BENTHIC MARINE EXPLORATION OF BAHIA DE SAN QUINTIN, BAJA CALIFORNIA, 1960-61

GENERAL

By J. LAURENS BARNARD

Introduction

Enclosed bays and lagoons of the arid eastern Pacific region between Pt. Conception, California and Acapulco, Mexico, have not been extensively studied, biologically. Such enclosures in southern California, U.S.A., have become so modified for industrial and recreational use that little natural environment remains for study. The present survey of Bahía de San Quintín in Baja California fulfills two primary purposes: a search for basic information on an unpolluted enclosure as near southern California as possible, and the initation of comparative investigations planned by the Institute of Marine BioResearch on many such enclosures in the eastern Pacific.

This report forms an introduction to a series of articles to be published on the geology, hydrography and benthic life of the bay, and includes those descriptive features not being treated elsewhere. This work was supported by the National Science Foundation, the Beaudette Foundation and contributions from Mr. and Mrs. Richard Dwyer, and Mr. David W. Hearst. I am indebted to Mr. and Mrs. Alfonso Vela of Bahía de San Quintín for their generous help with our field expeditions.

Survey History in The Eastern Pacific Ocean

Only a small effort has been made in quantitative marine biological surveying in the eastern Pacific Ocean, and most of this has been recent. Compared with the extensive surveying work in Europe in this century, the eastern Pacific has been sorely neglected. Not only have quantitative surveys been sparse, but the overall taxonomic exploration has been neglected, partially because of the lack of surveys. Apparently the initiation of general surveys is correlated with the development of successfully industrialized populations, and the west coast of the United States has reached this stage only recently, whereas Europe and Atlantic America reached such levels earlier in this century. Realization of this activity is now seen in such countries as New Zealand, Japan, and South Africa, all of which have now attained the economic stage at which this expensive kind of team-research activity can be supported and coordinated.

Another factor affecting quantitative surveying is the physiography of shorelines. Along the coasts of northern Europe and Atlantic America the shorelines are complexly indented, providing protected areas where small, inexpensive seagoing craft can be operated. The first surveying occurs in such areas and is extended into the open sea only when larger

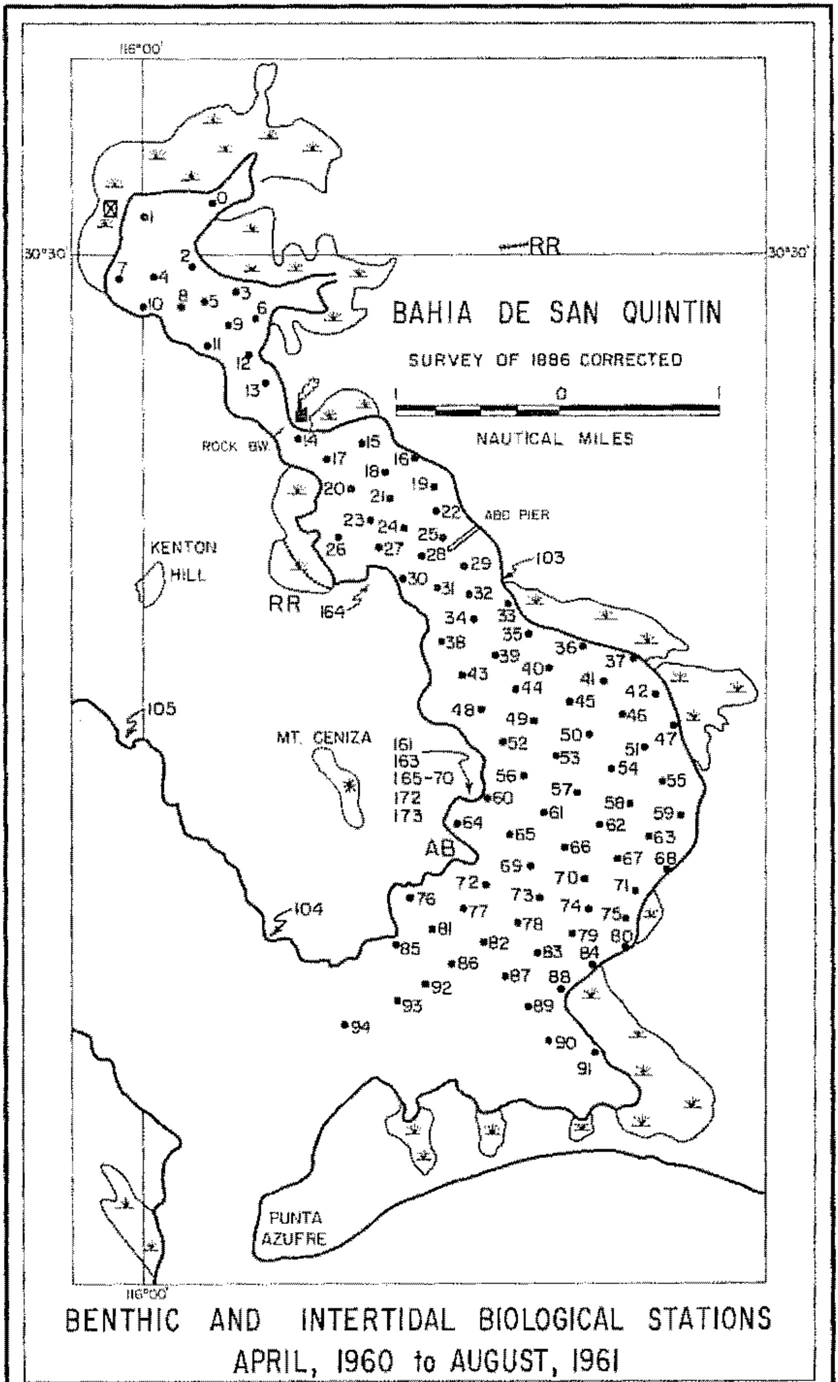

Fig. 1. Map of benthic biological and intertidal stations occupied in Bahía de San Quintin. X=area of transect in marsh (table 2). RR=remnants of railroad embankments. AB=Abalone Pt., site of former cannery and loading facilities.

sea-going vessels can be supported. The Pacific Coast of the United States is notable for its sparsity of protected embayments, only Puget Sound and San Francisco Bay being of major importance. In these two bays the first quantitative work was done (Shelford 1935 for Puget Sound and Sumner et al. 1918 for San Francisco Bay, with subsequent biological analyses by other authors). North and south of the United States, where numerous protected enclosures are to be found, the poor industrial and demographic development of the nations has prevented such kinds of activity. Until the *Velero IV* of the University of Southern California commenced its quantitative open-sea shallow water operations, the west coast of the United States had been neglected in that respect. The *Velero IV*, of 290 gross tons, operates generally south of Pt. Conception in a favorable weather zone. North of that point a larger, all year-all weather ship would be required for coastal shelf exploration, a development which is just being realized.

In essence, the short history of quantitative exploration in the eastern Pacific consists of reports by Shelford (1935) on Puget Sound, work in San Francisco Bay (bibliography in Filice 1958), the open sea operations in southern California by the *Velero IV* (Hartman 1955), and a number of scattered bay studies, often connected with pollution, as exemplified by the work of Reish (1959) and Barnard and Reish (1959).

Only two other papers outside this group of quantitative studies are pertinent to estuarine work of the eastern Pacific. One is the ecological study of Elkhorn Slough by MacGinitie (1935) which is a work of interest in natural history. Although not based on quantitative methods, it contains valuable information on habits and life histories of animals and a list of species in the estuary. In many respects Elkhorn Slough and San Quintin Bay are comparable, mainly in that each is a salt water enclosure with tidal flats and marshes, but Elkhorn Slough is influenced by fresh water inflow.

Information about animals of Newport Bay, California, and again Elkhorn Slough, is scattered through the book on Natural History of Marine Animals by MacGinitie and MacGinitie (1949).

Discussion of Quantitative Methods

A marine benthic biological survey is essentially an exercise in quantitative taxonomy, i.e., the collection of uniform samples on grid systems and the analyses of their contents by identifying and counting the numbers of each species. The scope of the survey is determined by the size and number of samples taken per unit of environment, the methods by which the samples are treated, such as the screen size through which they are washed, the extent to which the various phylogenetic groups can be identified through the services of available taxonomists, and the correlative environmental data which are taken concurrently and to which the

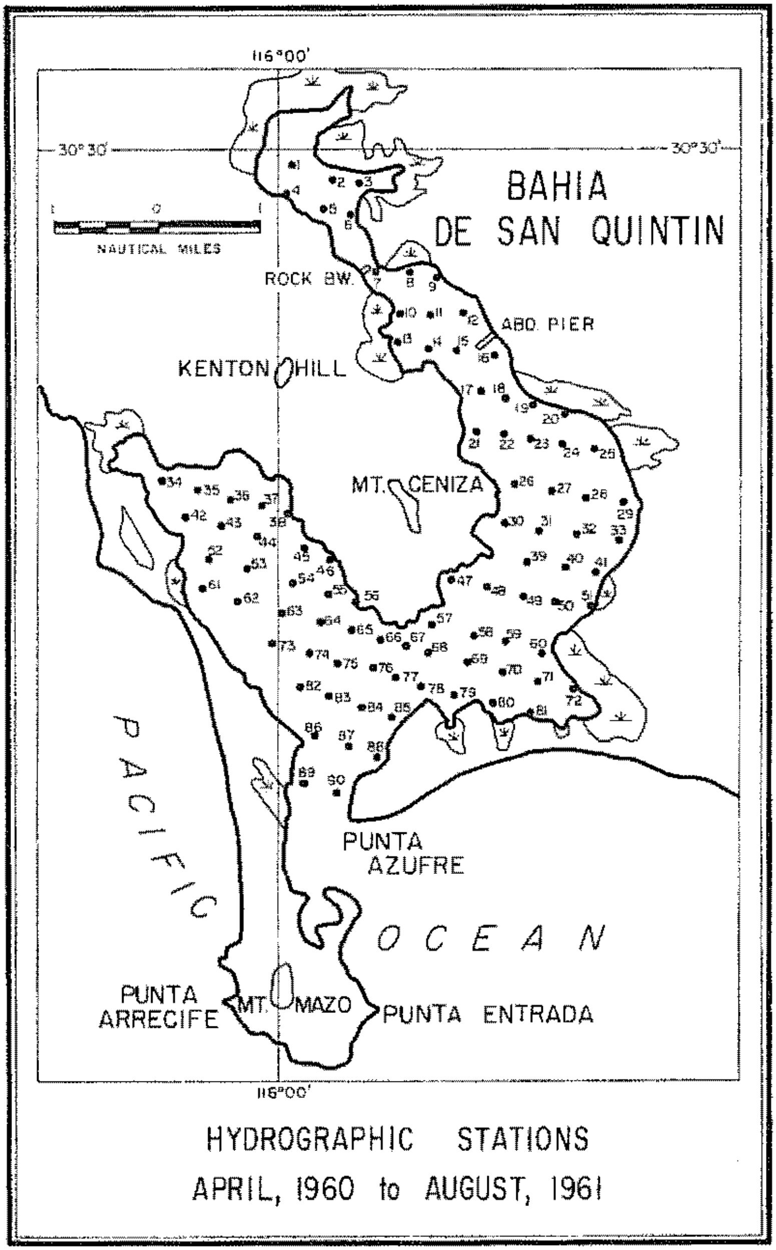

Fig. 2. Map of hydrographic stations occupied in Bahia de San Quintín.

biological counts can be related. See Barnard & Jones (1960) for a discussion of survey methods.

Our approach to San Quintin Bay was as comprehensive as possible, but with the major effort concentrated on the benthic life. It proved impractical from a financial standpoint to survey extensively the plankton of the bay (paper to be published by Johanna M. Resig) nor did we expend much effort in exploring mud flats for large deep-burrowing organisms such as clams and ghost shrimps, nor were we interested in dredging up quantities of the large, rare organisms in order to add to the overall taxonomic list (most of these larger organisms in the bay are sponges, and the lack of specialists prevents their identification). Thus, it was a program of quantitative benthic samples, the analysis of the organisms found in these samples, an analysis of the sedimentary characteristics of the bay and a quantitative program of hydrography, involving temperatures, salinity, and inorganic nutrients. It included a taxonomic analysis of the principal fishes in the bay, a taxonomic and semi-quantitative study of the aquatic birds, and a general survey of the marine plants, of which the most important is the eel-grass, *Zostera marina* (paper by E. Yale Dawson).

From our previous experience it has proved impractical to select a few stations for repeated monitoring of benthic seasonal changes, not only in the open sea but in small bays. It is possible to do this in water masses, but bottom areas are so variable over short distances that it is impossible to return to precise localities without anchoring permanent buoys, and this is impractical unless they can be guarded continuously from theft. We have found that the differences between two samples taken together in the open sea in the middle latitudes are as great as any seasonal effects might be, and that navigation has not been perfected to permit returning to a precise locality. In the nearshore open-sea, navigation has an error of at least 500 feet; in enclosed bays such as San Quintin it has an error of at least 100 feet, and in that distance the bottom may support several different communities. Only by resampling and analyzing the entire grid pattern of samples on a seasonal basis would it be possible to ameliorate the navigational errors by the pressure of sampling. It was not within our means to double our field and laboratory time to make these resamplings. Another method might have been to select certain stations where navigation error is low and to erect small grids of 9 or 16 samples for replication, but only one or two communities could be so studied without increasing the analytical load to a point greater than that of the initial survey. Thus, we have been unable to study statiscally the seasonal cycles of benthic organisms in San Quintin Bay.

The hydrography of San Quintin Bay has been studied on a seasonal basis during five replications in the months of April, August, November, February and August 1960-61. Initially, 90 stations were erected on a grid pattern of 15 samples per two square nautical miles (Fig. 1). In the first

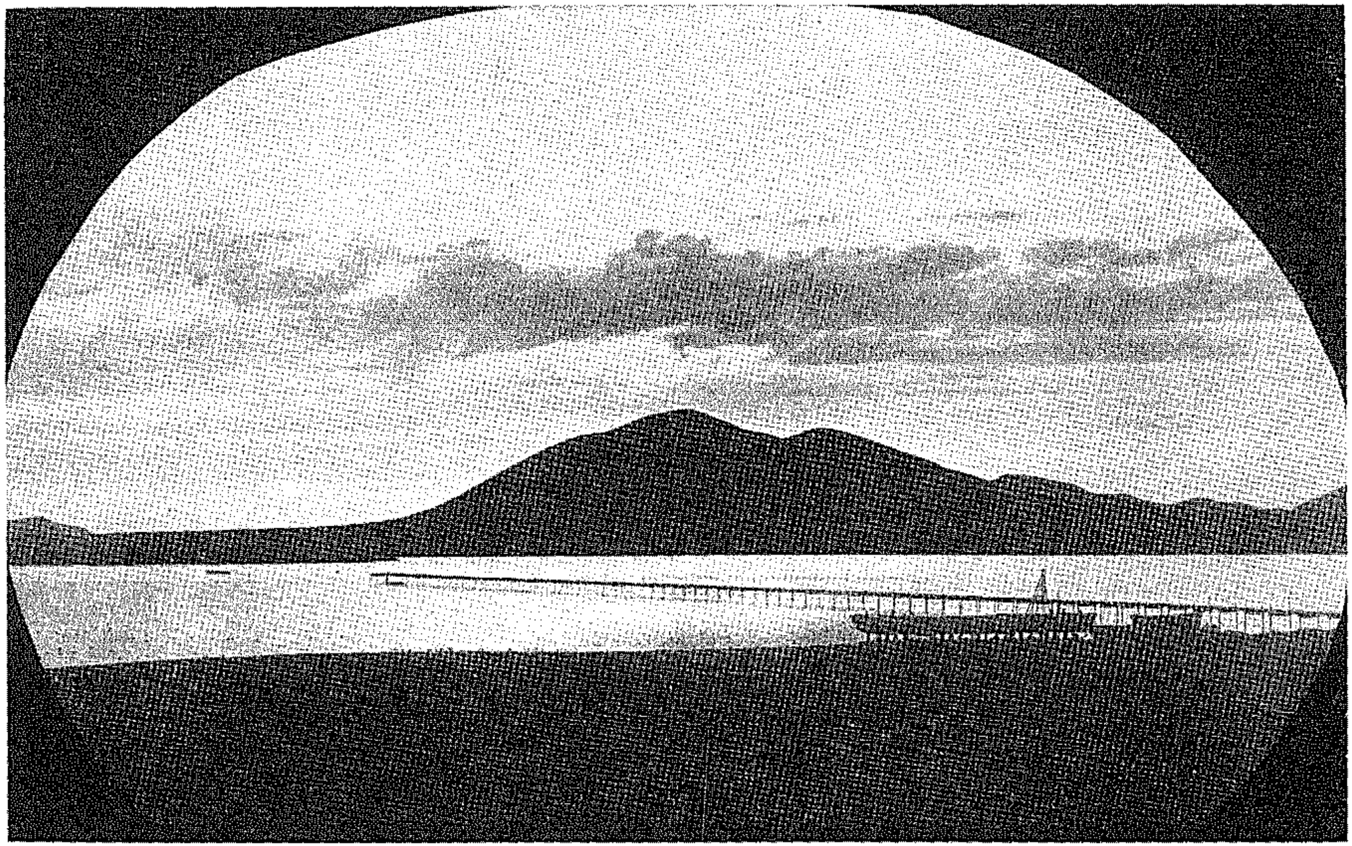

Fig. 3. Restored photograph taken about 1895 of Bahía de San Quintín and Kenton Hill from a "hotel" at the now abandoned pier marked on fig. 2. Numerous waterfowl are shown faintly. Photo in the collections of Mr. Alfonso Vela, cannery manager, Bahía de San Quintín.

survey of April only 63 of the 90 stations were occupied, for 27 stations lay atop sand bars or in waters shallower than 18 inches during a series of low tides. In later surveys samples were taken during series of high tides. From the initial plots of these samples it was determined that the subsequent surveys could be based on only 45 stations with about the same accuracy of determining variables. A separate paper concerning the hydrography of San Quintin Bay is to be published in Pacific Naturalist by John R. Grady.

Initially it was determined that the same 90 stations erected for the hydrographic studies would also be occupied for the benthic sampling program, so that the full 11.7 square miles of San Quintin Bay would be surveyed. During the first hydrographic survey in April 1960 a reconnaisance of the bottom was carried out and it was seen that the variability of topography, distribution of eel grass beds, diversity of sediments and major biological features would require denser sampling than 15 per two square miles. Thus, an area of six square miles of the eastern arm by the bay was selected on a sampling frequency of 15 samples per square mile for a total of 90 samples. This proved to be a highly satisfactory density in this survey, but it means that only the eastern arm of the bay has been surveyed. It is believed that several major differences occur in the western arm not representative of the eastern arm, mainly in the larger number of benthic mollusks.

The survey of bird life in the bay was stimulated by our desire to understand something of the dependence of birds on such lagoon-estuaries and in what ways they affect the invertebrate organisms. So little information has been published on the food and habits of shore birds that we believed some interesting contributions might be made in this line of research. Field scouting of the abundance and taxonomic composition of the bird fauna was made during the five field trips already mentioned. This involved daily checks on established grids of approximately half square mile areas as well as specific beaches, and included efforts to determine daily feeding migrations in relation to tides, time of day and winds. About 150 of the common shore birds, distributed among 11 species, were collected for stomach analyses and specific identification.

Fishes were collected during the November 1960 trip by means of seines, trawls, poisoning and SCUBA diving by a large party under the direction of Dr. Carl L. Hubbs of Scripps Institution of Oceanography. Many of the fishes were analyzed for stomach contents in an effort to determine the relationship between the dominant fishes and the invertebrates on which they feed.

Algae and eel-grass were collected by SCUBA diving, wading in tidal shallows and shore collecting. So few algae were recovered in the benthic grab samples that it is believed that most of the algae in the bay are concentrated in a narrow belt forming the margin of the bay, and this was not open to quantitative sampling due to shallowness of water. Eel-grass was well sampled by the benthic grab program.

Fig. 4. Ornithologists working in marshes north and east of cannery.

Field Methods

A working base was established in a motel (inn for motorists) located at the upper end of the east arm of the bay at water's edge near the sardine cannery and pier, an area from which our small outboard motor boats could be launched and cared for. The site was disadvantageous only because of its locality at an extreme end of the bay, so that it was necessary at times to travel long distances by boat before sampling commenced. For operations in the west arm of the bay the boats were hauled by truck and trailer to a launching site on the east shore of that arm. Better protection was afforded in this way from sudden winds which occasionally occur in these latitudes and which indirectly caused the death of three persons a few months before our first arrival.

Electricity was provided each night for a few hours from a generator in the cannery and permitted water chemistry analyses. Highly siliceous fresh water for drinking and washing of samples was provided by tank truck from a well a few miles away.

The survey of the bay was carried out in small boats with shallow draft, generally during high tides so that all sampling areas could be reached. The hydrographic program was carried out continuously and apart from the benthic program in order to permit collection of samples as simultaneously as possible.

Surface temperatures were measured in bucket samples with a centrigrade thermometer, and bottom temperatures with a Yellow Springs Model 43TJ thermistor. Salinity samples were collected in plastic bottles for analysis at the University of Southern California. Fixed oxygen samples were prepared in the boat for later analysis at U.S.C. using an Emery oxygen water bottle with the modified Winkler method. Silicate and phosphate samples were returned to the motel in plastic bottles where they were analyzed immediately. Water turbidity was measured with a Secchi disc, an ineffective means at many localities because of shallow water or occluding eel-grass. A hydrophotometer was used during one expedition. Navigation was accomplished by calculating magnetic fixes on U.S. CG-S chart 1043 based on four of the prominent cinder cones and by occupying stations on these fixes with the use of a portable pelorus. Reoccupation of about half of the stations was easily accomplished without navigational aid because of other landmarks, and it is believed that the pelorus method provided accuracy within 200 feet for the remaining stations lacking recognizable landmarks. Since the benthic stations were visited only once, it was unnecessary to return to precise localities, and the inaccuracy of a few hundred feet for the hydrography was considered insignificant to the study of water masses.

Benthic samples were collected with a Hayward orange-peel grab of an areal capacity of 650 square centimeters (1/16 square meter), modified with skirt and single cable closing features. The operation of the

70 pound grab by hand from boats was an arduous task. After pulling the grab on board the skiff the mud was emptied into a washtub and transferred to gallon cans. Twelve samples at a time were collected and returned to the shore facility where they were washed through a 32 mesh-per-inch Tyler screen (mesh openings 0.495 mm) using a freshwater hose. Half of the samples were composed of sands and silty sands which washed through rapidly and the other half were very sticky muds requiring considerable washing time (especially because of the small screen size) until it was discovered that they could be emulsified in large wash buckets by gentle kneading with the hands and the liquid "slip" poured through the screen. Because many small crustaceans float on the water surface after death, great care was taken not to splash water or overflow the screen. The coarse residues containing animals and plants were preserved in 4% formaldehyde and sealed in metal cans, using a portable canning machine. No glassware was used because of the breakage problem in traveling over the rough dirt roads of Baja California. The excellent condition of the preserved animals on their return to the laboratory in the United States was due in great part to the time-consuming care taken in their washing. Four full days were required for washing the 90 samples in the field.

A 250 cc sample of the sediment in each grab was placed in a cardboard container and dried for subsequent sediment analyses by Dr. D. S. Gorsline at Florida State University.

Laboratory Methods

Biological samples were removed from the metal cans and washed further in a 60 mesh-per-inch screen to remove cloudy sediments. Because further use of a 32 mesh-per-inch screen in the laboratory permits loss of animals broken apart during the field washing the 60 mesh screen is used in the laboratory to control this loss. Constant rewashing of samples permits more and more small animals to escape and some samples require more washing than others.

Each sample was sorted under a stereoscope to phyla. Weights of standing crop were taken of the various phyla, and then the groups were preserved for distribution to taxonomic specialists for identification and counting. Some samples of extraordinary complexity were split into 10%, 20% or 33% aliquots and only a fraction sorted. For instance, "station 13" was composed of some 20,000 small crustaceans and only 10% by weight of the sample was sorted.

Physiography of Bahía de San Quintín

Bahía de San Quintín lies at the shoreward edge of the Santa María Plain, a relatively featureless flatland west of the Santa María escarpment which trends north and south about 5 miles east of the ocean and which impinges on the coast just south of Bahía de San Quintín. The northern part of the plain devolves onto rolling hills, which are green with vegetation only during a short time of the winter-spring. Rainfall is scarce, probably less than 4 inches per year and often perhaps less than 2 inches. The low scrub vegetation belongs to the Californian phytogeographic area (Wiggins 1960, map). The southwestern edge of the Santa María Plain is clearly dominated visually from distances as great as 30 miles by a group of cinder cones molding the complex topography of the bay itself.

There is evidence that the eastern arm of Bahía de San Quintín was formed by fluvial action and is a drowned valley, but, except for flood runoff, there are no flowing streams today.

The westernmost seaward edge of the bay is a long sandspit (tombolo) connecting two cinder cones, the southern of which marks the entrance to the bay. The south shore on the open sea trends east and west, being formed of a sandspit protecting bayward marshes. The two northward trending arms of the bay are split by two prominent cones, Mt. Ceniza (Spanish=ash) and Kenton Hill, (Fig. 4) and most of this middle peninsula is formed of volcanic materials.

The eastern shore of the east arm, between the cannery and station 103 (see map 2), is composed of cliffs about 30-40 feet high, where Pleistocene beds have been worked by E. K. Jordan (1926). North of the cannery the shore is formed by marshes, (Fig. 3), but the west shore is cliffed into Pleistocene formations overlain by lava, as is the east shore of the west arm.

At the cannery an old causeway cuts off the upper third of the bay. (Fig. 4). The causeway extends eastward from the west shore and closes off about two thirds of the channel, so that the water of the upper bay occasionally flows quite rapidly through the channel during extreme tides. This is probably of some benefit during cannery operations in rapidly flushing out wastes, since the rushing water is on the cannery side. Apparently, the causeway was built during the time of an English commercial enterprise in the bay, sometime between the 1890's and 1920's. Remnants of machinery from an old flour mill stand on the cannery property across from the causeway. It is said that the English enterprise was the raising of wheat for milling and that the causeway supported a railroad track, with a trestle across the gap. The flour was shipped from the mill across the causeway to what is now known as Abalone Point where small ships were able to dock. Remnants of old roadbed have been pieced together to show in Fig. 2 the general route of the track. Two rock jetties project at Abalone Point where loading was accomplished. Abalone Point also was the site of a small abalone cannery where large piles of rusted tin cans (narrow mouth, press-fit lid type) and abalone shells are found today (Fig. 5). Some local residents say that attempts to generate electricity from the causeway millrace were made in the past. The writer discounts this story, since the "millrace" is rather infrequent. Dye was poured in the apparently rushing water but in an hour the patch moved only 100 feet westward out of the north-south millrace. Most of the surface rippling probably is the result of wind and density-boundary displacements

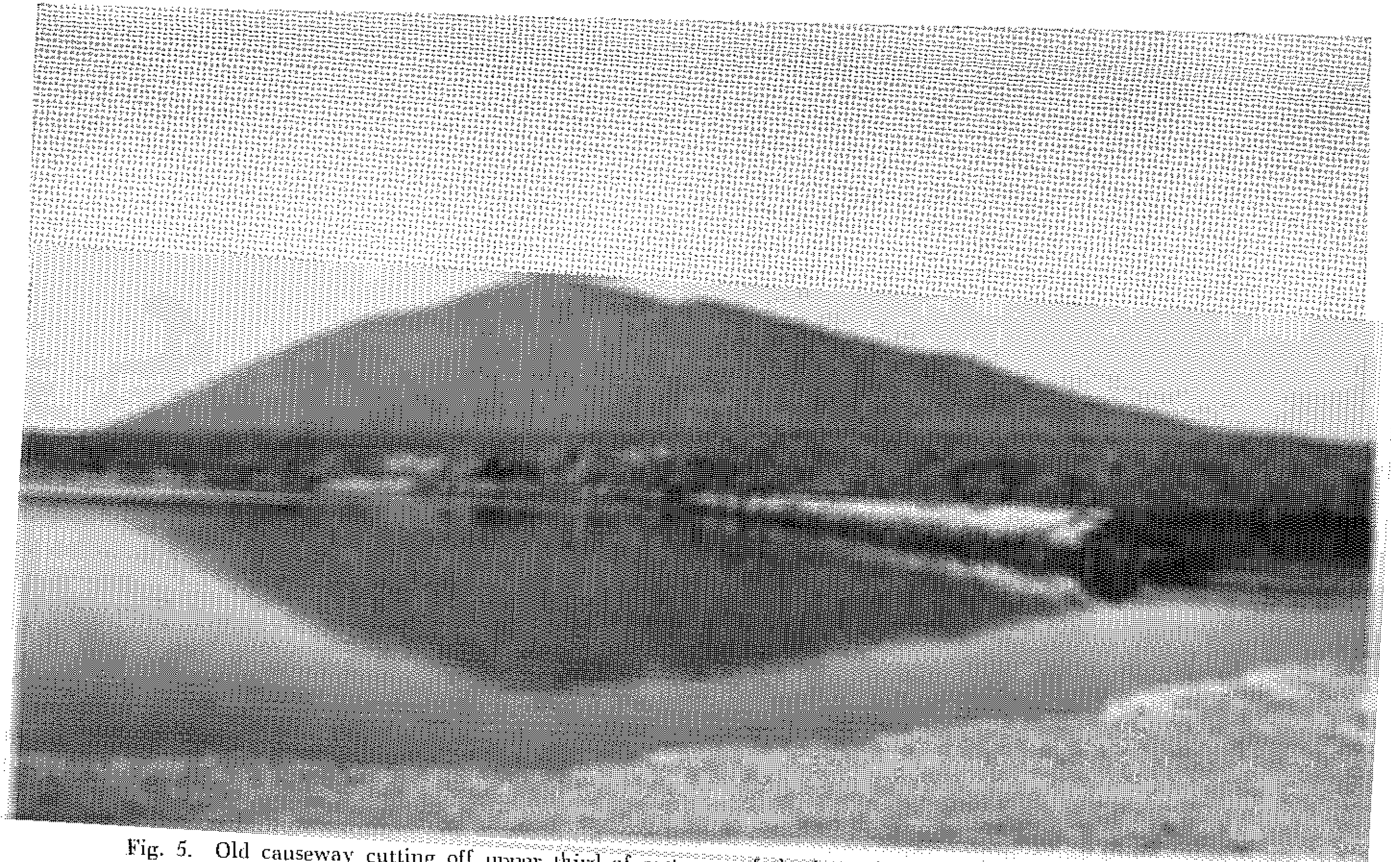

Fig. 5. Old causeway cutting off upper third of east arm of the bay with Kenton Hill in the background.

with only the subsurface water moving rapidly. Probably the more saline water in the upper bay flows seaward along the bottom as a density current.

Notwithstanding the low rainfall of the region, the Bahía de San Quintín area has a benign climate because of fogs and the relatively cool offshore California current. Upwelling occurs in the open sea immediately south of the entrance to Bahía San Quintín (Dawson, 1951), and this evidently accounts in considerable part for the relative coolness of the bay and the rather high nutrient content of its waters (see also Phleger and Ewing 1962). According to our field records of six shorts trips, summer afternoon air temperatures peak between 90 and 100° F, but, with northwesterly breezes, temperatures peak between 80 and 90°. Occasional warm winds sweep across the area from the hot interior of the peninsula. Early morning summer temperatures are as low as 45°, often with sea fogs and humidities of 100%, dropping to 10% in the afternoon. Winter air temperatures range from 45 to 80° F, especially in the low 60's, generally with highs less than 70°. In the months of March to June the area is dominated by peak northwesterly winds of 20 to 30 knots, generally blowing from midmorning to late evening. These winds may last 4 to 9 days, followed by 3-5 days of less forceful northwesterly gentle breezes or calms. Small fishing craft are forced into shelter during the windy periods or move up and down the coast from shelter to shelter in the middle of the night and early morning. Apparently this wind system embraces about 500 miles of the coast from Ensenada south to Magdalena Bay. Downslope winds of 3-4 day lengths occur occasionally from June to October as a result of the semi-permanent summer high in Sonora; these are northeasterlies and offshore winds. Between October and March north Pacific storm fronts are engaged and preceded occasionally by winds. The one rainstorm we have experienced at San Quintin was preceded by gentle easterlies followed by calm during the precipitation and then by fresh northwesterly breezes for 2 days. Tropical hurricanes are very rare. The latest, recorded in April 1938, swept up the west coast of Baja California as far as Los Angeles (when, by coincidence, the research vessel *Velero III* of the University of Southern California was caught in its fury between San Diego and Los Angeles). The marine climate of southern California has been summarized by Stevenson (1959) from an area 200 miles to the north and San Quintin probably falls under a drier and somewhat more windy facies of that "Mediterranean" system.

Commerce in The Area

Commercial development of the San Quintin area has been small in the past. The bay was discovered in the early 19th century and was first exploited for its abundant populations of sea otters which were completely exterminated by American and Russian hunters prior to 1850. By 1890 a small agricultural settlement was established by the English on

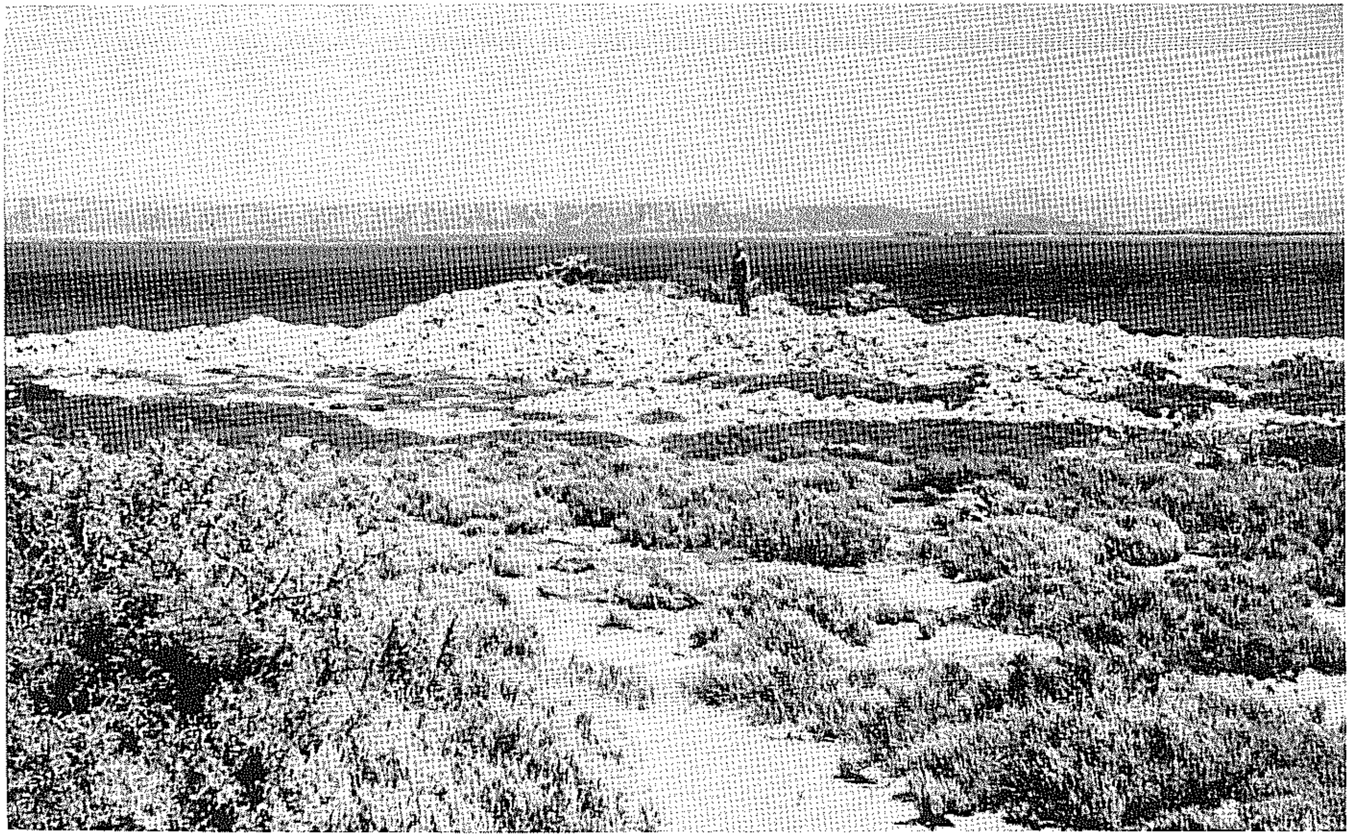

Fig. 6. Mounds of abalone shells at Abalone Pt., Bahía de San Quintín, remaining from a canning operation in the 1930's.

the plains east and south of Bahía San Quintín, and near the existing cannery, a village was built centering around the loading jetty and a wheat milling establishment. Regular shipping was conducted between 1890 and 1910 to Ensenada, but the enterprise was then abandoned and the population on the bay reduced to occasional fishing activities, principally for sardines in the open sea within a 50-mile radius of San Quintin. At present, the small cannery of 800 sardine-cases-per-day-capacity operates only about 30 days a year because of a decline in the fishery. It is supplied by a single vessel of 60-foot length and 20-ton capacity. Occasionally jack-mackerel and yellow-tail are packed for the Mexican market. Sardine fishing occupies the months of October to March, on moonless nights. The fishing vessel must cross the bar at the entrance of San Quintin at high tide, a factor often complicating delivery of the catch to the cannery during normal daytime working hours. In the early part of the catch season there is a labor shortage because of the harvest of local vegetable crops, so that the cannery often runs 20 hours a day using short shifts of workers. Normally the cannery operates with 60 workers but occasionally has to rely on 30 workers.

The catch boat must meet some competition for fish-schools from boats based in Ensenada. During operation of the cannery small scraps, blood and waste are sewered into the bay, but this affects only a few thousand square yards of water with increased phosphate levels, and decreased transparency. A normal fauna of sponges, tunicates and hydroids lives on the pilings of the cannery docks and the surrounding bottoms so that no long-term cumulative pollution effects have ensued. Dispersal of waste may be facilitated by the hypothetical tidal rush.

Abalones are fished from San Martin Island, 10 miles off the San Quintín coast and occasionally are landed at the cannery dock for shipment by truck to the abalone cannery at Rosario, 30 miles south of San Quintin. The abalone fleet is composed of several 25-foot open-sea skiffs powered by Japanese 1-cycle engines. Catches are made by hard-hat diving and are collected from the fleet of small boats by a 45 foot sardine boat belonging to the fishing cooperative of Rosario. In former years abalone fisherman used the west shore of the east arm, at the foot of Mt. Ceniza, as a shelling and canning station for abalones. A pile of more than 100,000 abalone shells remains there from a short-period operation in the 1930's (Fig. 5). Spiny lobster is fished also at San Martín Island for direct trucking to Los Angeles markets.

At one time turtles were supposedly abundant in San Quintin where their natural food, eel-grass, is still abundant. Apparently they have been completely fished out. No turtle fishery remains, but our expedition members saw three turtles in the bay in 1960 and informants indicate that turtles are captured there for local consumption whenever they are sighted by residents. It would be of considerable interest to enforce protection of these animals to permit reestablishment of a controlled fishery,

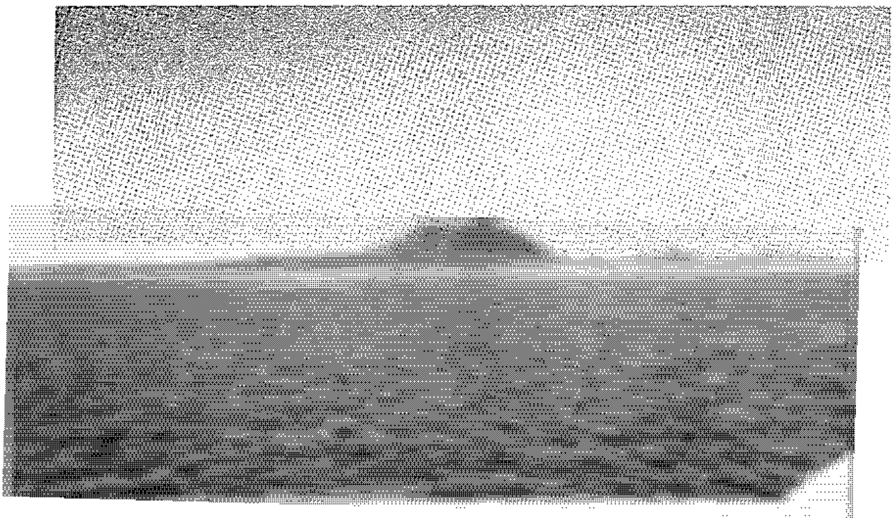

Fig. 7. General view of the broadest extent of Bahia de San Quintin, a view across the lower bay looking at Mt. Ceniza from the southeast.

for in future years they would have recreational value for tourists, and scientific value to students.

San Quintin is becoming a well-known ground for duck hunters. The shooting season commences in November and lasts until January. Brant is the principal species hunted. Unfortunately, some non-game birds are preyed upon by both U. S. and Mexican citizens, mainly for target practice, both during open and closed hunting seasons.

The American egret has been the victim of tourists with high powered rifles, and a favorite local sport of Mexicans is target practice on grebes. Fortunately, grebes form a difficult target because of their wariness.

Other resources of the bay are not used commercially to any extent. Occasionally shrimp of commercial size (*Penaeus* sp.) have been trawled near biological station no. 27 for local consumption, but this is sporadic, and commercial shrimp are of no importance locally. Both tourist and resident fishermen consume some perch captured from the bay. Sharks and guitar-fish are in considerable abundance but are rarely used, although it has been proposed that they might be sufficiently abundant for reduction to fertilizer.

Apart from marine resources the area surrounding San Quintin is being developed at a remarkable rate. Well water and artesian water seem in good abundance at present and several irrigated crops, such as tomatoes, peppers, corn and olives are harvested on local farms. Population is increasing rapidly. In six trips in 1959-61 it appeared that in the distance of 23 miles between Colonía Guerrero and San Quintin, the number of houses doubled, from about 30 to about 60, mainly in connection with increased agriculture. A small plant for processing tomatoes and peppers is situated on the main road, 5 miles inland from the cannery at kilometer 298 of Mexico Highway No. 1. Among other products, this plant supplies sauce for the sardine cannery.

A few orchards of olives have been developed or revived, and a few irrigated huertas (family gardens) supply many fresh vegetables such as calabasas, corn, beans, etc.

Commercial salt of 3000-4000 tons per year is produced from a series of ponds near the sea 6 miles northwest of the San Quintin cannery. This readily available salt has been the stimulus for much of the ship activity in and out of Bahía San Quintin for over a hundred years.

Kenton Hill is a snpply point for volcanic gravel, an excellent road material. A small quarry is situated there, and nearby, on the east shore of the west arm of the bay, are devices for loading gravel into barges. Some active gravel trucking was seen in 1960-61.

The Bay Bottom

Bahía de San Quintin is a shallow bay, about 85% of the eastern arm lying in depths of 6 feet or less at mean high water. Depths greater than this occur in channels that are strongly differentiated from the shallow bay flats by sharp depth changes. Generally the channels have depths of 18 to 24 feet, with one record of 36 feet. Only 13 of 90 samples in the eastern arm were deeper than 6 feet, and these were usually deeper than 15 feet, indicating the sharp changes. Essentially, only two depth provinces occur in the bay, the shallow flats and the deeper, narrow channels.

Two marked extremes of sediments occur in the channels. One is of rather well-sorted, compact sand mixed with a small amount of silt on which are to be found tunicate-amphipod assemblages. The other, of nearly black oozes, is found principally in lateral channels where tidal currents probably are ameliorated and where large amounts of decaying eel-grass and algae apparently are trapped and decompose.

The shallow flats are a mixture of sediments: (1) some of a clean, poorly compact sand, rather barren of surface animal life and apparently stirred considerably by benthic elasmobranchs; (2) a more compact silty sand or silt, forming bottoms of very sticky mud commonly found in intertidal mud flats, where fixed tubes of animals are to be seen and where the holes of burrows are retained; (3) flats of eel-grass, where the plants are growing on silty sand, often dark-grey or black from excessive metabolic activities. Fourteen of the 90 samples taken in the east arm (mostly in its lower half) were dominated by living eel-grass. A lateral channel trending east-west at biological station 27 apparently has gradual slopes where heavy stands of benthic red algae on mixed bottoms

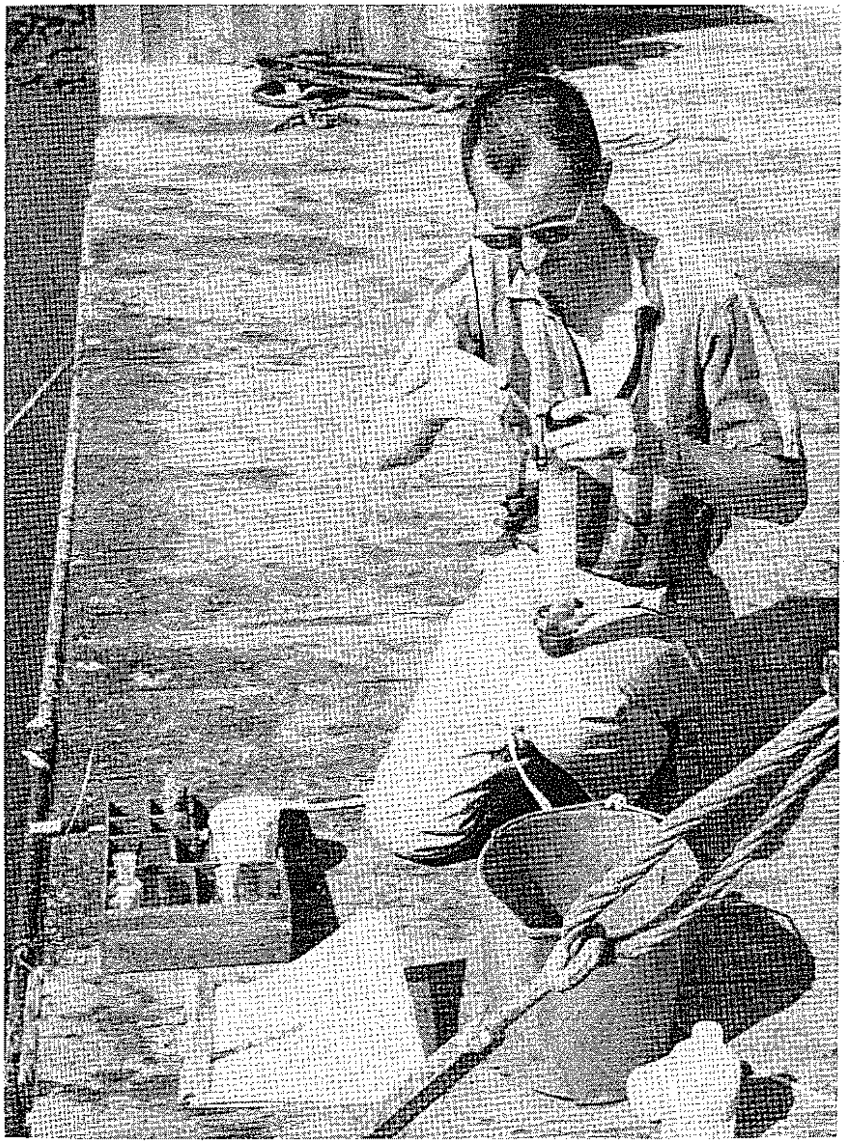

Fig. 8. Mr. J. R. Grady using the Emery oxygen bottle during a 24 hourly-series of hydrographic measurements at the cannery pier.

of sandy silt, black mud, and volcanic pebbles. Apparently, algae are confined generally to the narrow perimeter of the bay for they have been sparse in other benthic samples.

Bottoms near the cannery and in the bay north of the causeway are irregular and shallow. At some places they are characterized by yellow sponges, at others by sands and sticky muds. Occasionally the muds are mixed with dead gastropod shells (many are fossils), and at other places bottoms are formed largely of dead tubes of worms and crustaceans. Patches of eel-grass grow in channels leading into the marshes, but these areas have not been sampled extensively and details are unknown.

Marshes

The northern third of the eastern arm is dominated by peripheral marshes, as in one sector in the northwestern part of the west arm. Marshes predominate the southeast and south shore of the bay proper. The marshes are formed of the succulent *Salicornia* at higher levels and by the salt-grass *Spartina* at low levels. The principal macroscopic invertebrate animals living in the marshes are the purple-striped reddish shore crab *Hemigrapsus oregonensis*, occupying burrows along the steep banks of the meandering channels in the marshes, and the California horn-snail, *Cerithidea californica*, enormously abundant in small barren pools in the marshes, along the banks of channels, and even in the densest growths of marsh plants.

A transect of samples was made across the northwestern marsh of the east arm starting on bare soil at the edge of the marsh next to a dirt road passing the marsh along a cut in the hillside (table 3). Eighteen samples were taken 10 meters apart seaward of that point until the 19th sample would have been underwater (see transect marked on Map 2). This transect provides a record of the density of vegetation across the marsh for future reference studies, in the event that the area becomes polluted. The samples were collected with a post hole digger having a capacity of 3080 cc, the sample forming a cylinder of 20 cm length and 14 cm diameter.

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TABLE 1

HYDROGRAPHIC STATIONS, BAHÍA DE SAN QUINTÍN, April 1960

NUMBER	DAY, 1960	TIME	DEPTH (feet)	SECCHI (feet)
1	4-19	1600	2	
2	4-19	1600	1.5	
3	4-19	1600	1.5	
4	4-19	1600	5	
5	4-19	1600	6	
6	4-19	1600	5	
7	4-19	1600	9	
8	4-19	1600	6	
9	4-19	1600	4	
10	4-20	0700	2	
11	4-19	1600	11	
12	4-20	0700	3	
13	4-19	1600	1.5	
14	4-19	1600	15	

15		4-20	0700	6	4
16		4-20	0700	1.5	
17		4-20	0700	7	5
18		4-20	0700	6	5
19		4-20	0700	5	3
20		4-20	0800	1.5	
21	shallow				
22		4-20	0800	5	4
23		4-20	0800	4	3.5
24		4-20	0800	4	
25		4-20	0800	1	
26		4-20	0800	4	eelgrass
27		4-20	0800	10	5
28		4-20	0800	3	eelgrass
29	shallow				
30		4-20	0900	12	3
31		4-20	0900	6	eelgrass
32		4-20	0900	4	
33		4-20	0900	1.5	eelgrass
34		4-21	0800	2	
35	shallow				
36		4-21	0800	6	3.5
37		4-21	0900	5	3.5
38		4-21	0900	5	3.5
39		4-20	0900	2	eelgrass
40		4-20	0900	2	eelgrass
41	shallow				
42		4-21	0900	5	3.5
43	shallow				
44	shallow				
45		4-21	0900	5	3.5
46	shallow				
47	shallow				
48	Frautschy	4-20	1000	34	3
49		4-20	1000	33	3
50	shallow				
51	shallow				
52	shallow				
53		4-21	0900	5	3.5
54	shallow				
55		4-21	1000	5	5
56		4-21	1000	2	2
57	shallow				
58		4-20	1000	3	
59		4-20	1000	15	7
60	shallow				
61		4-21	1000	3	2.5
62		4-21	1000	5	3.5
63	shallow				
64		4-21	1000	4.5	4.5
65		4-21	1000	3.5	eelgrass
66	Frautschy	4-20	1100	20	8
67		4-20	1100	10	5
68	Frautschy	4-20	1100	32	6

69		4-20	1100	10	7
70	shallow				
71	shallow				
72	shallow				
73	shallow				
74		4-21	1000	2.5	eelgrass
75	shallow				
76	shallow				
77		4-20	1100	14	7
78		4-20	1100	10	6
79	shallow				
80	shallow				
81	shallow				
82	shallow				
83		4-21	1000	1.5	1.5
84		4-21	1200	1.5	1.5
85	shallow				
86	shallow				
87		4-21	1200	8	7
88		4-21	1200	14	7
89		4-21	1200	35	9
90		4-21	1200	20	6

TABLE 2

BIOLOGICAL STATIONS, BAHIA DE SAN QUINTIN, Orange-peel-grab, April 1960

NUMBER	DAY, 1960	DEPTH	SEDIMENT
0	11-6	< 7	black mud
1	4-22	< 7	gray clay
2	4-22	< 7	dark gray clay
3	4-22	< 7	gray clay
4	4-22	< 7	gray clay
5	4-22	< 7	dark gray silt
6	4-22	< 7	very dark clay, some lighter clay
7	4-22	< 7	black sandy silt
8	4-22	< 7	black silt
9	4-22	< 7	black sandy silt, small clay
10	4-22	< 7	dark gray fine sandy silt
11	4-22	< 7	dark gray sandy silt
12	4-22	< 7	gray fine sand
13	4-22	< 7	gray sandy silt with shell frags, clay
14	4-23	< 7	dark gray silty sand
15	4-23	< 7	dark gray fine sand
16	4-23	< 7	dark gray sandy silt
17	4-23	< 7	grey silt
18M	4-21	18-24	gray sandy silt
19	4-23	< 7	dark gray silty sand
20	4-23	< 7	gray fine sand, s.s.
21M	4-21	18-24	gray silt
22	4-23	< 7	dark gray fine sand, s.s.
23	4-23	< 7	gray very fine sand
24	4-21	18-24	gray silty sand
25	4-23	< 7	drak gray fine sand, s.s., e.g.

26	4-23	< 7	dark gray silt
27	4-23	< 7	dark gray silt
28M	4-21	18-24	dark gray silt, worm tubes
29	4-23	< 7	gray fine sand
30	4-23	< 7	gray sandy silt
31M	4-21	18-24	gray silty sand
32M	4-21	18-24	gray sandy silt
33	4-24	< 7	gray silty fine sand
34	4-23	< 7	gray silt, e.g., s.s.
35M	4-21	18-24	dark gray sandy silt
36	4-24	< 7	gray silty very fine sand
37	4-24	< 7	gray silt
38	4-23	< 7	gray silt
39	4-23	< 7	gray very fine sand, s.s.
41	4-24	< 7	gray very fine sandy silt
42	4-24	< 7	gray very fine sand (no. sed. smpl.)
43	4-23	< 7	gray very fine sand
44M	4-21	18-24	dark gray sandy silt
45	4-24	< 7	gray very fine sand, s.s.
46	4-24	< 7	gray silty very fine sand
47	4-24	< 7	gray silty fine sand
48M	4-21	< 7	dark gray fine sand
49	4-24	< 7	gray very fine silty sand (no. sed. smpl.)
50	4-24	< 7	gray silty very fine sand (no. sed. smpl.)
51	4-24	< 7	gray fine sand
52M	4-21	18-24	dark gray silty sand
53	4-24	< 7	gray silty fine sand, e.g.
54	4-24	< 7	gray silty fine sand (no. sed. smpl.)
55	4-24	< 7	gray fine sand
56M	4-21	20	black fine sand, s.s. (no. sed. smpl.)
57	4-24	< 7	all eelgrass, (no. sed. smpl.)
58	4-24	< 7	gray silty very fine sand s.s.
59	4-24	< 7	gray fine sand
60	4-25	< 7	gray very fine sand
61	4-25	< 7	gray silty fine sand, e.g.
62	4-25	< 7	gray silty fine sand, e.g.
63	4-24	< 7	gray fine sand
64	4-25	< 7	gray sandy silt
65	4-25	< 7	gray very fine sand
66	4-25	< 7	gray silty fine sand, e.g.
67	4-25	< 7	gray fine sand
68	4-24	< 7	gray fine sand
69M	4-21	18	gray fine sand (no. sed. smpl.)
70	4-25	< 7	gray silty fine sand, e.g.
71	4-25	< 7	gray fine sand, s.s.
72	4-25	< 7	black fine sand
73M	4-21	33	black fine sand, s.s. (no. sed. smpl.)
74	4-25	< 7	gray fine sand, e.g.
75	4-25	< 7	gray fine sand
76	4-26	< 7	gray silty fine sand
77	4-26	< 7	dark gray very fine sand
78			
79	4-26	< 7	black silty very fine sand, H_2S, e.g.
80	4-26	< 7	gray fine sand
81	4-26	< 7	black silty fine sand, e.g.

82			
83M	4-21	22	black fine sand, s.s. (no. sed. smpl.)
84	4-26	< 7	gray fine sand
85	4-26	< 7	gray silty fine sand, e.g.
86	4-26	< 7	gray fine sand, s.s. (no. sed. smpl.)
87	4-26	< 7	black sandy silt, e.g.
88	4-26	< 7	gray fine sand
89	4-26	< 7	black silty fine sand, e.g.
90	4-26	< 7	dark gray very fine sand, e.g.
91	4-26	< 7	gray fine sand
92	4-26	< 7	gray fine sand
93M	4-21	22	black fine sand, s.s. (no. sed. smpl.)
94M	4-21	20	black fine sand, s.s. (no. sed. smpl.)

M=Mercedes, small fish boat from which channel samples were secured.
s.s.=small sample
e.g.=eel grass

TABLE 3

San Quintin Bay, Marsh Samples, April 1960

Serial post-hole-digger samples at 10 meter intervals along line within marsh along north bay (X in Fig. 1).

Sta. No.	Plants	Leaves (gms)	Roots (gms)	Cerithidea alive	Cerithidea dead
X-1	Salicornia	85	640	8	3
X-2	Salicornia	130	560	5	2
X-3	Salicornia	102	540	7	2
X-4	Salicornia	85	420	7+1j	2
X-5	Salicornia	110	600	4	0
X-6	Salicornia	205	330	5	3
X-7	Salicornia	130	395	2	2
X-8	Salicornia	62	640	7	2
X-9	Salicornia &	5		0	2
	Spartina	105	540		
X-10	Salicornia &	25		0	1
	Spartina	155	580		
X-11	Salicornia &	120	670	0	1
	Spartina	5			
X-12	Spartina	56	650	0	1
X-13	Salicornia &	31	815	4	1
	Spartina	1			
X-14	Salicornia &	32	340	1	2
	Spartina	35			
X-15	Salicornia	52	260	6+9j	0
X-16	Salicornia	55	125	10+3j	1
X-17	Salicornia	105	390	1	0
X-18	Salicornia	135	410	2+1j	2

Gms/sq.m of leaves