THE PEARL OYSTER RESOURCES OF PANAMA

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Explanatory Note

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United States Department of the Interior
Oscar L. Chapman, Secretary
Fish and Wildlife Service
Albert M. Day, Director

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THE PEARL-OYSTER RESOURCES OF PANAMA

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INTRODUCTION

The Government of the Republic of Panama, through the U. S. Department of State, in 1947 requested the United States Government to detail to Panama a shellfishery expert to make a survey of the pearl oyster grounds along the Pacific coast of the Republic, with the view of determining the cause or causes of a rapid decline of this formerly valuable fishery. The cooperative undertaking was organized and carried out under the program of the Interdepartmental Committee on Scientific and Cultural Cooperation as a part of the cooperation between the United States Government and the Governments of the other American Republics. By January 1948, all necessary arrangements made through the Fish and Wildlife Service of the U. S. Department of the Interior and the U. S. Department of State were completed.

The Panamanian Government agreed to provide a suitable ship, crew, and gear necessary for field explorations to be conducted around the Archipielago de las Perlas in the Gulf of Panama and in the Gulf of Chiriqui. Through the courtesy of Dr. Alexandro Mendez P., Director of the Museo Nacional in Panama, one room in the museum building was set aside for office and laboratory work. For field work the Ministerio de Agricultura, Comercio e Indústrias assigned a former U. S. submarine chaser, renamed CHUCUÚA, which was adequately equipped for work in shallow water. It gives me pleasure to acknowledge here with thanks the efforts of Sr. Guillermo Mendez P., Ministerio de Agricultura y Comercio, Dr. Alfonso Tegeira, Secretario de Agricultura y Comercio, and Sr. Genaro L. Martinez, Jefe de la Sección de Minería y Pesca, in selecting competent personnel and providing facilities and materials necessary for the successful completion of the expedition. Valuable assistance in obtaining information concerning the past history and present condition of the pearl fishery was received from Señora Carmen A. Miró, Directora de Estadística y Censo; Sr. Galileo Patiño, Director de la Biblioteca Nacional in Panama; Sr. Hermanos Pinel, pearl oyster dealer in Panama; Dr. J. Zetek, entomologist in charge of the field office of the U. S. Department of Agriculture in Balboa; and Mr. Fred A. Durling, economic analyst of the American Embassy in Panama.

Field work around sparsely inhabited islands located several hundred miles away from home base could not have been successfully accomplished without the most excellent cooperation and help of my shipmates: Sr. Genaro L. Martinez, who was in charge of the expedition; Capt. Esteban Peralta, master of the CHUCUÚA; Sr. Celedonia Pinzón, diver; and Felix Bravo, his life-line tender. All of these persons not only did everything possible to expedite and facilitate my field work, but by their thoughtfulness and kindness greatly contributed to my personal comfort during the voyage.

HISTORY OF THE PEARL FISHERY IN PANAMA[1]

Discoveries of the pearl grounds along the coast of the New World played an important role in the expansion by the Spaniards into the territories of Central and South America. In many instances, the finding of rich pearl resources in shallow waters along the coast of the newly discovered continent and around its many islands was a powerful stimulus for establishing settlements and organizing trade with the Indians. Letters written by Columbus during the third voyage in 1548; and samples of gold, drugs, and pearls which he himself sent to Spain, or which were brought in by his sailors, so aroused public enthusiasm that many navigators, explorers, and adventurers began to organize expeditions to seek the treasures of the lands of the "Western Ocean."

Extensive exploitation of pearl oyster resources started almost immediately after the discovery of the new territories. These activities were at first confined to the section of the Atlantic shore of South America known since the early years of the 16th century as the Pearl Coast. It extended from Cape de la Vela on the East to the Gulf of Paria on the West, and included the present territorial waters of Columbia, Venezuela, and

1/ This brief account is based primarily on the writings of Oviedo (1535), Washington Irving (1831), and Mosk (1934, 1938) and others listed in the bibliography.

the Lesser Antilles. Soon, however, new pearl grounds were discovered on the other side of the Isthmus of Central America in the blue waters of the Pacific Ocean. Credit for the discovery of these valuable grounds located around the numerous islands of the Archipielago de las Perlas in the Gulf of Panama belongs to Vasco Núñez de Balboa, the discovered of the Pacific Ocean.

The history of this famous adventurer dates back to the end of the 15th and the beginning of the 16th century, when an impoverished gentleman of noble descent (hidalgo), answering to the name of de Balboa, settled on Hispañiola. He struggled against severe odds trying to cultivate his land and pay his ever-increasing debts. As a consequence of his financial failures, in desperation he concealed himself in the hold of a ship bound from San Domingo to San Sebastian, and sailed hidden in the provisions which he himself delivered to the ship from his farm. In this ignominious manner the future discoverer of the Pacific Ocean in the year of 1510 reached the continent of the New World. After many vicissitudes, Balboa found himself in the Gulf of Darien. Still trying to reestablish his good standing with the King of Spain, he decided to undertake something spectacular. Exciting rumors he heard from the Indians of the existence of a great blue ocean on the other side of the mountains stimulated him in September 1513 to organize an expedition for which he assembled a strong force of 190 Spaniards and about one thousand Indians. On September 25 or 26 of that year, at the head of the first column, Balboa reached the summit of a mountain range from which he sighted the Pacific. A few days later, on September 29, the party advanced to the shores of a bay which at present is known as the Bay of San Miguel. A few miles westward in the mist of the sea loomed a group of islands which, he was informed, were ruled by a powerful "Calique" who kept the entire seaboard in terror. Balboa visited the islands and found that the waters around them abounded in finest pearls; he named the entire group Islas de las Perlas.

Indians who valued only the meat of pearl oysters could not understand the white man's joy at seeing the pearls, which they could not eat. The fact that Indians who inhabited the territory of the Isthmus of Panama were not interested in pearls and did not use them for adornment is confirmed by subsequent archaeological explorations, for pearls were not found in the graves, which, besides skeletons, contained large numbers of shark teeth and sting rays' spines. It is known, however, that together with various sea foods, including crawfish, pearl oysters were commonly eaten by the tribes inhabiting the eastern shore of the Gulf of Panama and the islands.

At the beginning the pearl fishing was profitable. In 4 days Balboa's men gathered about 96 ounces of pearls. The success of the first days encouraged the Spaniards. They organized pearl fishing parties, employed large numbers of Indian divers, and showed them how to open the oysters without roasting them, as was their custom, and spoiling the pearls. Scarcity of historical records makes it impossible to estimate the quantity and value of pearls gathered at this time from the Pearl Islands. It is known, however, that upon leaving the coast of the Gulf of Panama, Balboa received from a local chief a tribute consisting of 160 ounces of gold and 200 large pearls.

The value of the pearls shipped from the New World to Spain is not known. The official records of the amount of "the quint" or one-fifth of the appraised figure which the King's officers collected as a duty on pearl fishery are scarce and obviously too low. Von Humboldt (1822) mentions that until 1530 the annual value of the pearls shipped to Europe averaged, according to the Spanish Treasury records, only 800 piastras. He probably refers to pesos - a silver or gold coin weighing about 25 grams and equivalent to the American dollar. One must remember, however, that real values of different Spanish coins known as "peso duro", "peso fuerte", "peso sencillo" should be determined on the basis of their purchasing power at different historical periods and cannot be compared directly with the present day evaluations.

The share contributed by the Pearl Islands at Panama is not known, but occasionally the records mentioned the finding of some exceptionally good pearls from these islands. Thus, Mosk (1938) stated that in 1543 one Martin Alonso carried to Spain gems valued at 9,000 ducats, and that the largest pearl of the lot was from the Pearl Islands near Panama.

(Ducat was a gold or silver coin. Its value greatly varied in different countries. We may assume that it was worth 11 Spanish Pesetas or about 2.75 U. S. A. dollars.) Many valuable pearls brought to Europe undoubtedly escaped the eyes of the Spanish king's custom officers, and were not recorded.

There is no doubt that, with the marked decline of the pearl fishery along the Atlantic coast in the latter part of the 16th century, pearl grounds of the Pacific coast of Panama were exploited with greater intensity. Of particular interest in this respect are the records of the Cardona Company, which conducted its operations almost exclusively on the West Coast, although its pearl fishery license, granted in 1612, applied as well to the Pearl Coast of the Atlantic. The company was organized on a very large scale. Its six well-outfitted vessels sailed from Cadiz in July 1613, and visited the Caribbean Islands, apparently for the purpose of acquiring negroes; for the royal decree of June 25, 1585 had forbidden the use of Indians in pearl fishing, and specified that only negroes were to be employed for diving (Recoplicación de Leyes de los regnos de las Indias, Madrid, 1774, book 4, title 25, law 31, quoted from Mosk, 1934). In 1614, the expedition of the company crossed the land of New Spain and established its headquarters at Acapulco, where it immediately began the construction of three vessels. The ships, of about 200 tons capacity, were ready by January 1615 and began their explorations. The method of locating pearl oyster grounds ("placeres") was unique. The Spaniards scanned the beaches in an attempt to locate shell mounds which resulted from the consumption of pearl oysters and throwing the shell on the beach. In the words of the Cordona's report (quoted from Mosk, 1934): "along the sea coast, on the interior (Gulf) side, for a distance of one hundred leagues, one does not see anything but mounds of pearl shell." The description refers to the Gulf of California, but undoubtedly the same method of finding pearl grounds was used by the Spaniards throughout the range of their explorations.

Intensive fishing resulted in a rapid decline in the yield of pearls. It is interesting to note that the earlier explorers had some understanding of the principles of conservation. For instance, one report of the Cordona Company stated that their expedition of 1613 to Margarita Island (Venezuela) was fruitless because the grounds were full of small oysters. To have taken them out, according to the report, would have been a detriment to the interests of the pearl fishery and of the royal treasury (Mosk, 1934).

General falling of prices of pearls in Europe in the 17th century was probably the main reason for the decline of pearl fishing. This was beneficial to the pearl oyster resources, for during the period of relative inactivity the grounds depleted by previous intensive exploitation had a chance to recover.

We have no data regarding the yield of the fishery in the 18th and 19th centuries. Regular statistical data which are being collected by the Panamanian Government are available only since 1907. At the beginning of the present century, the pearl fishery along the Pacific coast of Panama was well developed; it provided steady livelihood to a number of communities scattered on the islands of the Archipielago de las Perlas and in the Gulf of Chiriqui, especially around Coiba and other islands. The main product of the fishery during the last 50 years has been the mother-of-pearl shell. With the decreasing number of pearl oysters on the grounds, the chances of finding a valuable pearl became so remote that the Panamanian pearls lost their importance in the economic life of the country, although the hope of becoming rich overnight still persists and lures the inhabitants of the Pearl Islands and incidental visitors to the Pearl Archipielago to try their luck. Many oysters are being taken in this mostly vain hope, and their shells discarded. Because of this situation, the number of oysters recorded in official statistics must be considerably smaller than the actual number taken from the sea.

Present statistical data are based on records of export of mother-of-pearl shells from Panama City and Colon. Unfortunately, records of landings of mother-of-pearl shells are not always available. In view of the fact that there are no large warehouses in Panama or in Colon for the storage of shells, it is reasonable to assume that the greatest part of the annual catch of shells was exported.

Data of the yield of pearls are even less reliable, for frequently the purchase of a lot of pearls was done privately without making any official record of the transaction. With these limitations, the statistical data are useful in showing the declining trend of the pearl fishery during the last twenty years (Fig. 1). The detailed data, supplied by the Dirección Estadística y Censo, are summarized in Table 1. Two factors may have caused the wide fluctuations in the quantities of shells exported from Panama shown by these data: increase or decrease in the demand for Panama shells in the world market, and the abundance or scarcity of pearl oysters on the grounds. The quantity of shells shown by official record of export in 1918 is entirely out of the range of the fluctuations for the preceding and subsequent years and cannot be explained by any special conditions which might have affected the fishery at this time. Although this figure was checked several times by the staff of the Office of the Dirección Estadística and found to correspond with the data entered in the books, there is admittedly some error in records. Of more interest are the several sharp declines in the export of mother-of-pearl shells for the years 1914-1917, 1921, 1923, and 1931. Low figures for 1914-1917 are undoubtedly due to the World War I in Europe, while a temporary decline in 1923 may be attributed to unsettled economic conditions in Germany, the principal country importing Panamanian mother-of-pearl shells. Thus, decline for 1923 probably was caused by market conditions rather than by the scarcity of oysters. Steady decline in the production of shells after the peak of 1925 is due, however, to the general decline in the supply of pearl oysters.

Years of forced inactivity from 1939 to 1943 inclusive had no beneficial effect on the oyster population. In 1944-45, when the fishery was officially resumed, the divers found the pearl oysters extremely scarce. They also reported seeing, on several formerly productive grounds, many dead or dying oysters. It has been the aim of the present investigation to determine the cause of the existing depletion and to suggest the methods of restoring the fishery.

Figure 1 --- Quantity and value of mother-of-pearl shells exported from Panama in 1905-1947.

Table 1 --- Quantity and value of mother-of-pearl shells and pearls exported from Panama from 1908 to 1947 (Dirección Estadística y censo)

YEAR	Mother-of-pearl Shells			Pearls	
	Kilograms of shells	Total value in balboas	Value in balboas per kilo	Pearls in carats	Total value in balboas
1908	223,905	23,291	0.10	...	...
1909	354,689	35,811	0.10	...	...
1910	625,008	50,914	0.08	...	...
1911	651,405	73,505	0.11	...	...
1912	458,114	83,224	0.18	...	...
1913	527,187	96,702	0.18	...	...
1914	161,378	34,555	0.21	...	...
1915	306,155	75,840	0.25	...	...
1916	189,483	26,924	0.142	...	...
1917	196,676	23,543	0.12	...	...
1918	1,228,776	77,848	0.06	...	...
1919	353,086	65,366	0.19	...	...
1920	276,658	61,610	0.22	...	...
1921	184,244	46,850	0.254	...	...
1922	681,250	139,740	0.21	2/	10,000
1923	42,563	4,556	0.11	...	...
1924	632,198	68,512	0.11	2/	57,524
1925	746,611	92,008	0.12	2/	40,375
1926	383,730	37,411	0.10	2/	20,132
1927	465,404	58,645	0.13	2/	30,680
1928	253,479	33,486	0.13	2/	12,565
1929	329,150	37,382	0.11	2/	22,726
1930	174,687	19,440	0.11	2/	3,950
1931	40,364	4,668	0.12	2/	3,000
1932	53,623	3,814	0.07	2/	3,350
1933	156,393	12,028	0.08	25	915
1934	52,143	3,436	0.07	73	1,555
1935	96,485	13,224	0.14	291	13,826
1936	179,787	18,815	0.14	381	14,670
1937	189,489	23,231	0.13	339	10,818
1938	52,560	8,810	0.17	3	275
1939	...	...	...	...	...
1940	...	...	...	...	...
1941	...	...	...	...	...
1942	...	...	...	...	...
1943	...	...	...	...	...
1944	2,347	500	0.21	...	...
1945	...	...	...	...	...
1946	1,670	905	0.54	...	...
1947	3,986	2,913	0.73	...	...

2/ No information about quantity. For years 1907-1921 and 1939-1947, there were no exportations. Balboa is equivalent to one U. S. dollar.

ECONOMIC IMPORTANCE OF PEARL FISHERY

Pearl fishery in Panama has been a small industry which contributed annually from 0.3 to 1.3 per cent, or only a minute fraction, of the total value of the country's export (Table 2). In the document (Prospectus, Republic of Panama) from which these data are quoted, the value of pearls and mother-of-pearl shells is shown together with the value of tortoise. Export of the latter is, however, so insignificant that its inclusion does not materially change the percentage figure.

Table 2 --- Total value of exports from Panama and the value of the exported pearls, tortoise shell, and mother-of-pearl (from the Prospectus, Republic of Panama)

Year	Total exports in balboas	Export of pearls, tortoise shells and mother-of-pearl shells in balboas
1936	4,158,406	46,917
1937	4,069,727	53,631
1938	3,743,968	26,612
1939	3,487,378	10,606

Balboa is equivalent to one U. S. dollar.

In spite of the small size of the fishery, its relative importance to the national economy has been greater than it may appear, because the total production of pearl and shells was exported. In a country in which the value of imports several times exceeds that of exports, every item that may be exported becomes important. Furthermore, in the economic life of various small communities engaged primarily in fishing, income derived from the pearl fishery has been a very substantial item. Thus, the proceeds from pearl fishing were of great importance to the inhabitants of several towns and villages on the Pearl Islands (Fig. 2), in the coastal areas of the Province of Darien, and in the Gulf of Chiriqui. San Miguel, on the Isla del Rey, was the principal pearl-oyster center. It is true that for several hundred fishermen of this community, pearl fishing was only a part-time occupation, which required no special investment in gear. Oysters were gathered by naked divers from a depth not exceeding 6 fathoms. When sufficient shells were gathered they were taken by boat to Panama, and sold there to wholesale shippers. The inhabitants also caught fish, and engaged in farming on small patches of land cleared in a forest jungle. Oyster meat provided additional protein food, while cash received from the sale of shells was used for the purchase of clothing, kerosene, and other necessities. With the almost complete disappearance of pearl oysters in recent years, the economic life of this community was greatly upset, for no other source of income was available to the population to compensate for the loss caused by the scarcity of oysters.

Relative importance of various localities as centers of pearl oyster fishery in Panama may be determined from the scattered data of the landings of mother-of-pearl shells in the Statistical Bulletins (Boletin de Estadística, Republica de Panama). For instance, records for 1912 show that the San Miguel district contributed 75.7 per cent of shells landed in Panama (44,855 kilos out of 59,280). Next in importance was Remédios, in the coastal area of Chiriqui Bay and Garachiné, in the Bay of St. Miguel on the west side of the Gulf of Panama. Other districts of production could not be identified from the official

Figure 2 —— Saboga. Typical small village on Pearl Islands.

data because they show the ports of registration of fishing boats rather than the areas of their operations. Pearl fishermen are not confined, however, to one particular locality. This is especially true for some of the diving boats capable of working at any place along the coast of Central America. Sr. Pinel, one of the large pearl-shell dealers in Panama, informed me that his 12 boats frequently fished as far as the coast of Ecuador and the Gulf of California. Total figures on production of Panama pearl oysters may include, therefore, some undetermined portion of the catch taken outside of the Panamanian waters. I believe, however, that this quantity was small, because not many boats were capable of making long voyages.

Although the Panamanian Government collects license fees for each diving boat, data on the number of boats engaged in pearl fishing and the number of fishermen employed in this industry are not available. Revenues received by the Treasury from this source are shown together with the other items, in one lump sum. By inquiring among the wholesale pearl-shell dealers in Panama City, I arrived at the conclusion that from 1920 to 1935 there were probably from 40 to 50 diving boats which operated on the Pacific coast of Panama. Each boat carried a crew of 6 men (1 diver, 1 assistant diver, and 4 deck hands), and was equipped with one hand pump and one scaphander. The boats were about 25-28 feet long, had no engine, and were equipped with sails and oars (Fig. 3). Scaphander divers usually worked at low tide at a depth from 6 to 12 fathoms. Occasionally, they descended to 18 fathoms.

The diver was paid by the number of oysters he brought, usually at the rate of 2 pesos (dollars)3/ per quintal (100 lb.) of shells. Other men worked for wages. Each diver was expected to obtain at least 200 lbs. of shells per day; smaller catches were considered unprofitable. From the diving boat, the oysters were taken to a mother ship, where they were opened under the watchful supervision of an officer of the company. All pearls

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3/ The former Spanish American peso was normally worth $0.965.

Figure 3 --- Pearl-fishing boat used for diving during the expedition. Mast and sails were removed. Air pump is located in the middle.

were considered to be the property of the operating company. On Sundays the diver was permitted to fish for himself, but he had to turn over to the company one half of all the pearls and shells gathered on this day.

Naked divers worked by themselves at their own risk. Their maximum catch per man per day did not exceed 50 lb.

Germany was the principal market for the Panama mother-of-pearl shells, which were shipped to Hamburg. Other cities to which shells were exported in much small quantities were, in order of their importance, London, New York, Paris, Trieste, Barcelona, and Genoa.

VALUE AND QUALITY OF PEARLS

Statistical data on the quantities and value of pearls taken in Panama are less reliable than those referring to the mother-of-pearl shells. Many transactions in pearls were made privately without any official record. The quantities and values of pearls given in Table 1 can be considered as minimum figures, probably representing only a small fraction of the total catch. Comparison between the production of pearls and mother-of-pearl shells shows that in the economy of the country the trade in shells was far more important than the trade in pearls. The maximum annual values of $57,524 for pearls (1924) and $139,740 for shells (1922) are not very far apart, but the total recorded value of pearls for the years 1922-1938 is much less than that of the value of mother-of-pearl for the same period. This indicates that the production of shells was a much more stable and reliable source of income than the pearls. According to Sr. Pinel, some of the pearl fishing companies in Panama considered that the revenue from the sale of shells would completely cover their expenses, and profits would be derived entirely from the sale of pearls. Reliable information as to the abundance of pearls and their quality is, however, lacking. Any finding of an exceptionally valuable pearl is a matter of common knowledge. Frequently, however, the disposal of the pearl is a deep secret and its sale is not recorded in official statistics.

Most of the Panama pearls are white, but occasionally dark green, green, and pink pearls are found. Green pearls are considered great rarities and bring high prices. One of the recent findings, shown to me, was a magnificent deep-green pearl of about 4 1/2 carats. Its color and lustre were so exquisite that, in spite of irregularities in shape, the pearl was appraised at not less than $200 a carat. According to Sr. Pinel, the last valuable pearl of excellent quality found by one of his divers was obtained about 12 years ago. It was appraised and sold for about $5,000.

METHODS OF INVESTIGATION

Several explanations for the scarcity of pearl oysters in Panama waters suggested by the local press received considerable publicity. They fall into three categories: (1) oysters were destroyed by some unknown disease; (2) they were poisoned by the dumping of explosives and poisonous gases; and (3) they were killed by some specific poison or germ secretly placed near pearl grounds by the Japanese fishermen in retaliation for Japan's defeat in World War II. Advocates of each of these theories presented various arguments in support of their views. The reports of several divers that there were many dead or dying oysters on the principal pearl grounds around the Pearl Islands seemed to support the first view. The existence of a large dumping area set aside by the U. S. Goverment at the entrance of the Gulf, and shown on U. S. Coast and Geodetic Survey Chart No. 1019, provided grounds for the second assumption. The area in question is located, however, beyond the 1,000 fathom curve, about 50 miles south of the southern end of San José Island. The third theory was based on quotations from some unidentified person or persons who allegedly heard of the threats made by the Japanese that the pearl-oyster fishery would cease to exist after the deportation of Japanese citizens from Panama. Suggestions were also offered that the influx of water from the Humboldt current carrying "red tide" may have killed the oysters. In discussing the matter with many persons engaged in commercial fishing in Panama, I was unable to obtain evidence corroborating any of these theories. There was no marked discoloration of water, and no mortality of fish or other animals was observed, which one would expect to have occurred if the water were poisoned by chemicals or by the red tide (Galtsoff, 1949). Nobody was able to state with certainty where and when the mortality of pearl oysters had started; and nobody could present any evidence of suspicious behavior of Japanese fishermen on or near the pearl grounds.

My field observations were planned to provide answers to some of these questions. They consisted of the following: (1) quantitative samplings of pearl oysters to determine their abundance on various grounds, (2) records of the temperature, salinity, and pH of surface and bottom water, and tests for copper, (3) vertical sampling of plankton, (4) ecological observations on pearl-oyster grounds and adjacent bottoms, (5) microscopical examination of oyster tissues with the view of finding whether the oysters were infected by microorganisms or were diseased, and (6) observation on spawning of pearl oysters.

This plan, with some modifications dictated by circumstances, was carried out, although its execution sometimes was incomplete because of the lack of a trained assistant. As far as was feasible, the material collected at each station was examined alive, or was preserved for more detailed examination in the laboratory.

The vessel at my disposal, although of sufficient size (about 80 feet long) lacked any space below the deck that could be made into a laboratory. Consequently all microscopic and chemical work had to be done on deck; and all the instruments, materials, and notes secured at the end of each observation and covered with canvas to protect them from spray.

Quantitative sampling of pearl oysters was made by a professional diver using regular diving equipment (scaphander and hand pump); he was assisted by his crew of five. The diving boat was towed by the Chucuña and left at the places selected for diving. Record was kept of all the oysters (dead or alive) found by the diver and of the time of diving. The latter varied from 1 to 4 1/2 hours. It was fortunate that the Panamanian Government was able to secure for the expedition the services of Sr. Celedonio Pinzon, a diver of more than 30 years experience. His familiarity with the pearl oyster grounds was very useful in selecting representative locations for sampling stations and his intelligence and natural curiosity were helpful in collecting marine invertebrates associated with the pearl oyster or inhabiting the pearl grounds.

At each station, shallow waters adjacent to the shore and the tidal flats or rocks exposed at low tide were explored. Material was collected by using a small hand dredge and by hand picking. Temperature of surface and bottom water was recorded to the nearest tenth of a degree Centigrade, and the salinity was computed from hydrometer readings made aboard the ship. The pH of the water was determined colorimetrically, using Heilige discs and Cresol Red indicator. The readings were corrected for salt error. Plankton was collected with No. 20 silk net 1 foot in diameter. Tissues of oysters and plankton were preserved in picro-formal solution (Bouin 3) or in 3 per cent formalin in sea water.

Invertebrates collected during the survey were examined in the laboratory of the National Museum in Panama (Fig. 4) and shipped to the United States for more detailed study. It is regretted that part of the material obtained at the first eleven stations was lost in transit from Pearl Islands to Panama. A miscellaneous collection of Panamanian invertebrates comprising over 5,000 specimens has been deposited in the U. S. National Museum in Washington. A small number of Bryozoa incrusting mollusk shells was forwarded for identification to Dr. R. C. Osborn, and upon completion of his studies will be deposited with the Allan Hancock Foundation of the University of Southern California in Los Angeles.

ECOLOGICAL CHARACTERISTICS OF PEARL OYSTER BOTTOMS AND OF ADJACENT GROUNDS

The range of distribution of the pearl oyster of Panama, *Pinctada* (*Margaritiphora*) *mazatlanica* (Hanley) (Fig. 5) extends from the Gulf of California to the Gulf of Panama. The species has been reported also from Galapagos and Peru. Throughout this wide range it is found on hard or rocky bottoms. Adult specimens are from 5 to 7 inches in length. The does not form continuous banks or beds typical of some of the species of the edible oysters

Figure 4 --- National Museum, Panama. Headquarters of the expedition was located in the corner room of the second floor - left of the tower.

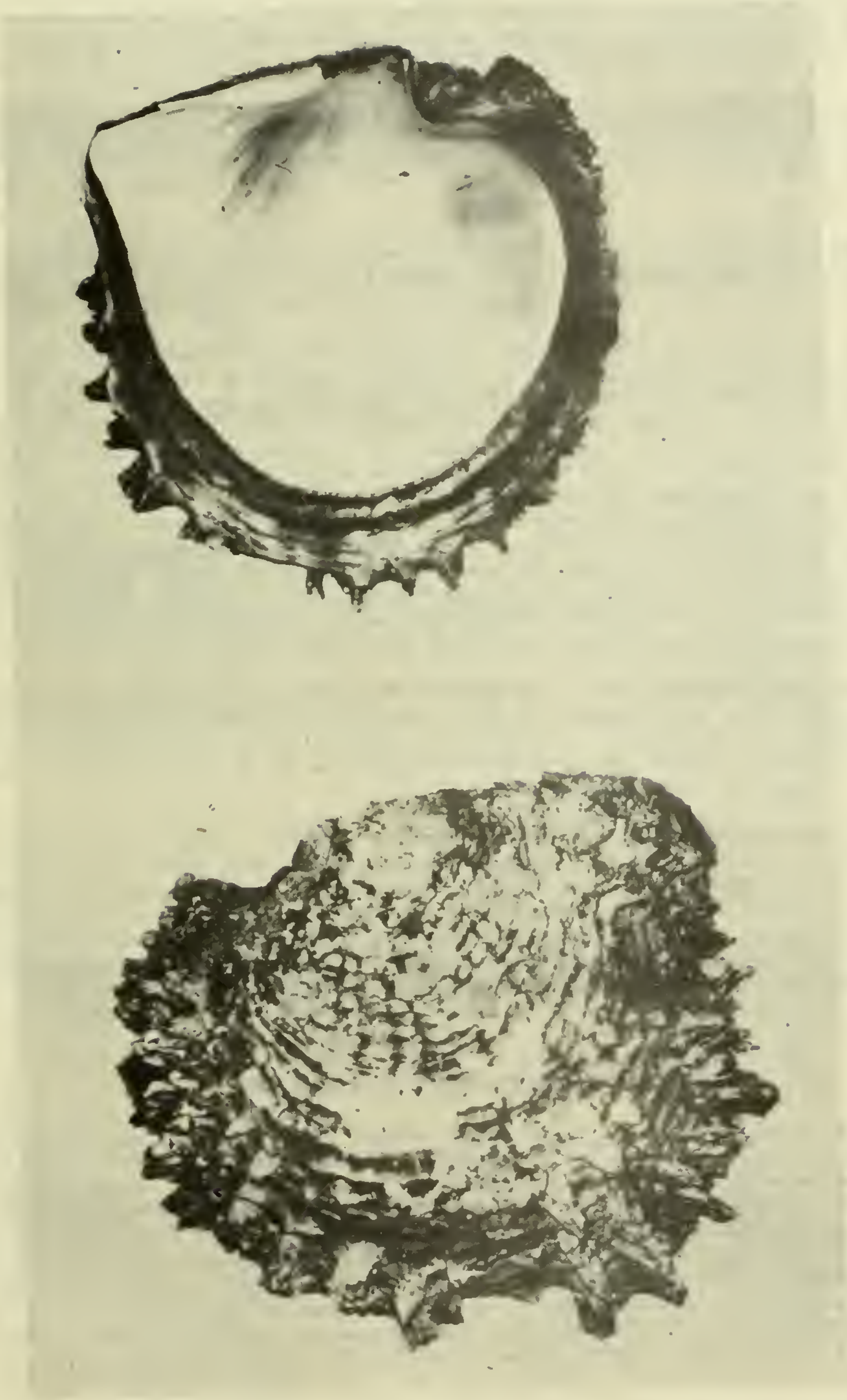

Figure 5 --- Pearl oyster of the Pacific coast of Panama, Pinctada mazatlanica. Adult specimen.

like Ostrea virginica, O. chilensis, O. gigas and others. Pearl oysters, firmly attached to the substratum by a byssus, may be found in large quantities growing in close proximity to each other, but without forming clusters. On the bottom of the sea, the pearl oyster grows in a vertical position, or slightly inclined, at about 35 degrees to the horizontal surface. Objects to which the oyster attaches itself vary greatly, but small rocks and corals are most frequently used. Occasionally pearl oysters are found on semisoft bottom made of a mixture of mud and sand, but this type of bottom is not typical for the species.

Along the Pacific coast of Panama, Pinctada mazatlanica is found in shallow water along the mainland and around the islands in depths probably not exceeding 18-20 fathoms. It is quite possible that the oysters live in deeper water, but since commercial divers do not descend below 18 fathoms, the maximum depth at which the pearl oysters may be found is not definitely known.

Around the Pearl Islands in the Gulf of Panama, and near Coiba Island in the Gulf of Chiriqui, the pearl grounds are likely to be found in relatively narrow channels between the small islands, where rapid tidal currents provide a good exchange of water.

Pearl oysters do not occur in the tidal zone above low water level. The reason for this is found in the peculiarities of the closing mechanism of the adductor muscle. No physiological studies have ever been made with Pinctada mazatlanica, but my experiments with the related species of pearl oyster of the Hawaiian Islands, P. galtsoffi Bartsch, show that when the oyster of this species is taken out of water it is not able to keep the valves of its shell closed. After a brief exposure to air, the adductor muscle of the oyster relaxes, the valves gape, the sea water retained between the shells is spilled and the mollusk dies. The gaping of the valves may be prevented if the oysters are tightly packed in boxes between layers of seaweed. If the behavior of P. mazatlanica is similar to that of P. galtsoffi, it would explain its absence from the tidal zone. It is generally known that in edible oysters of the genus Ostrea the adductor muscle has the ability to remain contracted for days or even weeks, keeping the valves tightly closed. Because of this, edible oysters remain alive for a long time after being taken out of water.

In the Gulf of Panama and in the Gulf of Chiriqui, the distribution of the pearl oyster is restricted to a rather narrow shelf of hard bottom. Around the islands, this zone of suitable bottom is limited by a 20-fathom contour. Along the mainland shores, it is confined to a 5-fathom depth, below which the bottom, as shown by the Coast and Geodetic Survey charts, becomes soft and muddy.

From the information I received from various persons familiar with the pearl industry in Panama, I conclude that no extensive pearl-oyster beds have ever existed along the continental shores of Panama, although a few specimens of pearl oyster may be found here and there along the coast. In selecting my sampling stations, I was influenced by the past experience of pearl divers, and made observations in the locations which in the past 30 years were known to be productive in pearl oysters. These grounds were primarily confined to the sheltered and relatively narrow channels between the islands of the Archipielago de las Perlas and around Coiba Island in the Gulf of Chiriqui (Fig. 6).

SUBMARINE TOPOGRAPHY OF THE GULF OF PANAMA

The bottom of the Gulf of Panama gently slopes seaward for a distance of about one hundred miles where at the edge of the continental shelf the depth over a short distance of 10 to 15 miles rapidly increases to 100 fathoms. Within the next 15 miles in the southern and southeastern direction the depth reaches 1,000 fathoms. Considerable portion of the Gulf is occupied by many small and large volcanic islands which form the Archipielago de las Perlas. At the northern end of the Pearl Islands, a submarine valley beginning at the 20-fathom contour at the mouth of Rio Chepo (Bayano River) can be traced for a distance of about 80 miles along the western side of the Islands. According to Terry (1941) the valley is perceptible to the 400-fathom line, where radiating channels suggest a delta. Terry thinks that the relation of this submarine valley to the ancient Bayano (Chepo) River is unmistakable.

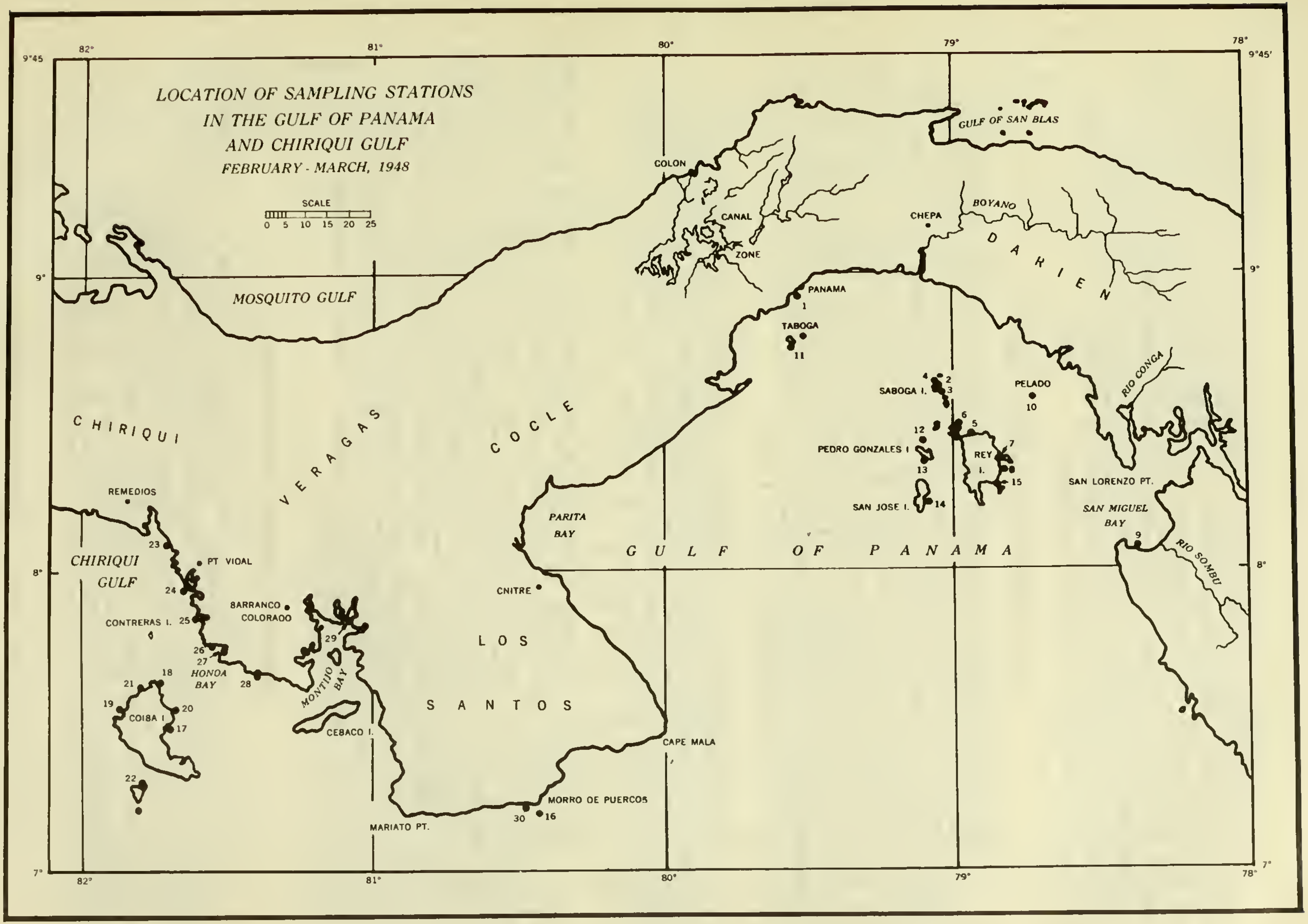

Figure 6 --- Location of sampling stations in Gulf of Panama and Chiriqui Gulf, 1948.

It is interesting to point out that no similar canyon can be found in front of the Bay of San Miguel through which empties the entire drainage of the province of Darien. Terry (1941) suggests that in Pleistocene times the Darien drainage may have turned northwest round the Pearl Islands. The hypothesis is, however, difficult to reconcile with the existence in front of the bay of a well-marked channel which extends south to the 4?-fathom curve. This origin of the submarine valley in the Gulf of Panama presents, therefore, an interesting problem to geologists. From an ecological point of view, the presence of such a valley along the western side of the Pearl Islands is significant, for it affects the water movement of the Gulf which in turn influences the distribution of water temperature and of current-borne larvae of marine invertebrates.

WATER MOVEMENTS IN THE GULF OF PANAMA

The movement of water in any part of the sea is one of the principal physical factors of marine environment which affects the propagation, distribution, and the rate of growth of various forms, whether living freely or attached to the bottom. In the Gulf of Panama the movement of water is definitely related to bottom topography. It has been shown by Fleming (1938) that, because of the shoaling of bottom toward the head of the Gulf, there is a corresponding increase in the range of tide from the entrance to the head of the bay. Over the entire area, the maximum differences in the range of tide are great, varying in places from 5 feet at neap tides to over 22 feet at spring tides. The greatest tidal range is found in the innermost part of the Gulf. Thus, near Balboa the values for the average neap and average spring tidal ranges are 12.6 and 16.4 feet respectively. At the entrance to the Gulf on the west side at Cape Mala the average ranges are 10.3 and 13.0, and on the east side at Piñas Bay, 10.8 and 13.8 feet.

Associated with the large tidal range and its periodical fluctuations are, of course, the tidal movements of water, which are also related to bottom topography. Thus, in places, one encounters very strong tidal currents, especially rapid in many narrow channels between the numerous islands of the Archipielago de las Perlas. Fleming has computed that an average velocity during the half-tidal period is about 0.17 m/sec. (about 2 nautical miles during the half-tidal period) at neap tides. At spring tides, the movement is of the magnitude of 4 nautical miles in each direction during the same period.

The tides along the coast of Panama are of semidiurnal type. Because of the great range of tide in the Gulf of Panama, large volumes of water enter and leave the Gulf, reaching maximum velocities twice during each tidal interval of about 12.5 hours, and following down to almost zero twice during the same period of tide. Since the direction of the tidal current reverses itself with each flood and ebb, no actual transport of water is involved in tidal changes, but the tidal currents are of great importance in mixing the water of the Gulf, and, presumably, in replenishing and dispersing the nutrient salts. The mixing must be important also in distributing the free-swimming larvae of many sedentary animals, including the pearl and edible oysters. One must expect also that near the edge of the continental shelf there is considerable vertical movement of water. Fleming (l.c.) has deduced that, besides tidal movements, there is in the Gulf of Panama a counterclockwise rotating motion of water which has a velocity of about 0.5 knot. The tidal currents are superimposed on this nontidal movement which is probably of greater oceanographic importance in bringing new nutrient materials to the Gulf.

TEMPERATURE, SALINITY, AND pH OF WATER

During February-March 1948, the distribution of temperature in the upper layer of sea water (0 to 8 fathoms) along the Pacific coast of Panama followed a definite pattern which may have biological significance. As can be seen from examination of the chart (Fig. 7), there was a noticeable difference between the temperature of water east and west of the Pearl Islands. All the readings made west of the islands fall within 25-27° C., while much cooler water of 21-22° C. prevailed on the west coast of the islands. I had no opportunity to make a study of temperature distribution in the western portion of the Gulf, between San José Island and Parita Bay. Unfortunately, the day when the CHUCUÚA made a run from Cape Mala to Taboga, the sea was too rough to make any observations. Temperatures of

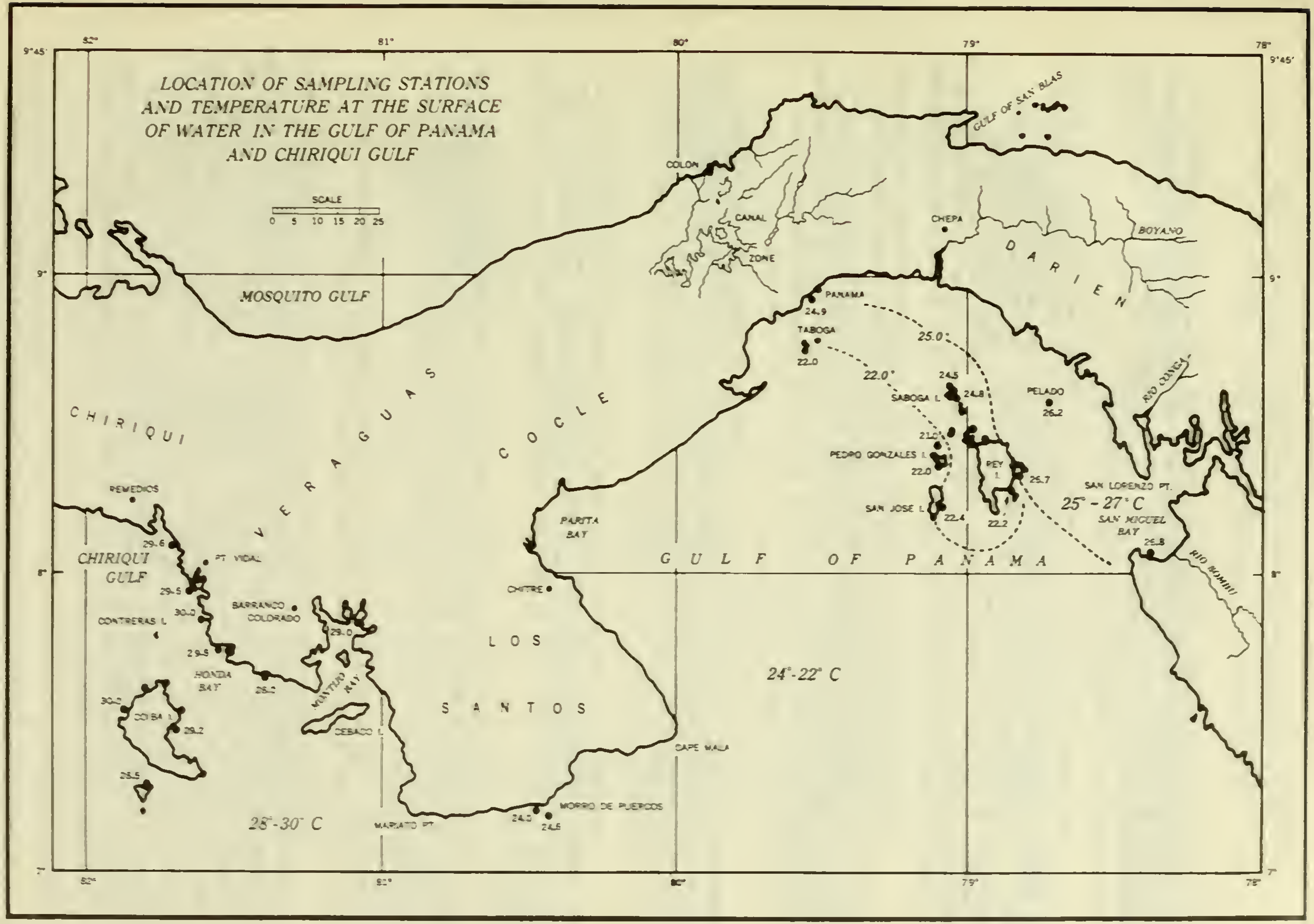

Figure 7 --- Temperature at the surface of the sea in the Gulf of Panama and Chiriqui Gulf, February - March 1948.

24.0°-24.6° C. were found along the southern coast of the peninsula which separates the Gulf of Panama from Chiriqui Gulf (between Cape Mala and Punta Mariato). The temperature of water in the eastern part of Chiriqui Gulf was consistently higher than that in the Gulf of Panama, varying from 28.0° to 30.0° C. The difference of about 5° C. between the two gulfs must have considerable biological significance.

The presence of relatively cold water in the western part of the Gulf of Panama may suggest an upwelling along the submarine valley west of the Pearl Islands. It would be, however, premature to make far-reaching deductions from the admittedly inadequate data. Further hydrographical studies are needed to explain the observed distribution of temperature along the coast of Panama. The suggestion that the difference in water temperature in the Gulf of Panama and Chiriqui Gulf is due to the influx of cold water from the Humboldt Current or from its branch known as the Galapagos Current does not appear to be sound, for the latter current extends north only as far as 5° N. latitude and veers west.

Thermal conditions in the upper layer of water in the Gulf of Panama are rather unstable. This is disclosed by a series of temperature measurements made during World War II by the Woods Hole Oceanographic Institution[4/]. They show that, during a few days between January 24-25 and January 28-29, 1945, the surface temperature of water taken at hourly intervals between 8:00 a.m. and 7:00 p.m. at two stations located west and northwest of the Pearl Islands varied as much as 2.1° C. and 2.9° C. depending on direction and velocity of wind and water currents.

In view of these observations, it is reasonable to expect that the temperature differences east and west of the Pearl Islands are caused by meteorological conditions and may not be always as pronounced as they were during my observation in February-March 1948. On the other hand, it seems that the temperature differences between the Gulf of Panama and the western part of the Chiriqui Gulf are of more permanent nature and are determined by the hydrography of the two bodies of water.

The salinity of the water at different stations varied from 32.0 to 35.9 parts per thousand; the highest values were observed at the stations located offshore, or near the coast, but far away from the discharge of fresh-water streams. The decrease in the concentration of salts to about 32 parts per thousand was due to the influx of fresh water (Tables 3 and 4).

The same is true for the pH of the water, which, with the exception of one reading of 7.6 (Station 29) and two readings of 8.4 (Station 9 and 24), fluctuated between 7.9 and 8.3. Changes in the pH primarily caused by the intensity of photosynthesis can be attributed to local concentrations of phytoplankton and variations in the intensity of illumination.

There was no evidence of the influx of less alkaline waters from the greater depths of the Gulf which could have adversely affected the pearl oyster.

Thinking of a popular belief that pearl oysters may have been poisoned by dumping of explosives and ammunition at the entrance of the Gulf, I made a limited number of determinations of copper in the samples of water collected at Taboga Islands (Sta. 11), San José Island (Sta. 14), Morro Puercos (Sta. 16), and Coiba Island (Sta. 18). No copper was detected in 100 ml. samples of water, using di-ethyl-di-tio carbonate reagent. Since copper can be detected by this reagent in the concentration of 0.01 mg. per cubic meter or more, I conclude that there was no excess of Cu ions which may have been indicative of the pollution of the water by heavy metals. I had no opportunity to make analyses for other metals. In the water contaminated by dumping of chemicals and explosives, one may have expected to find significant deviation from the normal values of the pH. As can be seen from Table 4, the pH values were all within the range of fluctuations that one may expect to find under normal conditions in the sea.

4/ I am grateful to the Woods Hole Oceanographic Institution for permission to consult these still unpublished data.

Table 3 — List of sampling stations in the Gulf of Panama and western part of Gulf of Chiriqui, Panama, February-March 1948

Station number	Location	Lat. N.	Long. W.	Date	Time	Remarks
				1948		
1	Panama Harbor, near Panama City.	8° 58'	79° 31'	Feb. 7	18:00	No diving
2	Isla Saboga.	8° 38'	79° 04'	Feb. 8	07:30	
		...	...	Feb. 10	07:50	
3	Isla Saboga, southern end, east side.	8° $36\frac{1}{2}$'	79° 04'	Feb. 9	10:45	
4	Isla Saboga, Canal de Santiago	8° 39'	79° 04'	Feb. 10	08:30	
5	Isla del Rey, opposite San Miguel	8° 28'	78° 57'	Feb. 10	13:00	
		...	...	Feb. 11	07:00	
6	Isla de Mina, N.E. side. .	8° $29\frac{1}{2}$'	79° 00'	Feb. 11	09:30	
7	Isla de Cañas, west side (Lecaida Canal).	8° $23\frac{1}{2}$'	78° $50\frac{1}{2}$'	Feb. 12	09:30	
8	Punta Gorda, east side of Isla del Rey.	8° 21'	78° $50\frac{1}{2}$'	Feb. 13	07:30	
9	Ensenada de Garachiné, opposite Garachiné . . .	8° 05'	78° 24'	Feb. 14	08:00	No diving
10	Islote el Pelado	8° 38'	78° 42'	Feb. 15	12:20	
11	Taboga	8° 47'	79° 32'	Feb. 29	09:00	
12	Isla Señora y Isla Señorita	8° 27'	79° 06'	Mar. 1	08:30	
13	Isla Pedro Gonzales, south eastern side	8° 23'	79° 05'	Mar. 1	10:30	
14	Isla de San José, Ensenada Playa Grande	8° 15'	79° 06'	Mar. 1	17:30	
		...	...	Mar. 2	08:00	
15	Isla Santelmo, N.W. side .	8° 17'	78° $51\frac{1}{2}$'	Mar. 2	16:40	
16	At sea about $1\frac{1}{2}$ miles off Morros Puercos	7° 13'	80° 26'	Mar. 3	09:30	No diving
17	Coiba, Bahia Damas, opposite Colonia Penal . . .	7° 32'	81° 42'	Mar. 4	08:30	
18	Coiba, Canal Coibita, northern end, south of I. Rancheria	7° 38'	81° 43'	Mar. 4	10:00	
19	Coiba, Punta Hermosa . . .	7° 32'	81° 49'	Mar. 4	12:00	No diving
20	Coiba Punta Job (east side)	7° 33'	81° 41'	Mar. 5	10:00	Diving only
21	Coiba, South of Punta Baltasar (known locally as Punta Santa Cruz) . .	7° 37'	81° 47'	Mar. 8	07:30	
22	Isla Jicaron, Punta David.	7° 18'	81° 46'	Mar. 9	07:45	
23	Near Puerto Nuevo, east of Punta Entrada.	8° 05'	81° 43'	Mar. 9	17:00	
24	Punta Pajaron. . , ...	7° 55'	81° 38'	Mar. 11	18:00	
25	Punta Pizbá.	7° 50'	81° 35'	Mar. 11	12:45	
26	Between the Mainland and Isla Medidor	7° 46'	81° 35'	Mar. 12	08:00	
		...	...	...	12:01	
27	Bahia Honda.	7° 46'	81° 31'	Mar. 12	13:30	
28	Between Islas Cativos and Mainland. Gulf of Chiriqui.	7° 42'	81° 28'	Mar. 13	10:45	
29	Bahia Montijo, Rio San Pedro	7° 52'	81° 05'	Mar. 13	17:00	No diving
30	Morro Puercos, about 1,000 feet offshore and 3 miles west of the lighthouse .	7° 15'	80° $29\frac{1}{2}$'	Mar. 14	17:00	No diving

Table 4 --- Temperature, salinity, pH of sea water, and number of pearl oysters found at each station in the Gulf of Panama and Chiriqui Gulf February-March 1948

Station No.	Date	8/ Time	Depth	Water temperature	Salinity	pH	Number of pearl oysters: Adult Live	Adult Dead	Young Live	Young Dead	Hours of diving
			Fathoms	°C	Parts per thousand						
1	Feb. 7	18:00	0	24.9	35.7	8.1	..	..	..	..	..
2	8	07:30	0	24.5	33.5	8.1	..	..	..	..	..
			3	..	33.6	8.3	0	0	0	0	4
	9	07:50	0	25.2	32.2	8.4	..	..	..	..	..
			5	23.8	33.9	8.4	..	..	..	..	..
3	9	10:45	0	24.8	33.5	..	..	..	..	..	..
			4	24.8	33.5	..	0	1	0	0	4
4	10	08:30	0	23.8	..	..	..	..	..	..	..
			2	23.8	34.0	..	1	6	2	0	4 1/2
5	10	13:00	0	26.4	32.8	8.4	..	..	..	..	..
			2.5	26.2	32.8	8.4	0	0	0	0	3
6	11	09:00	0	26.4	34.9	8.1	..	..	..	..	..
			2.5	26.2	35.3	8.1	15	0	0	0	2
7	12	09:30	0	26.0	32.7	8.3	..	..	..	..	..
			3	26.0	32.7	8.4	..	..	..	..	..
			5	..	33.2	8.3	6	13	0	0	2
			12	..	33.2	8.3	0	0	0	0	3
8	13	07:30	0	25.2	33.3	8.4	..	..	..	..	..
			7	..	33.2	8.3	1	8	0	0	3
9	14	08:00	0	26.8	32.8	8.1	..	..	..	..	..
			2.5	..	32.7	8.1	..	..	..	..	..
10	15	12:20	0	26.2	33.1	..	..	..	..	..	..
			13	..	33.1	..	0	1	0	0	3
11	29	09:00	0	22.0	31.4	8.0	..	..	..	..	..
			2	..	32.4	..	..	..	..	..	..
			10	..	33.3	7.9	0	8	0	1	3
11	Mar. 17	15:35	0	22.6	..	..	..	..	..	..	..
12	1	08:30	0	22.8	33.2	8.2	..	..	..	..	..
			6	21.0	34.1	8.0	2	4	0	0	2
13	1	10:30	0	22.0	34.4	8.0	..	..	..	..	..
			2.5	21.4	34.2	8.1	..	..	..	..	..
			6	..	34.9	..	1	0	0	0	1 1/2
14	2	08:00	0	22.4	35.0	8.1	..	..	..	..	..
			2	21.8	34.8	8.0	..	..	..	..	..
			14	..	35.1	..	0	5	0	0	2 3/4
15	2	16:40	0	22.2	34.9	8.1	..	..	..	..	..
			4	..	..	..	0	5	0	0	2
16	3	09:30	0	24.6	35.7	8.1	..	..	..	..	..
17	4	08:30	0	29.2	35.9	8.1	..	..	..	..	..
			4	..	33.8	..	0	0	0	0	4
18	4	10:00	0	29.2	32.4	8.1	..	..	..	..	..
			5	..	..	..	0	5/80	1	0	6
	8	07:00	0	28.5	32.9	8.2	..	..	..	..	..
19	4	12:00	0	30.0	31.9	8.3	..	..	..	..	..
			3	29.6	32.3	8.3	..	..	..	..	..
20	5	10:00	4	..	..	..	1	4	..	..	3
21	8	07:30	0	28.4	32.9	8.2	..	..	..	..	..
			5	..	32.0	..	0	14	0	0	2
22	9	08:00	0	28.5	32.8	8.3	..	..	..	..	..
			5	..	33.1	..	1	3	0	0	3
23	9	17:00	0	29.6	32.9	8.3	..	..	..	..	..
			8	..	32.7	..	0	8	0	0	2
24	10	18:00	0	29.5	32.4	8.3	..	..	..	..	..
			7	..	33.7	..	0	4	0	0	2
25	11	12:45	0	29.8	33.1	..	..	..	..	..	..
				..	..	..	0	6	0	0	1
25	12	08:00	9	..	32.2	8.1	0	6	0	0	4
26	12	12:01	0	30.0	32.9	8.4	..	..	..	..	..
			8	..	33.3	8.1	7/4	6/2	0	0	1
27	12	13:30	0	29.6	32.9	8.2	..	..	..	..	..
			3	..	..	..	4	2	0	0	2
28	13	10:45	0	28.2	33.3	8.3	0	0	0	0	3
29	13	17:00	0	29.0	32.0	7.6	..	..	..	..	..
30	14	17:00	0	24.0	33.5	..	Too rough	for diving			..

5/ Single shells, very old.

6/ A few days before this observation, local diver obtained 16 live oysters and reported that recently a "boatload" was taken in one low tide (4-5 hours).

7/ 3 ripe males, 1 ripe female.

8/ Time refers to the beginning of observations at each station.

Pearl-oyster grounds in Panama suitable for commercial exploitation are confined to a narrow coastal zone surrounding the islands. In width, this zone extends from low-water mark to a depth of about 12 fathoms. Rugged cliffs of volcanic origin, pounded by powerful surf, are the most typical habitat of the tidal zone, which in places extends for about 20 feet vertically above mean low water. Because of this great range of tides, large shore areas, sometimes several hundred feet wide, are exposed at low water. Depending on the configuration of rocks, the slope is steep or may be gentle (Figs. 8 and 9). Tropical jungle descends almost the water line, and the extended branches of the trees frequently touch the surface of the sea at high tide. At everal stations, such typical marine forms as barnacles and oysters were growing on the lower sides of the horizontal branches of the trees; while common land snails, Orthalicus princeps decentor (Pilsbry), occupied the uppermost side of the same branch. On Isla de Mina, where the photograph (Fig. 9) was taken, several live snails were collected from the branches of a mangrove tree shown in the center of the picture, while many dead shells of this species found on ground were occupied by hermit crabs. The monotony of rocky shoreline is often interrupted by a glistening expanse of white sandy beaches wedged between the blackness of the rocks (Fig. 10). Some of the beaches are very small, not more than a few hundred feet long, while others extend over a distance of several miles.

A belt of muddy bottom, several miles wide, extends along the north and northeast coast of the Gulf of Panama and on both sides of the Bay of San Miguel. Bottom deposits of this area consist of a material washed out by soil erosion and deposited by fresh-water streams along the coast line. I had an opportunity to visit the mud flats in the Ensenada de Garachiné, in the Bay of San Miguel, where they extend over an area about 12 miles long and 7 miles Wide. A considerable portion of these flats is occupied by narrow and long reefs made of shells of the edible oyster, Ostrea chilensis Philippi. The reefs are bare at low tide and are surrounded with very soft and sticky mud. In general configuration and structure, they resemble the oyster reefs of Ostrea virginica formed on muddy bottoms in Texas and Georgia (Galtsoff, 1931).

Figure 8 --- Volcanic rocks along the northern shore of Coiba Island - low tide.

Figure 9 --- Tidal flats, Isla de Mina. High water level covers the lower (horizontal) branches of the mangrove trees.

Figure 10 --- Typical small sand beach between the volcanic rocks on one of the islands in Gulf of Panama.

Because of great range of tide, the distribution of animals in the tidal zone in relation to the elevation above mean low water presents a very interesting subject for observation. A sequence of changes in the composition of animal communities, beginning with those occupying the uppermost positions and ending with the forms living below low-water mark and never exposed at low tide repeats itself with great regularity. Variations, if any, are of minor nature and occur only when typical rock habitat is modified by special local conditions. Because of such regularity in vertical distribution, it is possible to discuss it without repeating in detail the records of observations made at each station.

The rocks of the uppermost tidal level are well polished by the sea. They are occupied by various species of Littorina and Nerita scabricostata Lam. Hundreds of specimens of this gregarious gastropod are frequently found attached to the vertical surfaces of rocks (Fig. 11). Slightly below this level, one encounters large cones of Siphonaria gigas Sowerby (Fig. 12), and huge barnacles, Tetraclita squamosa panamensis Pilsbry.

Horizontal surfaces of the rocks are pockmarked with numerous pools varying in diameter from a few inches to several feet. The walls of these pools are very smooth. Owing to crystal clearness of the sea water, the pools present an excellent opportunity for a collector, for their bottoms are covered with a multitude of gastropods, crabs, and small fishes which find shelter there during the receding tide. In several instances a brilliantly green carpet of Halicystis sp., growing in great profusion, covered the bottoms of such pools. They probably owe their origin to erosion by the sea water, assisted by mechanical grinding by pebbles and broken shells kept in motion by the surf (Fig. 13).

The vertical crevices of the rocks provided places of refuge to thousands of very agile crabs, which were very difficult to catch; compound ascidiae, medium-sized black sea urchins, Diadema sp., with very sharp spines, and marine snails among which Thais and Purpura predominated. Thais crassa Blairsville was the most common gastropod of this habitat. Next in abundance was Leucozonia cingulata Lam. In places Thais crassa was

Figure 11 --- Nerita scabricostata on rocks near high-water mark. Pearl Islands.

Figure 12 --- Siphonaria gigas on rocks near high water level. Gulf of Panama.

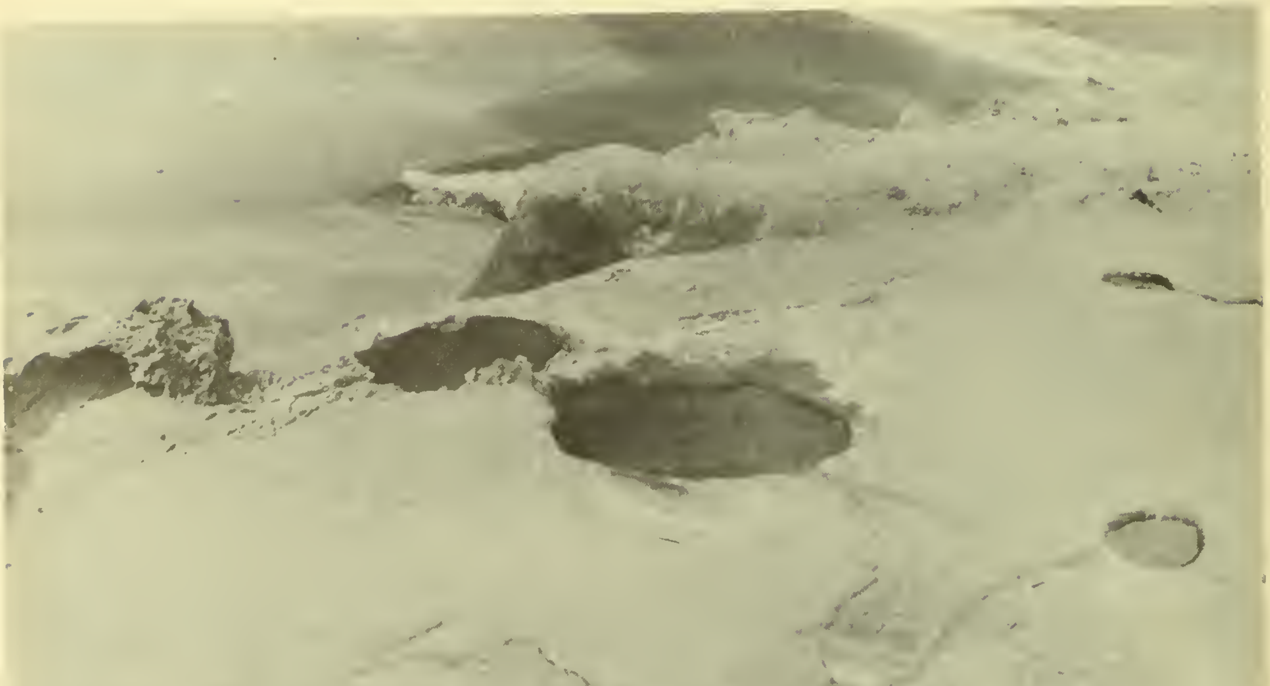

Figure 13 --- Small basins filled with sea water on the top of rocks in the tidal zone give shelter to thousands of small gastropods and crabs. Bottom is frequently covered by a green carpet of Halicystis.

replaced by Purpura patula pansa Gould. It is interesting to note that the size of Purpura found on the Pearl Islands varied from 4 to 5.5 cm., while much larger specimens reaching 7 cm. in length were found along the mainland coast.

The middle portion of the tidal range is occupied by very large number of small oysters, Ostrea cumingiana mexicana Sowerby. The species is distributed from Lower California to Central America. All of the specimens in my collection were small, rarely exceeding 2.5 cm. in length. The interior of the shells is olive green, while the exterior is white. The margins have many small plications by which the species can be easily distinguished from other oysters found in Panamanian waters. The oyster sets in great abundance on rocks. A broad white band from 2 1/2 to 4 feet wide, consisting almost exclusively of shells of this species, is very conspicuous on the dark brown background of tidal cliffs, and is noticeable almost everywhere along the shores of the Pearl Islands (Fig. 14). Since the rocks above and below the setting zone do not appear to be different from those occupied by the oysters, an explanation for a great intensity of setting in a rather narrow band within the tidal range must be looked for in the behavior of the oyster larvae, which for some reason must concentrate at this particular level. At the time of my observations, the gonads of this oyster were ripe, but no larvae were found in the plankton.

Approximately at the level occupied by O. cumingiana mexicana, and below it, one frequently encounters large Chiton stockesii Broderip, usually occupying small holes in the crevices of the rocks, many compound ascidiae, and Pseudochama ectogyra (Conrad). The shells of the latter lamellibranch were so overgrown by small barnacles and other fouling organisms that they were almost undistinguishable. Small crevices, ledges, and depressions in rocks abounded in various gastropods, among which the more numerous were Turbo saxosus Wood, Calliostoma iridium Dall, Leucozonia cingulata Lamark, Crucibulum imbricatum Sowerby, Astraea buschii Philippi, and brilliantly colored Fissurelidae. Less abundant were Phasianella sp., Tegula sp., and various small cones.

Figure 14 --- Young oysters, Ostrea mexicana, on rocks about the middle of the tidal range. Pearl Islands.

The lowermost portion of the tidal zone was usually occupied by larger gastropods, among which the most conspicuous were Fasciolaria princeps Sowerby, Malea ringens (Swainson), Cymatium tigrinum, Tritonalia diomedaeus Dall, Vasum caestus (Broderip), Galeodes patula Broderip, Strombus peruvianus (Swainson), Murex (Phyllonotus) princeps Broderip, and Murex (Phyllonotus) regius Sowerby. The color of the inner surface of the shell of Murex regius varied from faintly pink to red. In certain places (Stations 14, 18, 26, and 27) great numbers of large Galeodes patula (Broderip), Murex (Phyllonotus) nigritus (Philippi), and Melongena patula Broderip were found in broken rocks scattered over the tidal flats. This typical community of large gastropods extended below low-water level (Fig. 15), and was frequently encountered at many other stations.

Algae were almost absent in the tidal zone. With the exception of Halicystis sp. covering the bottoms of small tidal pools, and occasional occurrence of Galaxaura rugosa[9] (Ellis and Solander), Lamoureux, juvenile plants of Padina sp., and small pieces of Lithothamnion sp., the rocks were devoid of algal growth. Only at Isla de Mina (Station 6) and Punta Pajaron (Station 24), the large areas of rocky shores were covered with the brown and slippery carpet of Spyridia aculeata (Schimp) J. Ag. and Galaxaura sp. In both places I found great number of Galeodes patula. Dead shells of this large gastropod were abundant in many places, while live snails were found only on rocks below low water. Within the tidal zone, live specimens of this species were found only at the two stations mentioned above.

Figure 15 --- Rocks along the shores of Isla Santelmo, low tide. White spots on the top of central rocks are the droppings of egrets and pelicans, which abound along the shore. Large gastropods (Galeodes, Fasciolaria) are very common between the rocks.

9/ Identified by Dr. Wm. R. Taylor of the University of Michigan.

The tidal rocks maintained large populations of crabs, most conspicuous among which was the hermit crab, Coenobita compressus (Guerin).[10] It was found in the shells of various gastropods, and was especially abundant between the rocks and in narrow crevices of the Islote Pelado (Station 10).

Of other crabs, Ocypode gaudichaudii H. Milne Edwards and Lucas was very abundant in Ensenada Monita, near the Isla Medidor (Station 26).

Rocky bottom below low water

Rocks below low-water mark were inhabited by the majority of the invertebrates found at the lower level of the tidal zone. There were, however, several groups which were not found in the exposed positions above low-water mark. To those belong the hydroids, corals, gorgoniae, sea stars, pearl and edible oysters (except O. mexicana), and larger hermit crabs.

The algae in the shallow water below low-water mark were as scarce as in the tidal zone. In a few places I collected specimens of Asparogopsis taxiformis (Delile) Collins and Hervey (Station 24, Punta Pajaron), occasional Galaxaura rugosa, and a few Lithotamnion.

Hydroids were frequently encountered growing on shells of oysters and other mollusks. Unfortunately, part of my collection containing hydroids was lost in shipment to Panama and the specimens could not be identified.

The corals were rather common, but never formed reefs or extensive colonies. The specimens frequently brought up by divers belong to the genera Porites and Pocillopora. Occasionally, round columns of Agaricia sp. and flat and leaf-like specimens of Sideastraea sp. were observed. In general, the growth of corals was by no means luxuriant, although they were encountered at almost every station. With the exception of muddy bottoms of the Bay of San Miguel, the gorgonians were abundant almost at every station. More frequently found were the large colonies of Gorgonia stenobrochis Valenciennes (Fig. 16), Leptogorgia laxa Hickson, and Leptogorgia alba (Duchassaing et Michelotti). Less frequent, but still rather common, were Gorgonia media (Vernie), Gorgonia pulchra (Verrill), and Eugorgia damana Verrill.[11]

Near Isleto Pelado (Station 10), at a depth of about 7 fathoms, the diver encountered a very large number of huge colonies of an Antipatharian of brilliant orange color. The specimens brought up on deck measured from 5 to 6 feet across and 6 to 7 feet in height. Many live Pteria peruviana (Reeve) were attached to its branches (Fig. 17), among which crawled small Ophiuridae. According to the description of the diver, the bottom of the sea looked like a fantastic forest of gayly decorated Christmas trees. This Antipatharian was not found at any other station. According to a personal communication from F. M. Bayer, it is apparently a new species which will be described by him at the earliest opportunity.

The sea stars commonly found among the rocks of the shallow littoral zone belonged to the following species, kindly identified by Austin Clark, Curator of Echinoderms in the U. S. National Museum: Pharia pyramidata Gray, Leiaster teres Verrill, Nidorellia armata Gray, and Phataria unifascialis Gray. Less frequent were Mitrodia bradleyi Verrill, Pentaceraster cumingi (Gray), and Acanthaster ellisei Gray. The latter species is represented in my collection by a large specimen, whereas formerly only very small individuals of this sea star were known. At Isla Señora y Isla Señorita (Station 12) one specimen of Ophidiaster ludwigi was found which, according to Austin Clark, is the second known finding of this species (U. S. National Museum, Report, 1948, p. 25).

Many large lamellibranchs were found attached to the rocks below low-water mark. The most conspicuous among them were the heavy shells of Spondylus pictorum Schreiber (Fig. 18), Ostrea megodon Hanley, Pinna Lanceolata Sowerby, Pinctada mazatlanica Hanley, and many others.

10/ Identified by F. A. Chace, Jr., U. S. National Museum.
11/ Identified by Dr. Frederick M. Bayer of the U. S. National Museum.

Figure 16 —— Gorgonia stenobrochis, very common gorgonian in shallow water in the Gulf of Panama.

Figure 17 --- Pteria peruviana attached to the branches of an Antipatharian coral, probably a new species. Isleto Pelado, Station 10, 7 fathoms.

Figure 18 --- Spondylus pictorum. Single valve of this mollusk weighs about 2 1/2 lbs.

Spondylus pictorum was the most conspicuous mollusk in the shallow water. The shells of this lamellibranch are so firmly cemented to rocks that it is very difficult to obtain both valves of an adult specimen. The majority of shells brought by the diver were about 20 cm. long, one valve weighing as much as 4 pounds (1.8 kilos). The thickness of shell varied from 3 to 5.5 cm. The shells of young Spondylus pictorum have long curved spines. In old specimens, they are usually lost; but in the specimens measuring about 12 cm., some of the spines are still noticeable. It is difficult to understand why Spondylus secretes such a heavy shell. In Panama, this mollusk lives attached to rocks beyond low water, where it is not affected by the pounding of the surf. The outside surface of the shell is heavily overgrown by many fouling organisms, among which the most conspicuous are the shells of Chama buddiana C. B. Adams, and the calcareous tubes of annelids. Many small hydroids, sea anemones, sponges, and other invertebrates are attached to the shell. The valves are heavily infested by a boring sponge, Cliona sp., which penetrates to about 1/3 of the thickness of the shell, and by a boring mollusk Lithophaga aristata Dillwyn. The high intensity of infestation by this species becomes apparent only after the removal of the outside layer of shell (Fig. 19). One specimen, with surface area of shell of 75 square inches, was infested by 383 Lithophagae; or, on the average, each square inch of shell surface contained 5 holes made by this borer. The majority of holes were small, about 2-3 mm. in diameter, but there were 23 large oblong cavities about 4 cm. long which penetrated almost the entire thickness of the shell. Only a thin layer of apparently rapidly laid mother-of-pearl separated these cavities from the soft parts of the mollusk. It appears that rapid deposition of shell substance is the only means at the disposal of Spondylus in protecting itself against the borers. Thus, the ability to produce very thick shell and to continue the deposition of shell substance as the latter is penetrated by borers is probably a method of defense which has great survival value to the species.

Among other lamellibranchs, mention should be made of the rock oyster, Ostrea megodon Hanley, which is generally distributed and is used for food. The oyster averaged 15-16 cm. in length. Its meat is rather tough but palatable.

Figure 19 --- Spondylus pictorum with outer layer of shell removed to show infestation by boring sponge (small holes), and boring mollusk, Lithophaga aristata (large holes).

Fan shells, Pinna lanceolata Sowerby, which frequently produce black pearls are abundant at many stations; some of the largest specimens were more than 30 cm. long.

Many heavy-shelled clams were found on bottom between the rocks. Among them, the most common are the orange-colored Macrocalista aurantiaca (Sowerby), various species of Tivela, and Antigona rigida Dillwyn. None of these clams is used by the local population for food.

Edible oysters, Ostrea iridescens Gray (Fig. 20) and Ostrea columbiensis Hanley were found attached to rocks a few inches below low-water mark. They have very thick shells, purplish inside; and are growing in groups, preferably in the vicinity of small creeks which empty into the sea. The meat is palatable, but was too salty, and lacked flavor. There was but little deposition of glycogen, and the gonads were ripe. The shells of O. iridescens were heavily infested by Lithophagae.

Among the large gastropods, the most abundant was the already mentioned conch, Fasciolaria princeps. Empty shells of this snail were frequently occupied by hermit crab, Aniculus elegans Stimpson. Next in abundance were Galeodes patula, Strombus peruvianus, Vasum caestus, Strombus gracilior Gray, Malea ringens, Cymatium tigrinum; and various species of Murex (M. nigritus, regius, princeps), which are frequently found in large numbers over a relatively small area of bottom. Many empty shells of M. nigritus were found along the mainland coast in the Gulf of Chiriqui (Station 26). Occasionally, odd-looking live specimens of Fusinus dupetitthouarsi (Kiener) were picked up among the rocks.

Numerous Porcellanid crabs were seen in this habitat. My collection includes the following species, identified by F. A. Chace, Jr.: Petrolisthes armatus (Gibber), Petrolisthes edwardsii (Saussure), and Petrolisthes sp. Besides the already-mentioned hermit crab, Aniculus elegans Stimpson, the collection contains Petrochirus californiensis Bouvier, Eriphia squamata Stimpson, Trapezia cymodoce ferruginea Latreille, and Ocypode gaudichaudii H. Milne Edwards and Lucas.

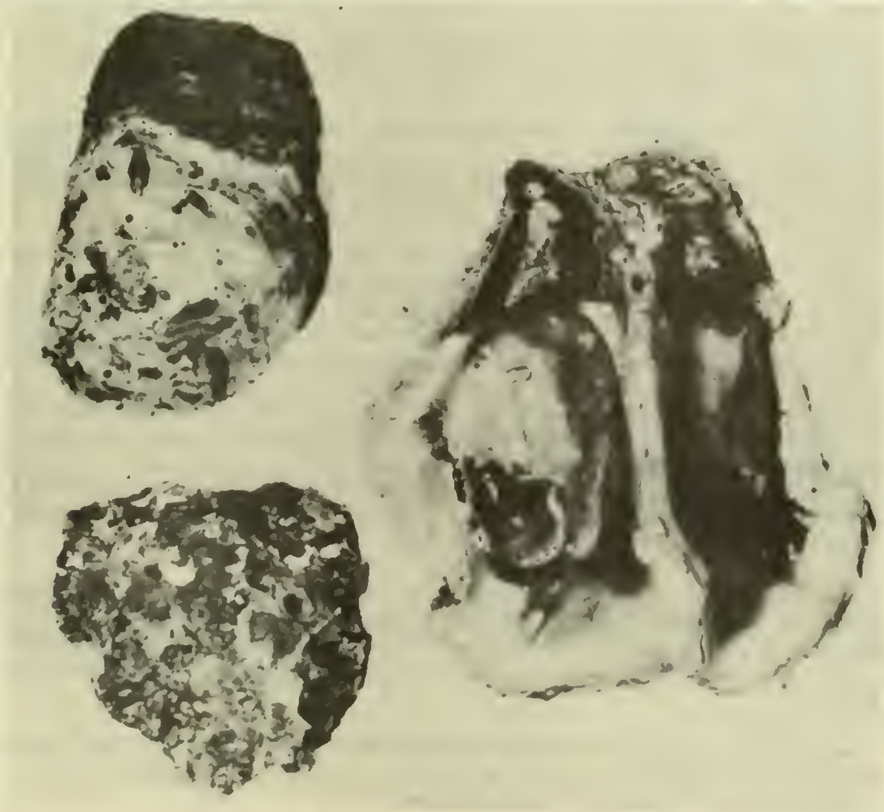

Figure 20 --- Ostrea iridescens at low-water level in tidal zone around Pearl Islands. Used for food. Notice infestation of shell by Lithophaga (left).

In summarizing the observations made on rocky shores and bottoms, one cannot avoid the impression that this particular habitat along the Pacific coast of Panama presents most favorable conditions for the flourishing of molluscan fauns. Both the lamellibranchs and gastropods are represented by a large number of individuals belonging to many species. The specimens are large and their shells heavy. What particular conditions are responsible for the thriving of mollusks in these waters is not known, but the fact has been noted already by A. Agassiz (Zetek, 1918) who attributed it to the hydrographical peculiarities of the Gulf of Panama and adjacent waters.

Sandy flats

Only a few observations were made on sandy bottoms, since pearl oysters are never found in such habitat. No diving was done on sand flats, and the material was collected by hand picking and dredging with a small rectangular dredge at a depth not exceeding 4-5 fathoms. The sand was usually of coarse variety, mixed with broken shells and occasionally with mud.

Several forms were found only in this particular environment. The most conspicuous of them is a very large sand dollar, Encope micropora L. Agassiz, about 13 cm. in diameter. The characteristic feature of E. micropora is that the maximum height of its body is anterior, between the abactinal system and the anterior edge (Clark, 1946), whereas in the closely related species, E. californica, it is posterior. Other species of sand dollars previously reported from Pearl Islands (Clark, 1946), namely Encope perspectiva and E. wetmorei, were not present in my collection.

Another sea urchin which was frequently found alive, and the shells of which are often cast by the waves on sandy beaches, is Toxopneustes roseus (A. Agassiz). Dr. Austin Clark, who identified the specimens, remarks that the unusually large pedicellariae of this species are powerful stinging organs, so the sea urchin must be handled with caution. I have not heard any complaints against the species from Panamanian fishermen, but according to a personal communication from Clark, the related species, T. pileolus of the mid-Pacific, is shunned by the natives, who will not touch it under any circumstances. It is reported that occasionally it causes death among Japanese fishermen.

A typical inhabitant of sand flats is a small gastropod, Cerithium sp., probably C. maculosum Kiener, about 30-35 mm. long. In certain places, as at Isla Santelmo (Station 15) this species was so abundant that a 10 minute drag yielded a dredge full of live snails.

Sand mixed with mud provides the most desirable habitat for various clams, among which the species of Anadara and Arca occupy prominent places. Live clams of these genera were frequently dredged or brought up by the divers, while dead shells were very abundant on flats above low-water mark. The largest of the clams was Anadara grandis Broderip and Sowerby. Specimens 12 cm. long, 13 cm. wide, and weighing over 3 pounds (both valves) are rather common on beaches, especially in the vicinity of villages, for this clam is extensively used for food. It is interesting to note that during pre-Columbian times, the Indians cut down heavy shells of this clam to a sharp edge and employed them as scrapers. Such crudely made tools found among various artifacts in the material excavated at the Sitio Conté, in the province of Coclé were described and reproduced in the "Archaeological Studies of Central Panama" (Lothrop, 1937, p. 95-96) conducted by the Peabody Museum of Harvard University.

Great numbers of A. grandis shells on beaches should not be regarded as an index of their relative abundance for the species is actively gathered by local residents, who discard empty shells and scatter them around the dwellings. The same remarks apply to the shells of the large snails, Malea ringens and Galeodes patula, which species are extensively used for food.

Besides A. grandis, the clams are represented by Arca pacifica Sowerby, which was found virtually at every station, and by various species of Glycemeris, among which Glycemeris multicostata (Sowerby) predominates.

Heavy shells of Antigona multicostata (Sowerby) as well as the orange-colored shells of Macrocallista aurantiaca (Sowerby) are very common on beaches. Both species live below low-water mark on slightly muddy bottoms. No live specimens of these clams are found above low-water level.

Among other clams, the beautifully colored pink shells of Sanguinolaria tellinoides A. Adams are abundant, especially on the beach near Punta Pajaron in the Gulf of Chiriqui (Station 24). Scallop shells were seen at almost every beach; they are represented by the following species: Pecten nodosus subnodosus Sowerby and Pecten circularis Sowerby. No live scallops were caught in the hand dredges. These mollusks, so highly esteemed for food in North America, are apparently not eaten by the Panamanians. Cockles, Cardium consors Broderip and Sowerby, and other species not yet identified were frequently encountered. Among other lamellibranchs, mention should be made of Cardita laticostata Sowerby, Codakia sp., Chione crenifera (Sowerby), Ch. undatella (Sowerby), Ch. kelletti (Hinds), Semele sp., various species of Mactra and Pitar lupanaria lupanaria (Lesson). The shell of the latter mollusk has long and very fragile spines, which probably restrict its movements greatly. The mollusk was found on extensive sand flats near Punta Pajaron (Station 24).

Most common gastropods on sandy flats are Terebra robusta Hinds and Turritella sp. (probably T. tigrina Kiener).

Among the many cone shells and other gastropods present on the beaches, the following species were recorded: Conus purpurascens purpurascens Broderip, C. archon Broderip, C. fergusoni Sowerby, C. dalli Sterns, C. gladiator Broderip, Strombus gracilior Gray (juvenile forms), young Malea ringens (Swainson), various Turridae, Trona cervinetta (Kiener), Zonaria sp., Zonaria arabicula (Lamark), Zonaria annettae (Dall), Cassis coarctatus Gray, Scaphander interruptus Dall, Acmaea sp., Aletes sp., Crepedula sp., and many others which could not be identified without more detailed study.

On Coiba Island (Station 19), some of the sandy beaches were covered with a thin layer of very fine mud inhabited by millions of small Olivella, somewhat resembling Olivella tergina Duclos, but differing from it by its rather dark greenish color and simpler pattern. The length of the mollusk varied from 5 to 10 mm. Larger forms, Oliva splendidula Sowerby and O. splendidula fuscata, were found in the same environment, but were less abundant. The shells of Olivella are used by the prisoners of the penal colony located on the Island for making attractive ladies' bags (Fig. 21), curtains, and other objects. Due to considerable variation in coloration and markings, the shells can be arranged in interesting patterns. I estimate that more than 3500 small Olivella were used to make the bag shown in Fig. 21. This occupation provides a small additional income to the prisoners, who sell their goods to the few visitors to the island. Shells of a fresh-water mollusk, Neritina latissima Broderip, are frequently found on beaches, especially in the vicinity of fresh-water streams.

In exploring the sandy beaches of Coiba Island, one frequently encounters the poisonous marine snake, Pelamydrus platurus. The snake is about 18 inches long, has a white belly and black back, with vertical marking on the tail. When swimming in water, it can be easily mistaken for an eel. Incidents of attacks by Pelamydrus platurus are rare. Although the sea snakes are very poisonous and the potency of their venom exceeds that of cobra, they are not aggressive, and when disturbed prefer to swim away. This behavior is quite opposite to that of the fer-de-lance (Bothrops atrox) and the bushmaster (Lachesis muta), which infest the forests and pastures on Coiba Island, and present a serious problem to the persons clearing tropical jungles or working along the shores overgrown by vegetation. Incidents of snake bites and ensuing death caused by the two most dangerous reptiles are frequent. As a matter of fact, during my brief visit to the island (Fig. 22), two large zebu bulls imported by the Government from India were killed by bushmasters. Records of the local hospital indicate that next to malaria which prevails on the island (Simmons et al, 1939), the most numerous cases of hospitalization are those of snake bites.12/

12/ During my stay on Coiba Island, at the request of the local authorities, I collected water from two warm springs on the island and forwarded the samples for chemical analysis to the Geological Survey. The report of the Geological Survey is given at the end of the paper.

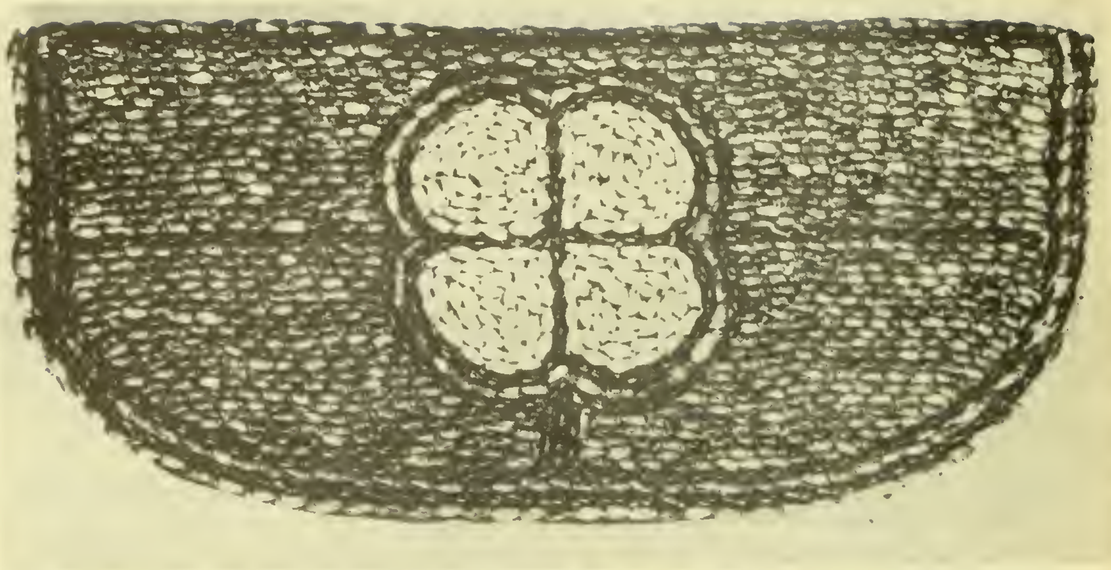

Figure 21 --- Ladies' bag made of shells of Olivella. Coiba Island, Panama.

Figure 22 --- Coiba Island. View from the administration building of the Penal Colony.

From ecological observations made along the coastal line of the Pearl Islands, on Coiba, and in the eastern part of the Gulf of Chiriqui, I conclude that the marine life of the entire area visited during the expedition was in flourishing condition. There was not a place where the luxuriant growth of littoral fauna appeared inhibited, and likewise there was no indication of any unusual mortality among any of the sedentary organisms. The area presents a most favorable environment for the propagation and growth of mollusks. This was evident from the large number of species inhabiting the coastal waters, and by the size and abundance of many gastropods and lamellibranchs. There was no indication in any of the places visited that animal communities were affected by red tide or by toxic material which may have been dumped into the sea.

Dead shells of pearl oysters, Pinctada mazatlanica, and of the clams, Macrocallista aurantiaca and Antigona multicostata, were found in several places below low-water mark (Stations 4, 13, 18, and 21). With the possible exception of Station 18 at the northern end of Coiba Island, where large numbers of old pearl oyster shells were taken by the diver, there was no evidence of excessive mortality of these mollusks. The appearance of clam and pearl-oyster shells overgrown on both sides by Bryozoa and other fouling organisms indicated that death had occurred a long time ago. Likewise, I saw no indications of a devastating effect of any predators and commensals. Many shells of various lamellibranchs and gastropods living within the lower level of tidal range and below low-water mark had holes drilled in them by predatory snails, boring clams (Lithophaga), and boring sponge. The number of dead shells was not excessive, however, and no gastropods were observed in the act of drilling. It is therefore impossible to state which of them was the most destructive.

The predatory habits of such common forms as Cassis, Tritonalia, and Eupleura, are well-known. It is reasonable to expect that these very active predators may cause a great deal of destruction among other mollusks. Their prey consists mostly of other gastropods (Zonaria, Oliva, Leucozonia, small Conus, and others), small clams (Glycemeris, Sanguinolaria), and scallops (Pecten circularis). A number of Tellina and Sanguinolaria shells were found with large holes bored, probably by sand collars (Polinices and Natica). The family Naticidae is represented in Panama by a score of species, but none of these snails was found in the act of attacking clams.

Pearl oysters, Ostrea megodon, Pteria peruviana, and Pinna lanceolata, are not attacked by drills or borers. Likewise, mollusks living within the upper third of the tidal range (Littorina, Siphonaria, Nerita, Purpura, Thais) are not molested by these carnivorous snails, which apparently do not climb far above the low-water level.

One of the striking features of the ecology of coastal water along the coast of Panama is the scarcity of calcareous algae and corals. Both groups are represented in local fauna and flora, but they never attain the luxuriant growth of the typical and coral-reef community. So far as temperature and salinity of water are concerned, conditions off the Panama coast are comparable to those of typical coral-reef lagoons such as one encounters in the Marshall Islands and other coral-reef regions of the Pacific. The question is, why, under these apparently suitable conditions, the growth of reef-forming organisms is restricted. The most conspicuous difference in the ecology of the coastal waters of Panama and of the typical coral-reef regions of the Pacific is the range of tide. As a rule, the tidal range in typical coral-reef regions is small, averaging from 2 to 3 feet, whereas the tidal range along the Pacific coast of Panama is almost ten times greater. I am inclined to think that this is probably the main condition which inhibits the growth of reef-building organisms, and at the same time encourages the growth and propagation of mollusks. We need, however, more information on the physiology and life histories of marine invertebrates of Panama in order to interpret correctly our ecological observations.

OBSERVATIONS ON PEARL OYSTERS

The abundance of pearl oysters in Panamanian waters was studied by using the following method. Grounds to be examined were selected on the basis of information received from experienced pearl divers, and by consulting with persons familiar with the pearl fishery of the Republic. Señor Celedonio Pinzon, the diver hired by the Ministry of Agriculture to work with me during the expedition, proved to be a man of high intelligence and industry.

He has had thirty years of experience as a pearl diver, was sympathetic with the purposes of the expedition, and very rapidly grasped the significance of quantitative data needed for making a census of the pearl-oyster population. The time he spent at each station, slowly walking under water and collecting oysters, was carefully recorded. The diver was instructed to take all pearl oysters, large, small, and dead ones, regardless of their commercial value. Furthermore, he was given an empty jar to fill with bottom water and was asked to bring any other animals and plants he could find. The diving stations were located in the areas which formerly abounded in pearl oysters. All diving was done during low tide. The exact area covered by the diver at each station could not be ascertained, because the rate of the diver's progress on the bottom depends on many circumstances — such as depth of the water, its temperature and transparency, character of the bottom, and currents. In many places strong currents interfered with diving.

The diver worked from his own small boat, equipped with hand pump, and propelled by oars. The crew consisted of his assistant, and four sailors. The diving boat operated within a radius of one or two miles from my ship, which at this time was making observations along the shore. Material brought by the diver was deposited in pails and baskets which were brought aboard for examination and preservation.

In the course of the investigation, the CHUCUÑA made 30 stations. The sea bottom was explored by the diver at 21 different stations. At 9 stations diving was impossible, and observations consisted of taking plankton samples and dredging. Live pearl oysters were found at 11 stations, while at 10 other stations only dead shells were encountered. The greatest number of live pearl oysters taken at one station was 15 (Table 4). This number was gathered during two hours of diving at 2.5 fathoms (Station 6 at Isla de Mina, Pearl Islands). The largest number of dead shells during 6 hours of diving was found at Station 18 at Coiba Island, at the depth of 5 fathoms.

The results of all diving efforts are summarized in Table 5, which clearly shows that the pearl-oyster population in Panamanian waters has been reduced to such a low level that it has become almost extinct.

Table 5 --- Total number of live and dead oysters collected in Gulf of Panama and Gulf of Chiriqui.

	Live	Dead	Hours of Diving	Live oysters per hour of diving
Adults	36	180		
Young	3	1		
Total	39	181	72 3/4	0.5

The average yield computed from the records of the survey was only one live oyster per two hours of diving. If one considers the total number of shells taken, the yield is three oysters per each hour of diving. Particularly discouraging was the scarcity of young oysters (Fig. 23), less than 10 cm. long, of which only four were collected. It is obvious that, being less conspicuous than the adults, they might have been overlooked by the diver. It is, however, improbable that a person with many years of experience and familiar with the underwater conditions of Panama pearl grounds could have overlooked many small oysters, especially as he was specifically instructed to search for them. The small number of young indicates a very slow rate of propagation of the depleted oyster population. An inference can be made that, under present conditions, many years would be required to increase the population of pearl oysters sufficiently to support a commercial fishery.

Size and weight of shells

The shells of Pinctada mazatlanica used in trade should be not less than 10 cm. long, and of sufficient thickness to permit the cutting and polishing of its nacreous layer. Old shells which remain in the sea water or on the beach for several weeks after the death of the mollusk lose their lustre and are useless for the trade. Oysters of less than 10 cm. in length may be used by the industry if the shells are sufficiently thick.

Since the shells are sold by weight, it is of interest to determine their length-weight relationship. For the reasons stated above, only shells of live oysters, not damaged by boring organisms, could be used for such a study. These requirements reduced the material available for weighing to 23 specimens. The frequencies of various length and weight classes are shown in Table 6. Oysters with thick and heavy shells weighing from 400 to 500 grams were more numerous than those of any other class. This indicates that the present population of pearl oysters consists primarily of individuals several years old. Small oysters less than 4 cm. in length were absent.

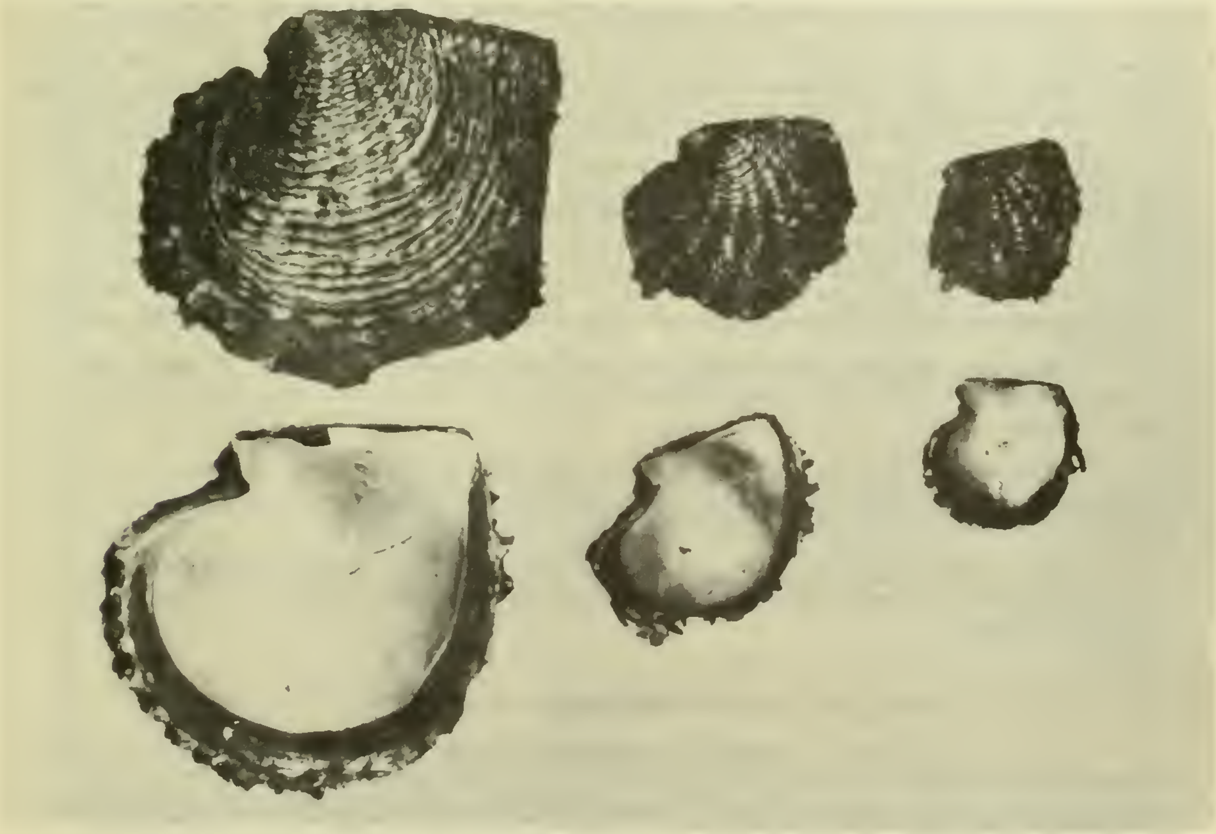

Figure 23 --- Three young pearl oysters, Pinctada mazatlanica. Pearl Islands, Panama.

Table 6 --- Frequency distribution of length and weight of pearl oysters.

Length cms.	Number	Weight grams	Number
4.0-6.0	3	1.0-100	4
6.1-8.0	1	101-200	4
8.1-10.0	1	201-300	4
10.1-12.0	6	301-400	2
12.1-14.0	6	401-500	8
14.1-16.0	6	501-600	
		601-700	1

The relationship between the weight of both valves and the maximum length of the oyster, measured at right angle to the hinge, is shown in Fig. 24. The curve is of the type which expresses similar relationships in other organisms, and is almost identical with the length-weight curve described for the Hawaiian pearl oyster, Pinctada galtsoffi Bartsch (Galtsoff, 1933).

No information is available regarding the rate of growth of the Panama oyster. Pearl fishermen of the Pearl Islands believe that small oysters about 5-6 cm. long are a few weeks old, and that in about 6 months their size increases up to 8-10 cm. These young oysters may weigh about 200 grams. This opinion is based on observations of those fishermen who visited the grounds at intervals of several weeks or months and noticed the size of young oysters which were too small to be used in commerce. How accurate this information is cannot be ascertained without adequate study. Reporting on his observations on the rate of growth of the black-lip pearl oyster (Pinctada margaritifera) of Australia, Nicholls (1930) stated that from October to July of the same year the increase in the diameter of shells of young oysters was about 20 mm. Nine months after the beginning of the experiment, the size of the oyster varied from 33 to 73 mm. It is quite possible that the Panamanian fishermen have misjudged the rate of growth of the Panama pearl oyster, and that it grows at approximately the same rate as reported by Nicholls for the Australian species.

From the inquiries made among the pearl-shell dealers in Panama, I infer that the majority of oysters exported from Panama were from 12 to 14 cm. long, each weighing about 1 pound.

Pearl-shell dealers who outfit their own crews consider that, to make the enterprise profitable, a diving boat must average from 200 to 250 pounds of shells a day. A satisfactory catch of a naked diver is from 15 to 20 pounds.

The small number of pearl oysters obtained during the present survey by an experienced diver is convincing evidence of an almost complete exhaustion of pearl-oyster resources of Panama.

Dead shells

As has been shown in Table 4, the number of dead oysters collected by the diver far exceeded the number of live ones. Among the 181 dead oysters, only five were found with both valves still connected by a hinge and with the inside surface of valves clear of any fouling organisms. It was obvious that these five were oysters which had died only recently. Both sides of the shells of other oysters were covered with a dense growth of

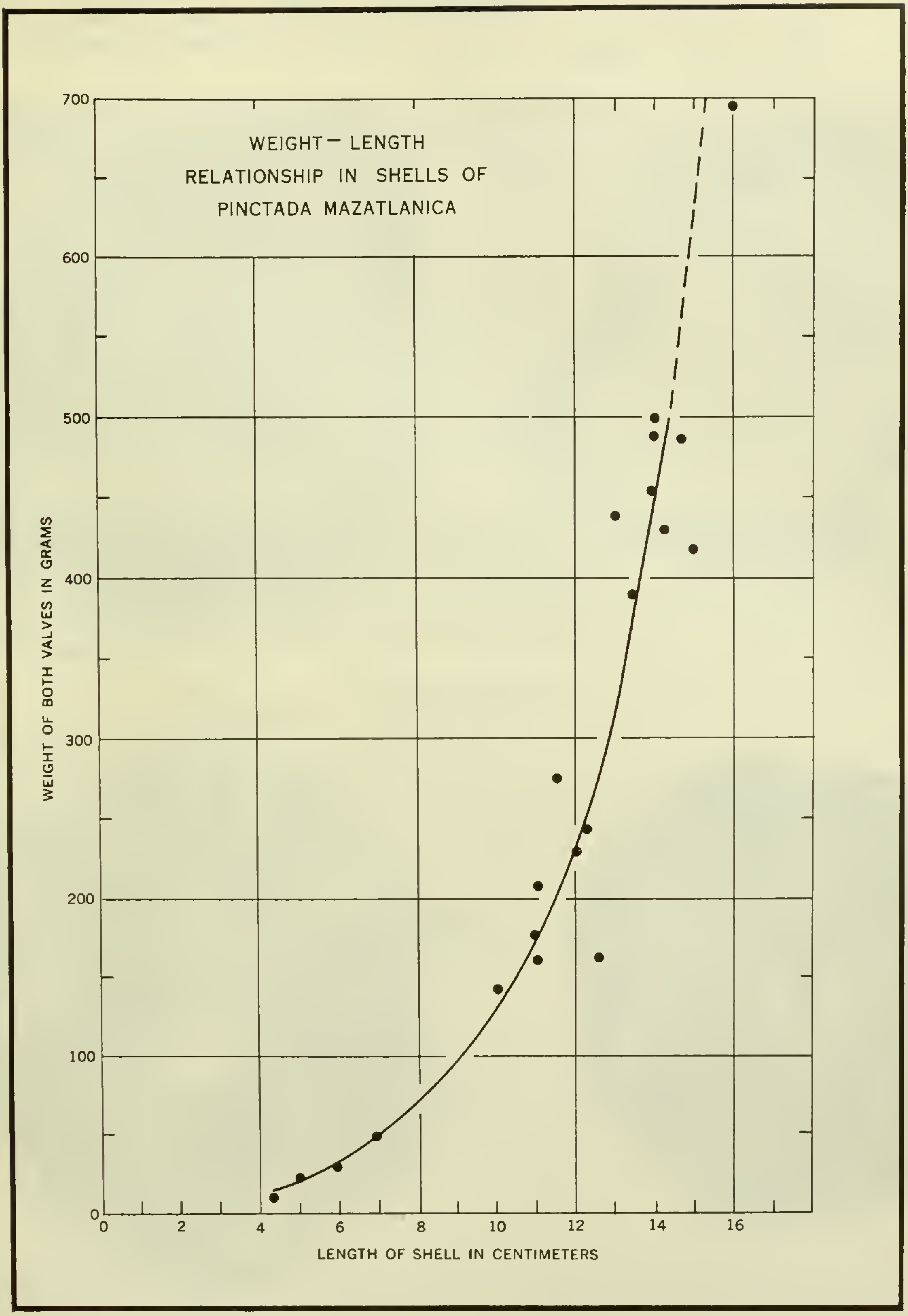

Figure 24 --- Length-weight relationship in the shells of pearl oysters from Panama, *Pinctada mazatlanica*.

Bryozoa, barnacles, calcareous tubes of Vermicularia and Aletes and other fouling organisms (Fig. 25). Many of the shells were so eroded and fragile that they easily crumbled in handling. Judging by their condition, the shells were for several years exposed to the action of sea water after the death of the oyster.

The largest number of dead shells (80) was found at Station 18, at the northern tip of Coiba Island. Locally the ground is known as Coiba Channel. It was considered the best pearling ground, which produced good shells and pearls. There were no small oysters among the dead shells found at this station; all the specimens brought by the diver were from 10 to 12 cm. long and had thick valves.

In the absence of information on the rate of growth of the organisms which foul the shells on the bottom of the sea, it is impossible to arrive at any accurate estimate of the time of death of these oysters. Judging by the degree of erosion of shell substance, I believe that they had been lying on bottom not less than five or six years. There was no evidence that all the oysters died at the same time, for various stages of fouling and decay of shell substance were found from undamaged shells to those which were almost completely destroyed. (Figs. 25 and 26).

The starfish, which is such a destructive enemy of edible oysters in North Atlantic waters, is very rarely seen on pearl-oyster grounds in Panama, and is not considered by local fishermen as an enemy of the pearl oyster.

Pinctada mazatlanica, like Pinctada galtsoffi of the Hawaiian Islands, does not grow in large clusters, and neither species forms continuous beds or reefs typical of the edible varieties of oysters. By its strong byssus, the pearl oyster is attached to rocks and corals. Being scattered over a large area of sea bottom, the chances of attack by drills and other predators are lessened in comparison with other sedentary mollusks which live in close proximity to each other, or form extensive reefs. Divers whom I interrogated on this subject informed me that they hever have been any mollusk or sea star feeding on

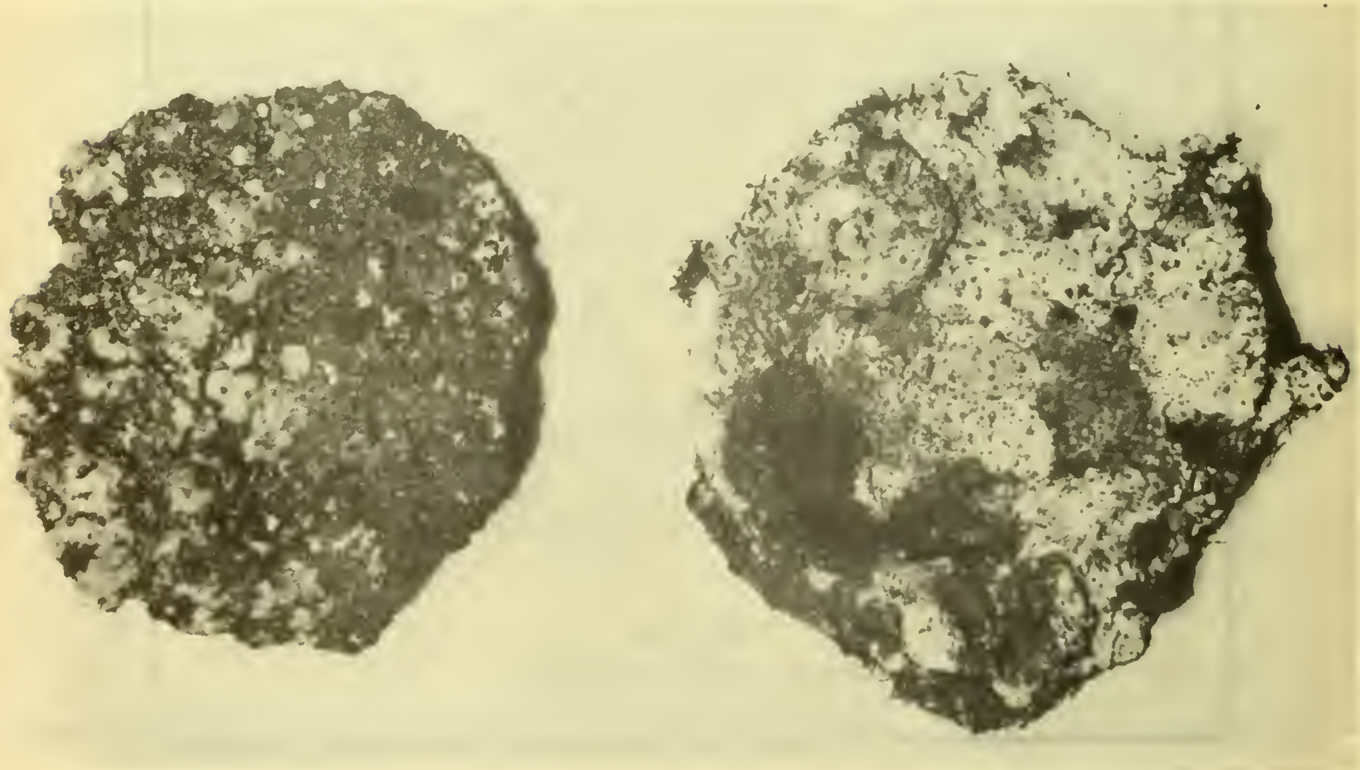

Figure 25 --- Dead shells of Pinctada mazatlanica. Eroded condition of shell substance and heavy growth of Bryozoa, Aletes (upper left on right shell) and other forms, indicate that these shells remained in the sea for several years.

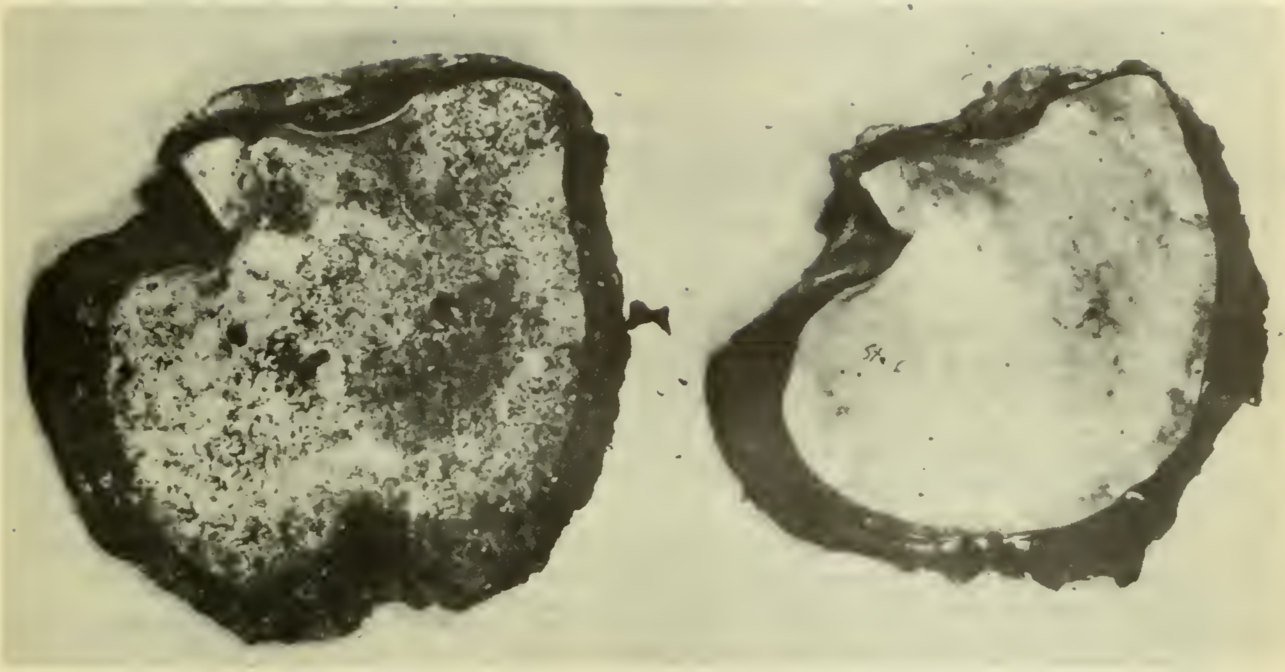

Figure 26 --- Dead shells of Pinctada mazatlanica. Inner sides are moderately overgrown by fouling organisms and shell substance not eroded.

pearl oysters. From my personal observations and from the information given by the fishermen, I conclude that predators are not a serious factor in the lives of pearl oysters in Panama, and that the depletion of the oyster population cannot be attributed to depredation by these enemies.

The relatively large number of dead oysters found in Coiba Channel probably represents the accumulation of shells during a period of years. These grounds were known to be productive, and in past years attracted many fishermen. Dead shells probably failed to attract attention when live oysters were abundant, but when they declined in abundance, each dead shell became conspicuous.

There is, of course, a possibility that a disease reduced the population of oysters to its present state. In order to explore the merits of this assumption, I have made a microscopic examination of oyster tissue, with special attention to the presence of parasites and other pathological evidence. Because of the scarcity of living oysters, this examination was not as extensive as I should like to have it.

Microscopic examination of tissues of pearl oyster

Every live oyster brought in by the diver was dissected, and its tissues examined within 24 hours after its removal from the sea. Owing to crowded conditions and lack of adequate laboratory facilities aboard the ship, the examination of live tissues was rather brief. It was limited to the inspection of principal organs, and examination of blood smears and preparations of small pieces of excised tissues.

On windy days, the laboratory work was impossible, and had to be postponed until more favorable conditions prevailed. Altogether, 25 oysters were dissected and examined in the field. Various tissues of eight of these oysters were preserved in Bouin-3 solution, and processed later in the laboratory at Woods Hole. The processing, including paraffin imbedding, sectioning, and staining was skillfully performed by Eugenia Galtsoff, former associate in zoology in George Washington University, whose assistance and cooperation are here gratefully acknowledged.

The purpose of the microscopic examination was twofold: a) to determine the existence of any identifiable pathological condition in the tissues, and b) to find out whether the oysters were infested by parasites. Particular attention was paid to the presence of spores of Nematopsis, a common gregarine parasite of the edible oysters of Middle Atlantic and South Atlantic waters of the United States; to the infestation of gonads by Bucephalus, a trematode worm which destroys the fertility of edible oysters; and to the occurrence of any other parasitic or commensal organisms which may be detrimental to pearl oyster. Examinations of fresh material were made by tearing out small pieces of organs, pressing them under a coverslip, and inspecting them at magnifications of x 250 and x 625. The use of neutral red, methylene blue, and other vital dyes was very helpful in producing differential staining. Imbedded and sectioned material was stained with haematoxylin and eosin. The results were negative. All the oysters examined appeared to be in every respect normal and devoid of disease. Nematopsis and Bucephalus were absent; and no other suspicious organisms were found in the tissues, blood, shell liquor, or attached to the inner side of valves. Mud blisters caused by tube forming annelids were found rarely.

The shells of live oysters were not infested by the boring sponge, which, however, was frequently found in old dead shells. A few specimens were found bored by Lithophaga, but the infestation was mild, and the holes did not penetrate the entire thickness of valves. The only commensal organism found in all pearl oysters was the shrimp Pontonia pinnae Lockington, which apparently has no adverse effect on its host. This shrimp occurs in both Pinctada mazatlanica and Pinna lanceolata, always confined to the cloaca. Each of the oysters I examined harbored two Pontoniae. The shrimp may be troublesome, for it painfully pinches the fingers of the person opening the oyster. Local fishermen believe Pontonia is the male of the oyster, and in some mysterious way is concerned with fertilization of female pearl oysters.

From the results of microscopic examination, I conclude that all live oysters I examined were in healthy condition and had no recognizable symptoms of any disease, malnutrition, or poisoning. They were free of parasites.

Sex ratio and ripeness of the gonads

Of the 27 live adult oysters the sex of which was examined in the field, 14 were females (4 of them spawned out), 10 were males, and the sex of the remaining three was not recognizable because of the indifferent stage of their gonads. At Station 6 (Isla de Mina) and Station 26 (Canal de Entro, Bahia Honda), attempts were made to fertilize the eggs. Small pieces of gonads of ripe females were teased in a finger fowl filled with sea water, and a small quantity of sperm suspension was added. Finger bowls were left on the table on deck, protected against direct sunlight. The temperature of the water in the bowls rose to 32.5° C. Samples of water with eggs were pipetted and examined under the microscope every 30 minutes for 6 hours. There was no fertilization of eggs. The eggs were left overnight and examined again. None showed a fertilization membrane, and there was no cleavage. At the end of the observation, the pH of the water in the bowls was 7.8. Failure of the fertilization test was a great disappointment, for the eggs appeared to be normal and in excellent condition. The sperm, however, remained immobile. One must remember, however, that the conditions under which the tests were made were unfavorable. The water in the bowls was too warm as compared with the temperature of the sea (26.2° C. at Station 6, and 29.5° C. at Station 26), and was continually agitated by the movement of the ship. It is impossible to state, however, whether the failure of fertilization was due to these conditions, or to some deficiency in sperm, which remained immobile in spite of the addition of fresh sea water. In the edible oyster, the motility of spermatozoa can be initiated easily by adding fresh sea water to the suspension of sperm.

Microscopic examination of preserved material showed that ovaries and testes of the pearl oysters were ripe. Some of the oysters had already spawned, and many of their ovarian tubules were empty. The gonad of one oyster was found to be hermaphroditic (Fig. 27). As one can see from the photograph, ripe eggs and ripe sperm were present. The female tubules were obviously in the after-spawning stage which suggested that sex reversal took place immediately after the discharge of eggs. The picture greatly resembles that of the gonad of hermaphroditic Ostrea lurida as described by Coe (1932).

The finding of one hermaphroditic oyster out of only eight specimens examined histologically suggests the possibility that in Pinctada mazatlanica the change from female to male phase takes place immediately following the shedding of eggs. It is obvious that more detailed studies are needed to throw more light on this interesting point in the biology of pearl oysters. In the studies of the pearl oyster of Ceylon, Herdman (1903) found no evidence of change in their sex. He stated that "in no cases were even stray ova found in the gonads that were determined as male, nor any spermatozoa in the females - although such traces of hermaphroditism were carefully looked for."

No hermaphrodites were found among the Hawaiian oysters, Pinctada galtsoffi, which I examined in 1930.

Sex reversal is known to occur, however, in the Japanese oyster, Pinctada martensi (Dunker), and in the Australian white pearl oyster, Pinctada maxima Jameson. This fact was established by Japanese scientists, R. Wada and S. Wada (1939, 1942), who made observations with oysters of known sex marked with lead tags. In both species, the change took place either from female to male or from male to female.

There is no evidence at present that sex reversal has any effect on the reproduction and fertility of pearl oysters.

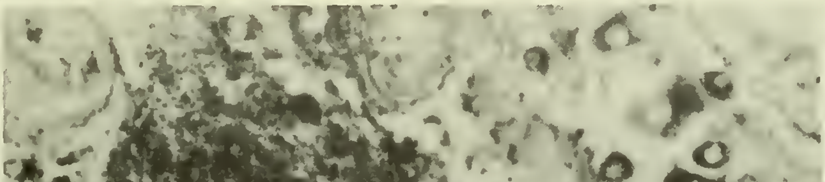

Figure 27 --- Photomicrograph of a hermaphroditic gonad of Pinctada mazatlanica. Dark mass in the center consists of ripe spermatozoa surrounded by eggs. From a preparation stained with haematoxylin-eosin, x 150.

Plankton samples with a small plankton net lowered to the bottom and slowly hauled up to the surface were taken at each station, primarily for the purpose of obtaining information regarding the presence of pearl-oyster larvae and of red-tide microorganisms. The material collected in the field was immediately examined under the microscope, and then preserved in 2 per cent formalin in sea water.

In general, the plankton was not abundant. At most of the stations, it consisted primarily of such pelagic diatoms as Rhizosolenia, Biddulphia, Ditylum brightwellii (West), Chaetoceras, Coscinodiscus, Eucampia, Thallasiothryx, and others. Dinoflagellates were less abundant. They were represented by Dinophysis, Ceratium, and various Peridiniaceae. None of these forms was predominant. Tintinnoidea were frequently present, and at certain stations Noctiluca was abundant. Fairly large numbers of Appendicalariae were found in many samples.

Large numbers of nauplii, lamellibranch and annelid larvae, present in the majority of the samples, indicated normal propagation of planktic and sedentary forms. Presence of copepods, Sagittae, and other forms usually found in coastal waters completed a picture which suggested a normal equilibrium between the various components of plankton. There was no indication of the blooming of the sea which may have been associated with the red tide (Galtsoff, 1948 and 1949).

Mucous-secreting algae played a conspicuous role in the plankton. At some of the stations (Station 2, Saboga Island; Station 11, Taboga; Station 13, Pedro Gonzalez), they outnumbered other organisms. In some places (Pedro Gonzalez), the patches of mucous drifting near the surface were so large that they were noticeable to the unaided eye. Microscopic examination showed two types of gelatinous masses: in one type the amorphous and transparent substance contained large numbers of a diatom resembling Thalassiosira subtilis (Osten) (see Cupp, 1943, p. 51); in the other type, no recognizable cells of diatoms or any other algae were found, but the gelatinous mass contained minute, light-refringent, oval granules. The identity of these granules, measuring about 2 mu in length has not yet been established. The large patches of mucous acted as a plankton collector, entrapping many organisms floating in the sea water.

At several stations, the samples of plankton contained straight-hinge larvae of the genus Ostrea. It was, however, impossible to identify the species. No pearl-oyster larvae were found in any sample. This is not surprising, because of the very small number of adult pearl oysters remaining at present in the Gulf of Panama and Gulf of Chiriqui.

In general, the total amount of plankton in the water was small. The slightly greenish water was very clear; its transparency, measured by Secchi disc, varied between 4 and 5 meters. Diatoms prevailed at virtually all of the stations, with the exception of Station 14 (Isla San José, Ensenada Plaza Grande) where rather suddently we encountered water of dark blue color and greater transparency (6 meters). It contained large numbers of small Salpae about 15 mm. long, slowly drifting with the tide. Quantitative sampling near the surface disclosed that there were 220 individuals per liter of water. Salpae were not found at any other station.

The general picture obtained from the examination of the samples was that of a typical marine plankton of warm coastal waters. There was no evidence of any abnormal conditions in the sea which could have affected the pearl-oyster grounds of that area.

OBSERVATIONS ON EDIBLE OYSTERS OF THE GENUS OSTREA

The genus Ostrea is represented along the Pacific coast of Panama by the following species: Ostrea cumingiana mexicana Sowerby, O. iridescens Gray, O. megodon Hanley, O. chilensis Philippi and O. columbiensis Hanley. Smith (1944, p. 51) lists also O. conchaphila Carpenter, O. multistriata Hanley, and O. tubulifera Dall; and Zetec (1918, p. 52) mentions O. aequatoriales d'Orbigny. These species were not encountered in my exploration. The most abundant oyster was the small O. cumingiana mexicana, which densely covered the rocks at the middle level of the tidal zone. The oyster is edible, but lacks flavor, and because of its small size is useless for commerce.

O. iridescens was found in many places attached to rocks and stones below low-water mark. The largest specimen was 15 cm. long and 7-8 cm. wide. The oyster is very flat, with small shell cavity; consequently there is but little meat inside a rather heavy shell. The meat is very salty; and, at the time of examination, very lean. Judging by the appearance, the tissues contained but little glycogen.

Ostrea megodon is a rather large, flat, and round oyster, about 18 cm. long and 15 cm. wide. The inner surface of the shell is black and slightly irridescent. The oyster cannot be eaten raw, but is palatable after it is cooked. O. megodon grows firmly attached to rocks below low water, and can be taken only by diver. It is doubtful that it could be exploited commercially.

O. chilensis closely resembles the Atlantic oyster (O. virginica). It has a deep cup-like shell which encloses a rather large body (Fig. 28). The muscle scar is not pigmented. Like O. virginica, O. chilensis may be found growing both on rocks and on muddy bottoms. Its distribution extends from the Gulf of California to Chile. The oyster apparently thrives on mud bottoms, especially near the river mouths. Extensive bars built of shells of this species exist in the Bay of St. Miguel (Ensenada de Garachiné). Wide mud flats of this bay extend over an area of several miles along the shore. At low tide, the flats are barren. They were reached by using an Indian "cayuga", a dugout canoe with slightly flattened bottom, which was pushed for several miles along the edge of the flats, and then dragged toward the reef. The oyster bars are surrounded by soft and sticky mud. They all extend at right angles to the shore. The bar which I examined in greater detail was from 40 to 65 feet wide and about 500 feet long. It represented an accumulation of old oyster shells and in its general appearance, resembled the bars of O. virginica on muddy bottoms

Figure 28 --- Ostrea chilensis, principal edible oyster of the Pacific coast of Panama. On mud flats, this oyster forms reefs resembling those made by O. virginica along the coast of Gulf of Mexico.

in Texas waters. The reefs stood about 2 feet above the surface of the surrounding mud. The majority of oysters on the bar were in vertical position, which is usually assumed by the oyster in order to protect itself from being engulfed in mud.

A few years ago, the oyster bars in Ensenada Garachiné were extensively fished by the local residents. There was no organized trade. Oysters were used primarily for consumption at home, but occasionally some of them were shipped to Panama. It was said that the reefs were prolific for the last ten years, but that the majority of oysters died in 1947. Examination of the reef confirmed this information. Most of the oysters were dead, although the valves were still connected by their hinges. During one hour of intensive search, I was able to find only seven adult live oysters and 13 live seed. The seed oysters varied from 1 to 2 1/2 inches in length (2.8-6.6 cm.). Examination of the tissues showed no pathological conditions. Only one specimen was lightly infested with Nematopsis spores. The cysts were found only in the adductor muscle. Of 10 oysters which were examined microscopically, one small specimen (1 inch long, 2.8 cm.) was in an indifferent sex stage. Others contained either ripe sperm or eggs; there were four males and five females. Many of the shells of dead oysters, especially the small ones, were drilled by snails which abounded on the reef. It was obvious, however, that mass mortality of oysters was due to some other cause than depredation by borers. Long exposure at low tide, which may have been caused by an unfavorable combination of wind and tides, may have killed these oysters. The presence of small seed oysters indicated that setting on the bar continued. It is therefore reasonable to expect that, in a few years, the oyster population of the bar will be re-established.

Since oyster reefs in Ensenada Garachiné are valuable to the local population as a source of protein food, it is desirable that they be managed in such a way as to prevent their destruction. Because of the small number of live oysters remaining on the bar at present, it is suggested that the bar be temporarily closed, and that fishing resumed when the oyster population is re-established.

PROBABLE CAUSE OF THE DEPLETION OF PEARL-OYSTER GROUNDS

From the observations made in the field, and from the examination of the preserved tissue of pearl oysters, the following facts become evident. The remaining population of pearl oysters on the principal grounds known to have been productive in the past years is so small that it cannot support the fishery. For practical purposes, the pearl fishery in Panama has ceased to exist.

The surviving pearl oysters appear to be healthy. They develop gonads; and, judging by the presence of small numbers of young oysters, the propagation of the species continues, although at a very low rate. In the absence of precise information regarding the rate of growth, it is difficult to foresee when the population of pearl oysters may reach its former abundance. My guess is that, barring unforeseen circumstances, the rehabilitation of the grounds would require a decade or more, provided the fishing is completely discontinued, and oysters are permitted to propagate and grow without any interference from man.

Field observations do not disclose any evidence that pearl oysters were killed by the red tide or by the dumping of some poison. I observed no significant difference in the conditions of sea bottom around Pearl Islands, Coiba, or along the mainland of the western part of the Gulf of Chiriqui. If the assumption is correct that oysters were killed by poisons brought in by the currents from the dumping area in the deep water at the entrance of the Gulf of Panama, one would expect higher mortality rate around Pearl Islands than at Coiba, located more than 200 miles east of the dumping area, and separated from the Gulf of Panama by a large peninsula (Fig. 6).

The resistance of various marine organisms to adverse conditions is different. Some of them are hardier than others, and therefore may survive in the concentration of poison lethal to less resistant forms. It is, however, inconceivable that any poison may be so selective as to kill only one species without affecting others living in the same environment. The Panama pearl oyster does not form densely populated reefs or banks typical of the edible oysters. It grows singly, attached to rocks and corals which provide substratum for many other forms. There was no evidence of unusual mortality among any of the bottom organisms living on pearl-oyster grounds, and no mortality of fishes was ever reported by the fishermen operating around Pearl Islands. Likewise, no unusual discoloration of water was noticed by the inhabitants of the islands or by the captains of tuna fishing vessels working along the coast.

Suspicion that waters around the Pearl Islands contained some mysterious poison that killed pearl oysters must be abandoned as wholly unsubstantiated.

The suggestion that some contagious disease destroyed a large percentage of oysters a few years ago cannot be answered with certainty. I was unable to find any diseased or dying oysters. Only a few specimens were found which, judging by the fact that their valves were still connected by the hinge, had died a short time before. Unfortunately, their tissues were completely decomposed or eaten by crabs.

Present observations show that the remaining oysters are healthy and not infected by parasites. It is, of course, impossible to infer from the observations made in 1948 what the condition of oysters was in 1937, when their yield began to decline.

Several considerations speak against the theory that contagious disease was the cause of the decline of the fishery. Dead shells found on bottom were in various stages of deterioration and fouling. If all of these oysters perished at the same time, there would be no such difference in the state of erosion of their shells. Furthermore, rapid decline of the pearl fishery, as shown by the records of export (Fig. 1), began in 1925, after the production had reached more than 700,000 kilos per year. Assuming that the average weight of an adult oyster of commerce is about 350 grams, the total number of live oysters removed from the sea in this single year probably was 2 million individuals. Intensive fishing in the following decade may have prevented the rehabilitation of the grounds, and reduced the oyster population to a lower level. Interruption of export of mother-of-pearl shells during the war years of 1939-1945 failed to bring rehabilitation of the grounds. It is possible that some unknown adverse environmental conditions prevented recovery during this period; but, on the other hand, one must bear in mind that interruption of export of shells did not completely stop the fishing for oysters in search of pearls.

Statistical data available at present record the total weight of shells shipped from Panama. The number of oysters taken by individual fishermen in search of pearls remains unrecorded. The figure is probably much less than the quantity of shells obtained by the organized fishery, but even a small drain upon the oyster population might have been significant biologically, especially in view of its already depleted state.

From all of the facts presented and discussed in this report, I conclude that overfishing was the most probable cause of the depletion of the pearl-oyster grounds in Panama. The decline of the fishery started after 1925; and, with inconsequential partial improvements has continued until the present. We know from historical records that the grounds near the Pearl Islands had been already depleted by the end of the 16th century, when pearling operations by Spaniards were abandoned in favor of new and more productive areas. The question is whether the population of pearl oysters may again restore itself if given adequate protection. In view of the extremely small numbers of oysters remaining on the grounds, it is impossible to give a categorical answer without a trial, but as long as there are still a few living and healthy oysters, it appears possible that the stock may be at least partially rebuilt.

The method of gathering of pearl oysters by divers inflicts no damage to the grounds. Dredges, patent tongs, and similar gear used in harvesting edible oysters are often destructive because of their excessive weight, and because the removal of shells or other hard objects makes the bottom unsuitable for the attachment of young oysters. In the case of the pearl fishery, the physical condition of the bottom is not altered by intensive fishing. The only question, then, is whether the rate of reproduction of the few remaining oysters will be sufficient to rehabilitate the grounds. No definite assurance that this will be the case can be given at present. It is recommended, however, that efforts be made to protect the remaining pearl oysters and to facilitate their propagation by the enactment of the following measures:

1) Complete closing of pearl fishery and prohibition of taking live pearl oysters for any purpose except that of scientific research.

2) Organization of pearl-oyster investigations to be conducted by competent fishery biologists for the purpose of determining the rate of rehabilitation of pearl-oyster grounds.

Because of the greatly diminished stock of oysters the proposed recommendations appear to be sound regardless of the cause of depletion. Should the suggested investigation reveal the existence of a new or heretofore undisclosed factor detrimental to pearl oysters, the course of studies may be modified and steps suggested for combatting the danger.

For the success of investigation it will be necessary to establish, around the Pearl Islands, several experimental grounds which should be inspected periodically to observe the time of spawning of oysters and the attachment of oyster larvae, to study the rate of growth of young oysters, to determine the presence or absence of oyster enemies and disease, and to record the temperature, salinity, pH, and plankton of the water. It is suggested that the experimental grounds be selected in the following areas: Taboga Island, Isla de Mina, and Saboga Island. It is further recommended that a more extensive survey be made around the Pearl Islands and in the Gulf of Chiriqui for the purpose of locating new pearl-oyster grounds.

In order to make a detailed study of the growth and propagation of pearl oysters, it is suggested that an additional small area in shallow water near Taboga Island be used as an oyster nursery, where small oysters could be planted and kept under continuous observation.

For the execution of this research program, it is suggested that arrangements be made through the Department of Natural Sciences of the University of Panama or with the Muséo Nacional for the employment of a full-time marine biologist and several part-time student assistants. It would be necessary for the Government of the Republic of Panama to provide floating equipment needed for field work, establish a small shore laboratory at Taboga, procure necessary scientific equipment and secure the services of a competent diver to assist scientists in underwater observations.

The outlined investigations should be continued for at least five years. If by the end of that period the results are promising and show that the population of pearl oysters has materially increased, the fishery may be reopened partially under strict government supervision. Proper balance between the intensity of fishing and the rate of propagation and growth of oysters may be maintained by the enactment of a system of management based on sound biological principles. Various conservation methods may be used to control the fishery, namely, closed season, rotation of grounds, establishment of a size limit on oysters, and limitation of fishing effort and gear. None of these measures, except complete closing of the fishery, is recommended now because the remaining oyster population is not large enough to support a commercial fishery.

In the past a number of communities scattered through the Pearl Islands obtained livelihood from pearl fishing. Their present economic status can be greatly improved by the restoration of the depleted pearl-oyster resources and by conducting the fishery in conformity with the principle of conservation. This principle can be stated in a very simple way: one should take from a natural resource no more than is restored annually through reproduction and growth.

BIBLIOGRAPHY

ALTOLAGUIRRE y DUVALE, de, A.

1914. Vasco Nuñez de Balboa. Madrid.

ANDERSON, C. L. G.

1911. Old Panama and Castilla del Oro. Sudworth Co., Washington. 559 pp.

BUNAU-VARILLA, PHILLIPE.

1892. Panama: le passé, le present, l' avenir. Paris.

CAHN, A. R.

1949. Pearl culture in Japan. General Headquarters Supreme Commander for the Allied Powers, Natural Resources Section, Report No. 122, 91 pp., Tokyo.

CATTELL, E. J.

1905. Panama. Foreign Commercial Guide of the Philadelphia Commercial Museum.

CLARK, AUSTIN H.

1946. Echinoderms from the Pearl Islands, Bay of Panama, with a Revision of the Pacific Species of the Genus Encope. Smithsonian Miscellaneous Collections, Vol. 106, No. 5, 11 pp., 4 pl.

COCHRAN, DORIS M.

1946. Notes on the Herpetology of the Pearl Islands, Panama. Smithsonian Miscellaneous Collections, Vol. 106, No. 4, 8 pp.

COE, W. R.

1932. Sexual phases of American oyster (Ostrea virginica). Biol. Bulletin 63: 419-441.

CUPP, EASTER B.

1943. Marine Plankton Diatoms of the West Coast of North America. Bulletin of the Scripps Institution of Oceanography, Vol. 5, pp. 1-238, pl. 1-5, 168 figures in text.

ERLANSON, C. O.

1946. The vegetation of San José Island, Republic of Panama. Smithsonian Miscellaneous Collections, Vol. 106, No. 2, 12 pp., 2 pl.

FLEMING, RICHARD H.

1938. Tides and tidal currents in the Gulf of Panama. Journal of Marine Research, Vol. 1, pp. 192-206.

GALTSOFF, PAUL S.

1931. The weight-length relationship of the shells of the Hawaiian pearl oyster, Pinctada sp. American Naturalist, LXV, pp. 123-133.

1931. Survey of oyster bottoms in Texas. U. S. Bureau of Fisheries, Investigational Report No. 6, 30 pp.

GALTSOFF, PAUL S.

1933. Pearl and Hermes Reef, Hawaii, Hydrological and Biological Observations. Biological Observations, Bernice P. Bishop Museum, Bulletin 107, 49 pp., 5 pl.

1948. Red Tide. Special Scientific Report No. 46, Fish and Wildlife Service, 44 pp. Washington.

1949. The Mystery of the Red Tide. Scientific Monthly, 68: 108-117.

Pearl fishery of Venezuela. Manuscript on file at Fish and Wildlife Service, Washington, D. C.

GALTSOFF, PAUL S. and R. H. LUCE.

1930. Oyster investigations in Georgia. Appendix V to Report of Commissioner of Fisheries for the fiscal year 1930, pp. 61-100.

HARING, CLARENCE H.

1918. Trade and navigation between Spain and the Indies in the time of the Haspburgs. Cambridge.

HERDMAN, W. A.

1903. Observations and experiments on the life history and habits of the pearl oyster. Report to the Government of Ceylon on the pearl oyster fisheries of the Gulf of Manaar. London, Pt. 1, pp. 125-146.

HILDEBRAND, SAMUEL F.

1946. A list of fresh-water fishes from San José Island, Panama. Smithsonian Miscellaneous Collections, Vol. 106, No. 3, 3 pp.

HILL, R. T.

1898. The geological history of the Isthmus of Panama and portions of Puerto Rico. Bulletin Mus. Comp. Zool. (Harvard) Vol. 28, pp. 151-285.

HOLMES, W. H.

1888. Ancient art of the Province of Chiriqui. Washington.

HOFFMAN, H. THEODORE.

1946. Economic situation in Panama, 1945. International Reference Service, U. S. Dept. of Commerce, Vol. 3, 6 pp.

1947. Marketing areas in Panama. International Reference Service, U. S. Dept. of Commerce, Vol. 4, No. 18, 11 pp.

HUMBOLDT, von, ALEXANDER and AIMÉ BOUPLAND.

1822. Personal narrative of travel to the Equinoctial Regions of the new continent during the years 1799-1804. 3d Edition, Vols. I, II, London.

IRVING, WASHINGTON.

1831. Voyages and discoveries of the companions of Columbus.

KELLOGG, REMINGTON.

1946. Mammals of San José Island, Bay of Panama. Smithsonian Miscellaneous Collections, Vol. 106, No. 7, 4 pp.

KIRKPATRICK, R. Z.

1926. Panama Tides. Proceedings U. S. Naval Institute, 52, pp. 660-4.

KUNZ, GEORGE FREDERICK and CHARLES HUGH STEVENSON.

1908. The book of the pearl. New York, 548 pp.

LOTHROP, SAMUEL KIRKLAND.

1937. Coclé. An archaelogical study of Central Panama. Memoires of the Peabody Museum of Archaeology and Ethnology, Harvard University, Vol. VII, 327 pp.

MEDINA, J. T.

1914. El Descumbrimento del Oceáno Pacifico. Santiago de Chile.

MORRISON, J. P. E.

1946. The nonmarine mollusks of San José Island, with notes on those of Pedro Gonzalez Island, Pearl Islands, Panama. Smithsonian Miscellaneous Collection, Vol. 106, No. 6, pp. 49, 3 pl.

MOSK, SANFORD A.

1934. The Cardona Company and the pearl fisheries of Lower California. The Pacific Historical Review, Vol. III, pp. 50-61.

1938. Spanish pearl-fishing operations on the pearl coast in the sixteenth century. The Hispanic American Historical Review, Vol. XVIII, Notes and Comments, pp. 392-400.

NICHOLLS, A. G.

1930. On the breeding and growth-rate of the Black-lip pearl oysters, (Pinctada margaritifera). Reports of Great Barrier Reef Committee, Vol. III, No. 2, pp. 26-30.

OVIEDO y VALDÉS, GONZALO FERNANDES de.

1535. Historia General y Natural de las Indias, Islas y Tierra Firme de Mar Oceáno. Ed. José Amedor de los Rios, Madrid. 4 Vols., 1851-1855.

REPUBLICA de PANAMA.

1908-1947. Dirección General de Estadistica. Boletin de Estadistica, 1908-1947, Panama.

1917. Codigo administrativo. Paragrafo septimo. Articulos 1615-1623. Edicio Oficial, Barcelona.

1931. Codigo fiscal, Capitulo III. De la Pesca y la Caza, Articulos, 395-416.

1946. Decreto numero 408 (Reglamentase la Pesca) Gaceta Oficial, Ano XLIII, Numero 9989, Martes 7 de Mayo, 1946.

1946. Decreto numero 449, (Reglamentase una Pesca). Gaceta Oficial, Ano XLIII, Numero 10181, Martes 24 de Deciembre de 1946.

1947. Prospectus Republic of Panama. March 24, 1947.

SCHUCHERT, CHARLES.

1935. Historic geology of the Antillean-Caribbean region, or the lands bordering the Gulf of Mexico and the Caribbean Sea. New York, J. Wiley, Sons. XXVI, 811 pp.

SHIPLEY, A. E. and G. HORNELL.

1904. Anatomy of the pearl oyster. Report to the Government of Ceylon on the pearl oyster fisheries of the Gulf of Manaar. London. Pt. 2, pp. 77-106.

SIMMONS, J. S., G. R. CALLENDER, D. P. CURRY, S. C. SCHWARTZ and R. RADDELL.

1939. Malaria in Panama. Johns Hopkins Press, Baltimore, p. 56.

SMITH, MAXWELL.

1944. Panamic marine shells. Beal-Maltbie Shell Museum of Rollins College, Winter Park, Fla. 127 pp.

STEVENS, HENRY.

1869. Historical and geographical notes on the earliest discoveries in America, 1453-1530. New Haven.

STEWARD, JULIAN H. (Editor).

1946. Handbook of South American Indians. Vol. 4. The Circum Caribbean Tribes. Smithsonian Institution. Bureau of American Ethnology. Bulletin.

TERRY, R. S.

1941. Notes on submarine valleys off the Panamanian coast. Geographical Review, Vol. XXXI, pp. 377-384.

U. S. NATIONAL MUSEUM.

1949. Report on the Progress and condition of the United States National Museum for the year ended June 30, 1948. 127 pp. (See page 25).

WADA, R. and S. WADA.

1939. Shiro-chogai no Shi-yu (The Sex in the Pearl Oyster, Pinctada maxima). Kagaku Nanyo (Science of the South Sea Islands), Vol. II, No. 1, pp. 4-45. (Quoted from Cahn).

WADA, S.

1942. Kagaku Nanyo (Science in the South Seas), Vol. IV, No. 3, pp. 202-208. (Quoted from Cahn).

WETMORE, ALEXANDER.

1946. The birds of San José and Pedro Gonzalez Islands, Republic of Panama. Smithsonian Miscellaneous Collections, Vol. 106, No. 1, 60 pp., 3 pl.

ZETEK, JAMES.

1918. Los Moluscos de la Republica de Panama. Revista Nueva, Nos. 1 y 2, 69 pp., Panama.

Analysis of samples of water collected by Paul S. Galtsoff
at Poza San Juan, Coiba Island, Panama, March 1948

Analyses by Geological Survey, United States Department of the Interior
(Parts per million)

Item	Hot Spring No. 1	Hot Spring No. 2
Silica (SiO_2)	95	81
Iron (Fe)	.11	.10
Calcium (Ca)	19	28
Magnesium (Mg)	1.0	6.9
Sodium (Na)	205	124
Potassium (K)	5.0	4.5
Carbonate (CO_3)	47	0
Bicarbonate (HCO_3) . . .	8	96
Sulfate (SO_4)	310	209
Chloride (Cl)	82	58
Fluoride (F)	.3	.2
Nitrate (NO_3)	.7	.4
Dissolved solids	791	560
Total hardness as $CaCO_3$.	52	98
Specific conductance ($K \times 10^6$ at 25° C.) . .	1100	783
pH	9.2	7.1
Color	6	4