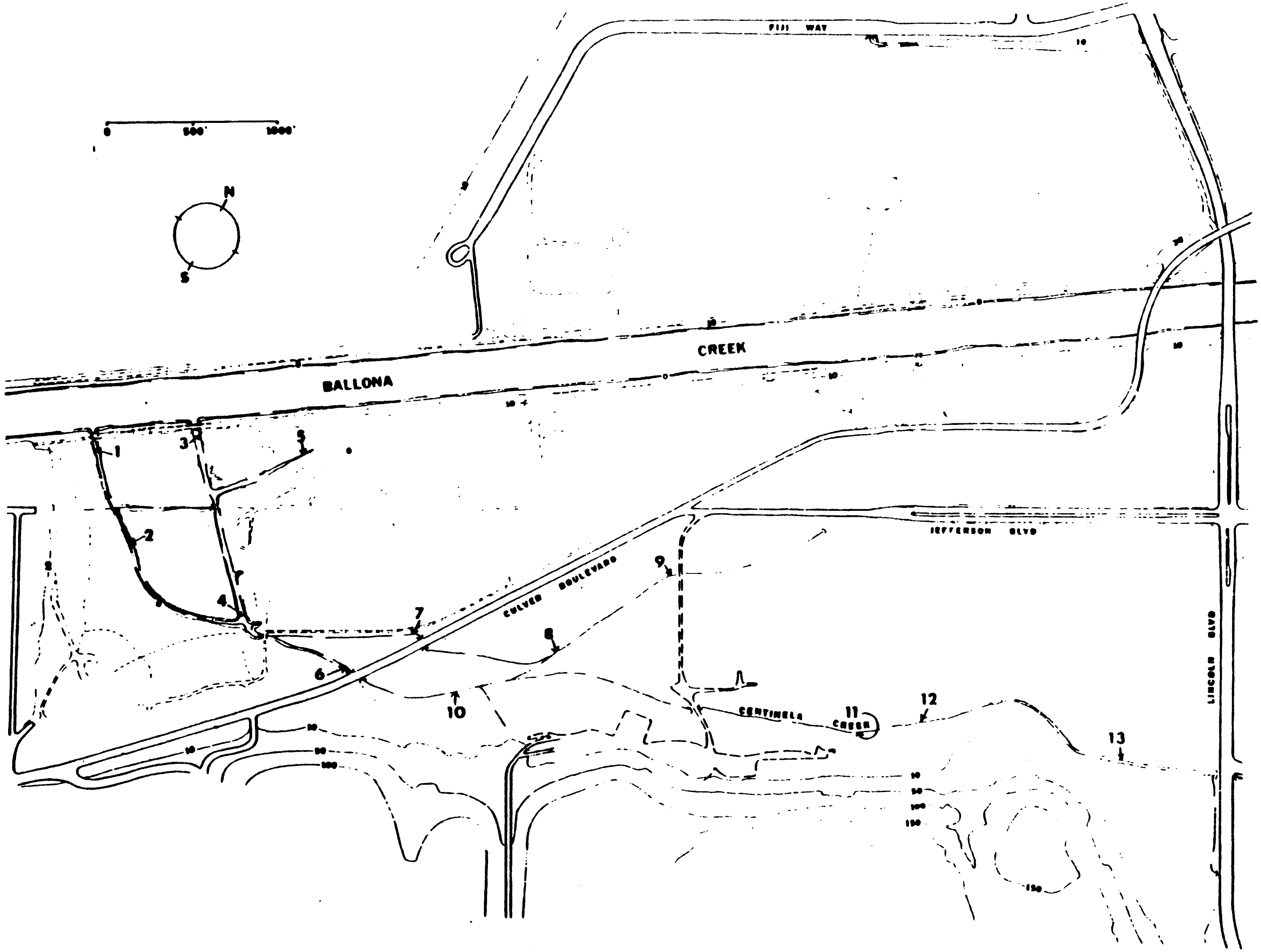

Figure 1. Ballona Creek Marsh showing the collecting Stations described in the text.

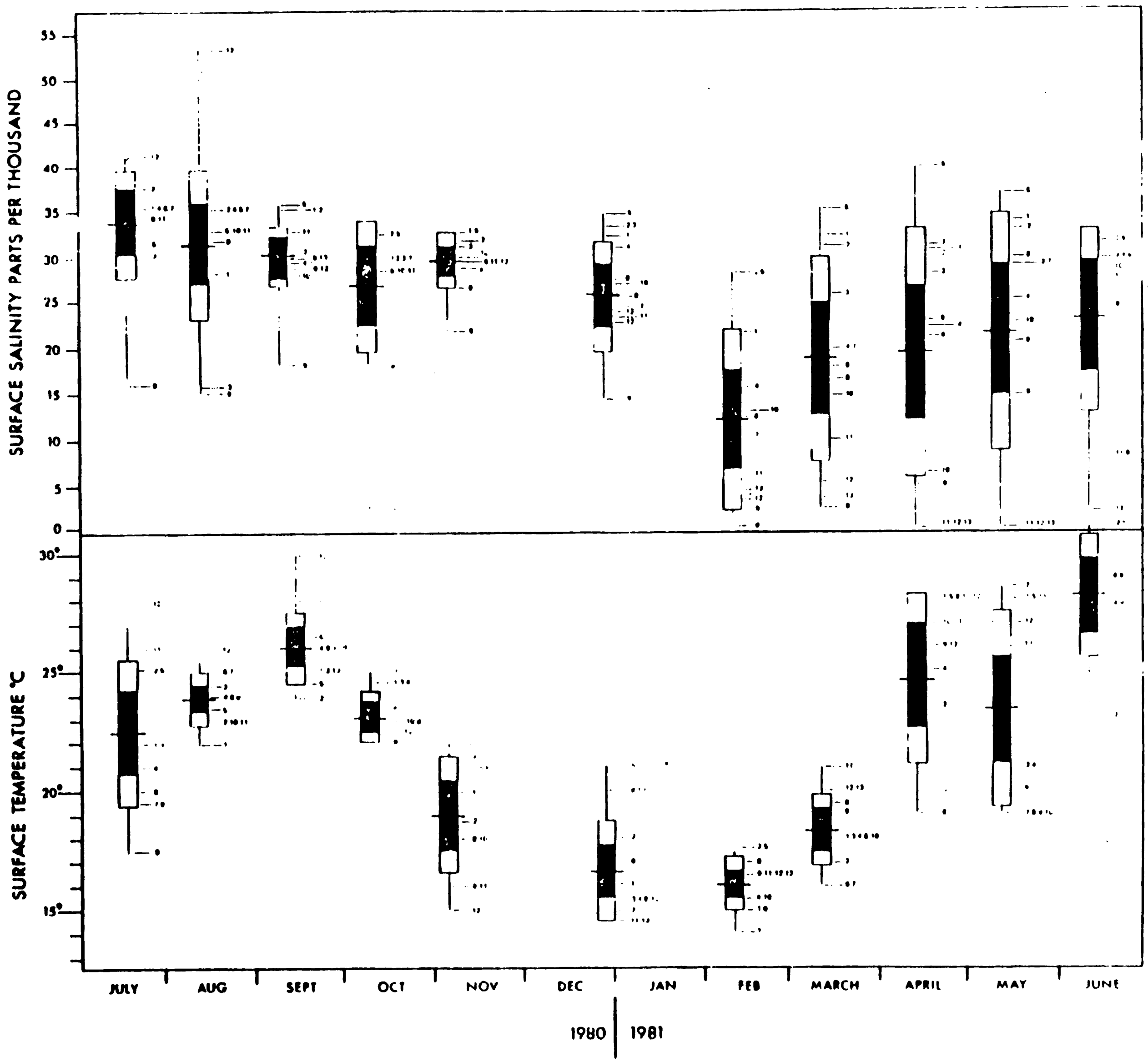

Figure 2. Surface salinity and temperatures recorded in Ballona channels during this study. Numbers lie opposite values for that particular station. The ends of the vertical lines represent the range of values, the strong horizontal line the mean, the black columns equal two standard errors on either side of the mean, and the open columns equal one standard deviation from the mean.

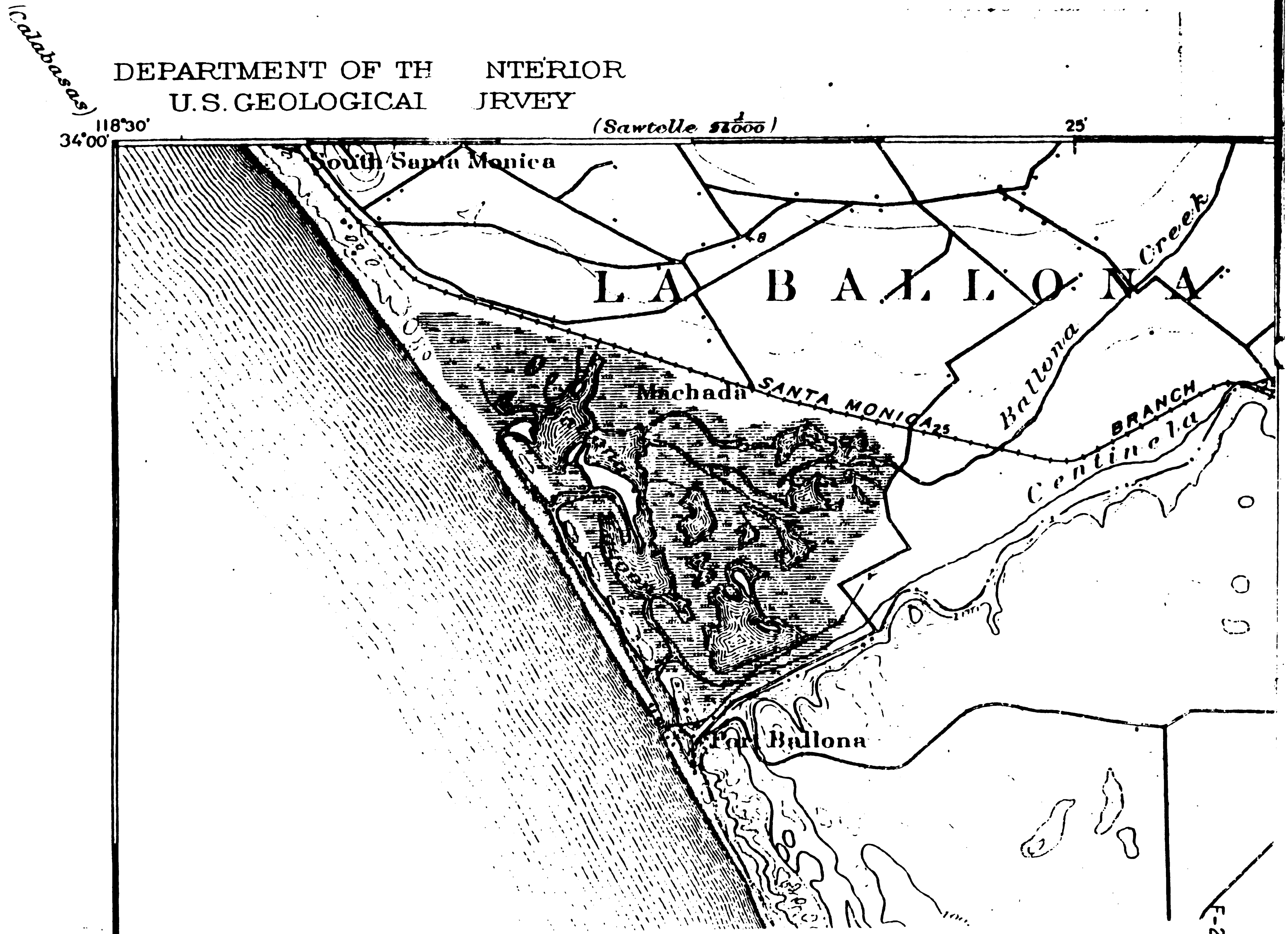

Figure 3. Topographic Map of Ballona Marsh, Redondo Sheet, U. S. Geological Survey, 1896 edition, based on surveys done in 1894.

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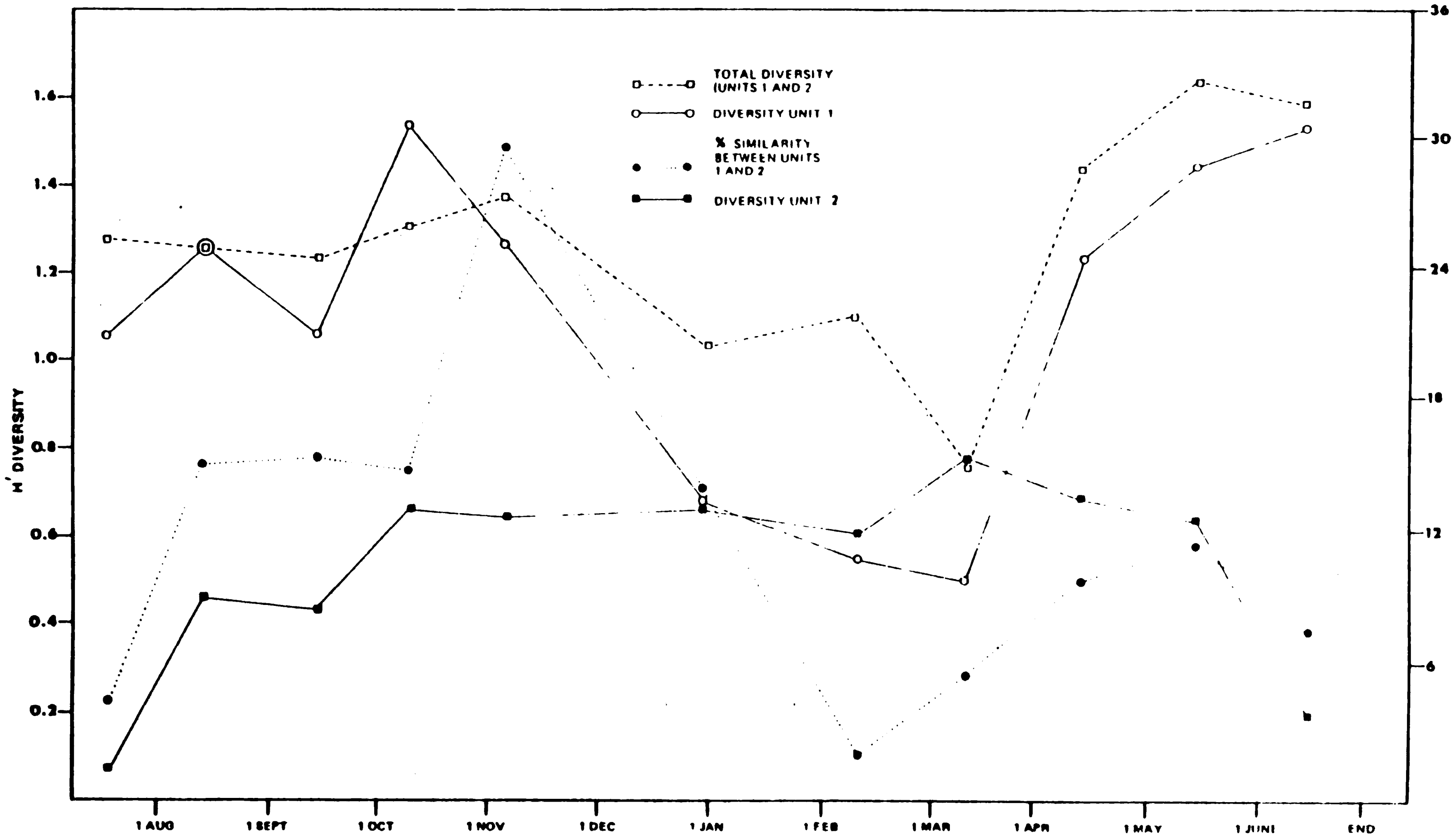

Figure 4. Diversity (H') of Units 1 and 2 and the percent similarity (PS) between the two units.

TABLE 1. Description and regular collection stations

Station	Deepest Depth (cm)	Estimated Average Width (m)	Bottom	Macroscopic Vegetation	Area or Volume Sampled (sq. m)	Remarks
1	10-40	0.75-2.1	Soft mud scattered shell.	None	13.12	Just inside small tide tidegates
2	2-30	0.75-1.0	Soft mud, scattered shell.	None	19.5	Small slough.
3	80-140	5-6	Mostly firm and with shell, mud at edges.	None	101.25	Just inside large tide-gates.
4	40-70	4-5	Soft sand, mud at edges.	None	93.75	Below junction of three sloughs.
5	4-35	0.6-1.0	Mud covered with shell hash in channel.	None	12.75	Just below 0.5 m high high falls over mudbank.
6	20-40	0.8-1.2	Soft mud with rocks and shell, live mussels.	None	3.375	Below culvert under Culver Blvd.
7	60-80	3-4	Soft to firm sand with shell, glass and rocks.	None	26.25	"
8	20-30	1.2-2.0	Soft mud.	Much green algae & *Ruppia* in warm months.	12.0	---
9	30-45	2-3	Soft mud.	Much *Scirpus robustus*, algae.	7.875	Below culvert on road.
10	4-20	1.0-1.5	Soft mud.	*Ruppia maritima* and green algae in warm months.	12.75	---

Table 1 (continued)

Sta.	Deepest Depth (cm)	Estimated Average Width (m)	Bottom	Macroscopic Vegetation	Area or Volume Sampled (sq. m)	Remarks
11	10-20	0.4-0.6	Soft mud.	Green algae in warm months.	15.0	---
12	25-40	0.5-1.2	Firm sandy mud.	Green algae in warm months.	18.75	Agricultural, lacking shore vegetation.
13	20-30	1.0-1.5	Soft mud.	Green algae, *Potamogeton pectinatus*, in warm months.	18.75	Agricultural, not collected July, August, dry September, October, November.
Plankton	1.0-1.5	6-7	Over firm to soft sand.	None	73.7 cu. meters	Some hauls net not completely submerged, see text.

TABLE 2. Fishes taken in seine hauls at established stations in Ballona Marsh in Units 1 and 2 by month.

BALLONA MARSH JULY 1980-JUNE 1981

	16, 17, & 24 July		13 & 15 August		10, 12 & 22 September		9 & 10 October		6 & 7 November		30 December		11 February		13 March		14 & 15 April	
Seine Stations	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Fundulus parvipinnis	236	3	118	44	175	83	24	194	250	115	38	24	6	30	67	77	175	187
Gambusia affinis	34	320	16	702	25	691	13	599	12	320		38		72		136	18	156
Atherinops affinis	638	1	207		486	1	118		179						33		587	
Mugil cephalus	5		1		1		2		3		13		11		16		6	
Leptocottus armatus	16		4		5		13		9				7		12		13	
Ilypnus gilberti																	2	
Quietula y-cauda															20			
Clevelandia ios	40		64	49	58	13	61	17	89	5	209		236		2065	5	1026	
Gillichthys mirabilis	9		19	2	18	1	60	3	8	1			10		31	1	61	
Acanthogobius flavimanus	13		7		1		2				1				36		52	
Paralichthys californicus			1															
Hypsopsetta guttulata									1		3				3		2	
Embiotoca jacksoni															1			
Cymatogaster aggregata																	1	
Seriphus politus																		
SPECIES TOTAL	991	324	527	797	769	789	293	813	551	441	264	62	270	102	2284	219	1943	343

Table 2 (continued).

13 May 1	13 May 2	12 June 1	12 June 2	Total 1	Total 2	Total	Common Name
66	35	75	4	1230	796	2026	California Killifish
11	131	14	168	143	3333	3476	Mosquito fish
361		143		2842	2	2844	Topsmelt
-		-		58	0	58	Striped Mullet
7		2		88	0	88	Pacific staghorn sculpin
		-		2	0	2	Cheekspot goby
		-		20	0	20	Shadow goby
316		89		4253	89	4342	Arrow goby
73	5	24	3	313	16	329	Longjaw mudsucker
48		20		180	0	180	Yellowfin goby
		-		1	0	1	California halibut
3		-		12	0	12	Diamond turbot
		-		1	0	1	Black perch
		-		1	0	1	Shiner perch
		-		9	0	9	Queen fish
894	171	367	175	9153	4236	13389	

Table 3. Fishes taken in plankton hauls in Ballona Marsh, July 1980 to June, 1981.

Asterisks mark larger (postlarval or larger) fishes taken incidentally with larval forms. Clinid A, Goby A, and Goby C are defined in text.

	Jul	Aug	Sep	Oct	Nov	Dec	Feb	March	April	May	June	Total Larvae	Total Juveniles & Adults	Total
<u>Engraulis mordax</u> (Northern anchovy)								1				1	-	1
<u>Fundulus parvipinnis</u> (California killifish)			1*	*3(6)				2*			1	1	6	7
<u>Atherinops affinis</u> (Topsmelt)	15 122*	1*	7*	*4(8)				5	1*(2.5) 1 (2.5)	123 4*	1* 80	226	140	366
<u>Leuresthes tenuis</u> (California grunion)			1							3		4	-	4
<u>Atherinopsis californiensis</u> (Jacksmelt)						5		2	1 (2.5)			8	-	8
<u>Hypsopsetta guttulata</u> (Diamond turbot)										2		2	-	2
<u>Leptocottus armatus</u> (Pacific Staghorn sculpin)						1						1	-	1
<u>Hypsoblennius gentilis</u> (Bay blenny)			1									1	-	1
<u>Heterostichus rostratus</u> (Giant kelpfish)								2				2	-	2
Clinid A (see text)						2						2	-	2
<u>Ilypnus gilberti</u> (checkspot goby)	3											3	-	3
<u>Clevelandia ios</u> (arrow goby)	3*	18*	22*	*2(4)		175*		424*	85*	61*		-	790	790
<u>Quietula y-cauda</u> (shadow goby)														
<u>Gillichthys mirabilis</u> (Long jaw mudsucker)						2 2*		5*	2*(50) 1 (2.5)	74* 2	2*	5	85	90
Goby A (see text)						3			1 (2.5)		11	15	-	15
Unident. Goby						1 (yolk sac larva)						1	-	1
Goby C (see text)								5				5	-	5
<u>Genyonemus lineatus</u> (White croaker)									1 (2.5)			1	-	1