Lou Marron - University of Miami

Pacific Billfish Expedition

PRELIMINARY REPORT · 1954

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THE MARINE LABORATORY
UNIVERSITY OF MIAMI

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FOR 1954

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Scientist in charge of Expedition

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Director

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TABLE OF CONTENTS

INTRODUCTION

Summary of Objectives and Results

DURING THE PAST several years the Marine Laboratory of the University of Miami has been engaged in research into ocean game fishes, not only in the north Atlantic, but also as far afield as Australia, New Zealand, South Africa and Panama. An extension of this work into the waters of the Pacific coast of South America was made possible through the generosity of Mr. and Mrs. Lou Marron, who provided not only the financial support necessary but, together with Mr. and Mrs. John Manning, self-sustaining members of the expedition, also contributed a considerable amount of time and energy to the organization of the field arrangements.

Since it was intended that the expedition should continue for several years, the first year's work, carried out off the coasts of Chile, Peru and Ecuador, was planned as a preliminary investigation, the results of which might be used as the basis for more elaborate and detailed studies in the future. Because of this, the principal accomplishments of the 1954 expedition were the detailed measurement and study of the anatomical features, breeding condition, and food contents of broadbill swordfish, black and striped marlin. It is believed that the expedition has set some kind of a record in the number of such fish ever to be scientifically examined in the course of a single expedition.

The results of this suggest that striped marlin do not spawn off northern Chile during the period of the expedition and that the females are considerably heavier than the males. It was also noted that striped marlin in these waters are decidedly more interested in taking bait while in water of higher surface temperatures. The natural food, as shown by analysis of stomach contents, appears to be restricted to squid. Although striped marlin are taken off Chile during almost the whole year, they are far more abundant from October to June. Off northern Peru they appear to be much more abundant from December to June. Striped marlin off the coast of Ecuador appeared to be immature.

No black marlin were found in Chilean waters. Off Peru almost all these fish were female and none in spawning condition. It appears that black marlin are more plentiful here during June and November and scarce during the remainder of the year. The food of these fish was widely varied.

The broadbill swordfish taken off Chile were apparently all females and not in spawning condition. They appear to be most numerous from July to October off Cabo Blanco, where they form an important commercial catch; but off Chile, May and June appear to be the months of greatest abundance. It appears likely that the swordfish form a single population which migrates northward from Chile to Peru during the (northern) summer, and that they move off into unknown spawning grounds during the (northern) winter.

Along with the direct examination of billfishes, plankton samples were taken for a study of life histories and in order to determine the general nature of the biological conditions of the waters from Chile to Ecuador. Physical measurements were made of the surface and underlying waters in order to obtain a preliminary idea of the desirable objectives for future hydrographic work. The ultimate purpose of this is to determine the manner in which physical oceanographic conditions such as currents, wind drifts, upwellings and associated temperature and salinity change, affect the biological content of the waters and consequently, the migrations, feeding habits and distribution of the billfishes.

The plankton samples were rich, particularly at the more offshore stations, but were disappointing in the comparative absence of young or larval fishes. Since one of the objectives of the expedition was to obtain material for life history studies, it is believed that future work of the expedition should allow for plankton collections in December and January. Since many fishes of the northern hemisphere spawn in early summer, there is reason to believe that the same may be true of the southern hemisphere. This was borne out by the gonad examinations.

Since the commercial fisheries of the entire coast include the billfishes and since commercial fisheries are, in certain ways, very important indices of organic productivity, a general study was also made of commercial sea fishery operations in Chile, Peru and Ecuador. A general account of this is given in this report with observations on the vessels, gear and methods employed. From this it appears that further information on the hydrographic conditions could be of value both in developing the fisheries and in ensuring wise control and management of these resources. An experimental longline operation was carried out in Peru with the help of the Wilbur-Ellis Company and under the supervision of Mr. Donald Bates of that company.

Preliminary examinations of the hydrographic data suggests that the Peru Current extends north as far as Isla La Plata, Ecuador, as a subsurface current, overlain by a southward drift of warmer waters from the equatorial countercurrent and Panama Current complex. The surface boundary between the Peru Current and the Equatorial countercurrent was located somewhat north of Cabo Blanco and the warm branch of the eddy, first observed by Gunther off Arica, was found to extend as far as Iquique and south.

The present report is of a preliminary nature and much of the data collected still remains to be analyzed. It is therefore necessary to point out that conclusions drawn are of a tentative nature, subject to modification as the work of analysis proceeds, and as further field work provides new material for study. The principal objective of this report is to make available the factual information and to provide a general basis upon which plans for future field work may be laid.

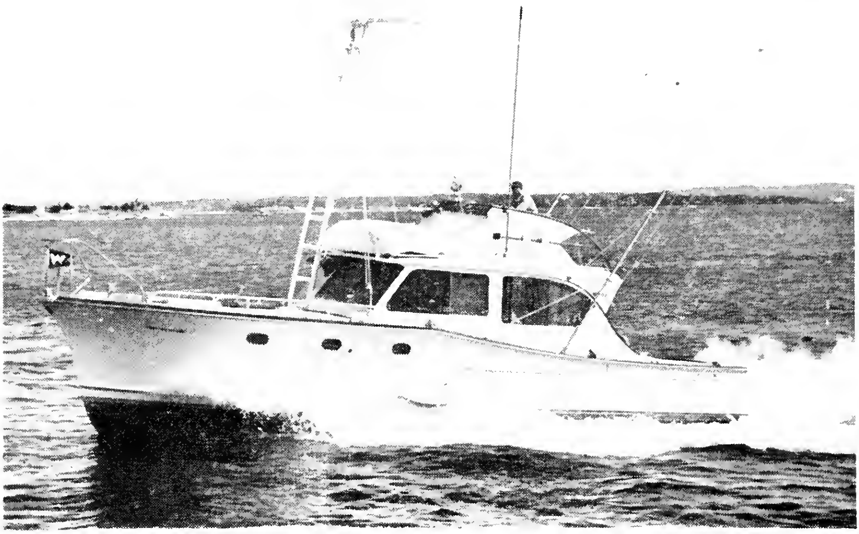

FIGURE 1. The 40-foot cruiser *Explorer*, especially designed for the expedition and built by Wheeler Shipyard Co.

Personnel and Equipment

The work of the expedition was under the leadership of Mr. Luis R. Rivas, who also was responsible for the ichthyological studies and for the direction of field investigations off Chile and Peru. Dr. F. G. Walton Smith directed observations off Ecuador. Mr. and Mrs. Lou Marron, with Mr. and Mrs. John Manning, were responsible for the capture of the greater number of the billfish specimens examined. Travelling arrangements, the location of field bases and general field management, were in charge of Mr. Marron, assisted by Mr. Manning, who remained in the field during the entire period of expedition. All members of the expedition gave assistance in the collection of samples and in the measuring and examination of specimens. Capt. Howard Thuet, and Mrs. Thuet, field secretary, were responsible for keeping numerical data and logs.

Plankton samples were examined on their return to Miami by Mr. Gilbert L. Voss and Mrs. Joan Clancey. Hydrographic data were analyzed by Mr. Frank Chew. Commercial fishery surveys in the field were made by Mr. John Manning, with the assistance of Mr. Rivas under the direction of Dr. Clarence P. Idyll. The present report is based to a considerable extent upon various government reports and similar sources of statistics.

FIGURE 2. Mrs. Eugenie Marron taking surface temperature off the coast of Chile.

During operations off the coast of Chile, Mr. Eduardo Ormeño Valenzuela acted as official observer for the Government of Chile. Commander José Barandiarán and Mr. Felipe Ancieta were appointed in a similar capacity by the Peruvian Government.

For the most part the expedition was land based, with trips offshore of one to seven days' duration. Hotel accommodations were available in Chile at Iquique. In Peru quarters were provided at Talara through the kind cooperation of the International Petroleum Company. Docking facilities were provided at Cabo Blanco by the Lobitos Oil Company. In Ecuador, living quarters were made available to the expedition through the kindness of Mr. Forrest L. Yoder and Mr. E. Hope Norton of the Ecuadorian Corporation. Mr. Emilio Estrada gave valuable help in setting up these arrangements. It would otherwise have been impossible to carry out shore based work off this isolated part of the coast where no adequate hotel accommodations exist and living conditions are generally primitive.

Most of the work was carried out from an especially-designed 40-foot cruiser, built by Wheeler Shipyard Co., under the direct supervision and on order by Mr. Marron (Figure 1). Capt. Walter Gorman and Capt. Howard Thuet served as masters of the cruiser, being responsible for its continued operation and also aiding in many ways with certain phases of the scientific work. At various times other vessels were chartered by Mr. Marron or

FIGURE 3. Mr. Lou Marron with giant squid taken off Iquique, Chile.

loaned to the expedition.

The 40-foot cruiser, christened *Explorer*, features many items designed for the purposes of the expedition. Included amongst these is a lifting boom with a capacity of 2,500 pounds, extra heavy towing chocks, automatic pilot attached to both cockpit and topside controls, Bendix depth gauge, Taylor temperature gauge permitting the taking of ocean temperatures while running, a special live-bait well, a deep freeze with a capacity of 16 cubic feet, and a completely new type of marine radio telephone.

Acknowledgments

Success of the expedition was made possible, not only through the hard work of the sponsors and of the scientific staff, but also as a result of the kind cooperation of a considerable number of individuals and agencies who gave freely of their advice and assistance, both in the planning and outfitting of the expedition and in the actual field operations. It is not possible to name all of these, but the following brief list is representative of the many to whom it is desired to accord grateful acknowledgments.

Representatives of the governments of Chile, Peru and Ecuador, for their continuing cooperation, and the personal interest shown by their excellencies, the ambassadors and the consul-generals in New York and Miami, and their officials in South America.

W. R. Grace Company and the Grace Steamship Line, whose agents in South America facilitated arrangements, and who handled and shipped the *Explorer* from New York to Iquique, Chile, and also the subsequent shipping of the cruiser to Peru and Ecuador.

Pan American World Airways System who put the facilities of their organization at the disposal of the expedition, as well as aiding in transportation and contributing a life raft for use aboard the *Explorer*.

Panagra (Pan American-Grace Airways, Inc.) for their contribution, cooperation and assistance as well as putting their facilities and personnel at the disposal of the expedition.

Wheeler Shipyard for building the *Explorer*, and special design of the cruiser.

H. W. Remerscheid, vice-president of the Bell & Howell Company, Hollywood Division. J. W. McAdams and their able staff, for their splendid cooperation. Moving picture records of the expedition were filmed entirely with Bell & Howell Company equipment.

Hudson American Corporation of New York, a subsidiary of Claude Neon, Incorporated, for supplying and installing radio telephone aboard the *Explorer*, and assigned one of their chief engineers for this purpose.

Dr. Norwood L. Simmons, chief engineer of the Hollywood Motion Picture Film Division of the Eastman Kodak Company, for his technical advice and assistance. Also, George H. Gibson and Leslie J. Baker of W. J. German, Inc. Their help has been invaluable.

Johnson Motors Company for their contribution to the equipment of the expedition, their interest and their appreciation of the research to be undertaken by the expedition.

The Cortland Line Company, Gladding Line Company, Gudebrot Brothers Company, and the Ashaway Line & Twine Manufacturing Company, for supplying fishing lines.

The Bendix Company for instruments, advice and cooperation in connection with electrical installations aboard the *Explorer*.

International Petroleum Company, for facilitating arrangements for oil and fuel supplies in Central and South American countries, and as hosts of the expedition during the stay in Talara.

Richard F. Kelly of Amrocta Company, for making contacts and expediting the movement of equipment.

Lobitos Oil Company, for the use of their dock at Cabo Blanco and for anchorage.

Assistance and scientific cooperation in the field work is acknowledged elsewhere in the text.

Chile

MR. AND Mrs. John Manning and Mrs. Jane Thuet began collecting marlin and swordfish off Iquique (Figure 10) aboard the chartered cruiser *Marlin* on April 22, 1954 and continued to June 13. The expedition vessel *Explorer* arrived in Iquique on May 2 and Mr. and Mrs. Lou Marron worked from her between May 4 and June 14.

FIGURE 4. Luis R. Rivas, scientist in charge and ichthyologist for the expedition, examining black marlin taken off Cabo Blanco, Peru.

From the beginning of the expedition until June 14, a total of 36 striped marlin and 7 broadbill swordfish were taken. These were measured from length, girth, and weight by Mr. John Manning and Mrs. Thuet. Gonads were also measured and samples preserved for microscopical examination. Surface water temperatures and meterological data were taken during the entire time spent at sea.

Mr. Luis R. Rivas took charge of the field work June 5, and with the assistance of Mrs. Thuet, continued to make morphometric studies of the billfish in greater detail and initialed a series of offshore cruises for the purpose of taking plankton samples for the purpose of life history studies. On June 15 and 16, five stations were occupied, about 20 miles apart on a line running due west of Iquique for about 100 miles. Plankton samples were rich and surface temperatures fairly uniform between 16°C and 17.5°C. All billfish sighted were recorded.

Towards the end of June the number of billfish sighted dropped rapidly and the next offshore traverse was accordingly made from Arica. Plankton and hydrographic samples were taken at stations about 5 miles offshore, about 40 miles apart, between Iquique and Arica; at stations 20 miles apart along a line extending 100 miles due west of Arica; two, about 40 miles apart on a 20° course from a point 100 miles west of Arica; and at a point about 25 miles due west of Punta Pichalo. Surface temperatures were almost entirely within a range of 15°C to 17°C. Additional specimens of billfish were obtained from commercial fishery operations at Arica.

A third offshore cruise was made during June 30 to July 2 to the south of Iquique. Two stations were occupied at points about 40 miles apart on a course of about 245° extending from Iquique to a point approximately 100 miles due west of Punta Lobos. Six stations were occupied at points about 20 miles apart on the line due west of Punta Lobos. A further station was located about 5 miles west of Punta Banancos. The plankton samples obtained during this cruise were particularly rich in larval and juvenile fishes and adult lantern fishes (myctophids) up to three inches long were captured. Surface temperatures were within a range of 14.5°C to 17°C. Observations were made on billfishes, whales and giant squid, which are very abundant in this area.

Among other interesting observations, the feeding habits of the thresher shark (*Alopias*) were studied at close range off Arica. The presumed use of the long tail for slapping and stunning fish (bonito) was actually confirmed by direct observation. Through the cooperation of Messrs. Scheib and Navarro of the fish cannery at Iquique, specimens of various species of scombrid fishes from adjacent waters were donated to the expedition for study. These included various species of tuna and bonito whose racial characteristics were hitherto unknown. While the *Explorer* was underway during sea work, material captured by the trolling handlines was preserved in the deep-freeze or measured aboard. In general, the sea was very smooth. and working conditions were excellent.

Shore work, which includes mostly the measuring and dissection of large specimens of billfish was conducted at a very convenient site on the waterfront. An excellent workbench was available, as well as a crane for hoisting large specimens directly from the *Explorer* to the workbench. A large storeroom, for the use of the expedition, at the Grace Company building, one block from the Hotel Prat and four blocks from our water-front installations, was provided.

The fourth and last cruise in northern Chilean waters was conducted in the area west-northwest of Iquique, during July 5 and 6. Eight plankton stations, spaced about 25 miles, were occupied during this cruise, which covered 250 miles.

In accordance with the shipping date of the *Explorer* to Peru aboard the Grace liner *Santa Rita*, which had been set for July 10, field activities were suspended on July 7 in order to prepare the cruiser for shipping. According to Chilean law, the vessel and equipment had to be packed, inspected and sealed by Customs from 2 to 4 days before shipping time.

Peru

The period, comprising July 13 to 17, was spent in Lima holding conferences with government officials in connection with the expedition's activities in Peruvian waters. Official documents clearing the *Explorer* for operation in Peruvian waters, as well as Customs facilities were obtained. Among others, Senator Manuel B. Llosa, Dr. Cristobal Vecorena, Director of "Caza y Pesca," Mr. Robert O. Smith, Technical Advisor to Peru from the Fish and Wildlife Service, Admiral G. Tirado, Peruvian Navy Chief of Staff and Commander E. Zimic, Director Hydrographic Office of Peru, were visited.

Mr. Felipe Ancieta was appointed observer for the expedition by the Director of "Caza y Pesca," and Lieutenant Commander José F. Barandiarán, Director of the Navy Department of Oceanography, was appointed as observer by Admiral Tirado. Mr. Ancieta is ichthyologist for the Peruvian government and has received some training at the University of Michigan, mostly in fresh-water fishes. Commander Barandiarán, physical oceanographer, who received his training at Scripps and at the U. S. Hydrographic Office, was of the greatest possible assistance to the expedition, particularly in view of his own contribution to the hydrographic knowledge of the area. Through the courtesy of Commander Barandiarán the opportunity was taken of visiting the well equipped oceanographic laboratory of the Peruvian Navy at Callao.

The *Explorer* was unloaded at Paita on July 19, and reached Talara under her own power the next day (Figure 10). During July 21 through 23, the scientific equipment was brought ashore and stored in a room kindly provided by the International Petroleum Corporation. Housing facilities for the members of the expedition were organized, and the *Explorer's* engines overhauled. The kind cooperation of Mr. Murray Matheson, Manager of I.P.C., and of Mr. Richard Goodwin of Grace Company is acknowledged.

The port of Lobitos, 8 miles north of Talara (Figure 10), being closer to the fishing grounds off Cabo Blanco, was decided upon as a temporary anchorage for the *Explorer*. She was moved to this point on July 24, and exploratory cruises began on the same date. It was soon discovered that the permanent, extremely rough condition of the sea would not allow the undertaking of long offshore cruises. After a visit to Cabo Blanco on the 25th, it was decided to leave the *Explorer* there and utilize its more advantageous facilities as a permanent anchorage. In addition to being at the doorstep of the fishing grounds, Cabo Blanco was located with regard to proposed oceanographic cruises into the Gulf of Guayaquil to the north and Punta Agujas to the south.

During the sixth trip out off Cabo Blanco on July 29, three plankton stations were occupied. During the seventh trip, July 30, two plankton stations were occupied.

On the basis of reliable information that sea conditions in the Gulf of Guayaquil, immediately to the north of Cabo Blanco, would be much better, it was decided to conduct a two-day cruise into that area during August 2 and 3. Five plankton and three bathythermograph and salinity stations were occupied during this cruise. Several patches of Red Tide were investigated close to shore off Zorritos. Samples were taken and preserved. As predicted by our hydrographers, the ocean turned from very rough to smooth north of Punta Sal (lat. 4° S) with a simultaneous rapid increase in water temperature from 18° C. off Cabo Blanco to 23.7° C. off Zorritos, 48 miles to the northeast. The various exploratory cruises from July 24 indicated a decrease in temperature as one travels away from shore and from north to south as one travels close to shore.

Arrangements had been made for the use of a tuna clipper from which detailed hydrographic observations were to be made. These failed to materialize and the bathythermograph records were reduced in number due to the difficulty of taking them by hand over the fish roller stem of the *Explorer*. Off the coast of Chile this was not too difficult, since sea conditions were fairly good. Off the coast of Peru, however, the sea was continuously of sufficient strength to handicap such work on a small boat.

In the Cabo Blanco area marlin were not too plentiful at first, but during

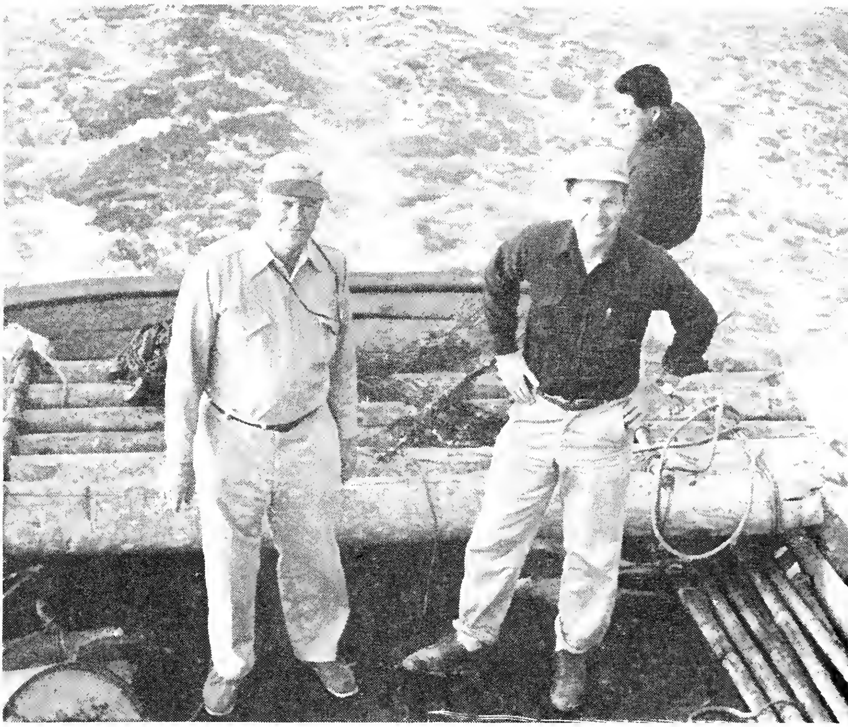

FIGURE 5. John Manning and Donald Bates, aboard purse-seiner *Corsario*, during longline cruise off Mancora, Peru.

the period of August 5 to the 26, a good run of black marlin afforded many specimens for study. No more marlin were available for study between August 26 and September 12.

Arrangements were made, while in Peru, for a cooperative investigation with the Wilbur-Ellis fishing company, through the courtesy of Mr. Donald Bates. Longline gear supplied by the expedition was made up under Mr. Bates' supervision in the form of an American modification of the Japanese gear and was operated for the first time in these waters on an experimental basis. In spite of the abundance of giant squid, the tests were generally successful. In addition to experimental fishing, the company kindly made it possible to take bathythermograph observations and plankton samples from the purse seiner *Corsario*.

Longline operations were continued from August 13 to October 15 but the *Explorer*, manned by Walter Gorman and Howard Thuet, left Cabo Blanco for work in Ecuadorian waters on September 12. The capture of billfish was resumed in the waters between Salango and Isla La Plata, Ecuador, on September 19, and continued until October 12, when the expedition ceased work for the remainder of the year.

Ecuador

Difficulties were experienced in Ecuador due to the comparative isolation of the coastal area investigated and the primitive nature of land transportation between Guayaquil and Salango. Thanks to the generosity of the Ecuadorian Corporation and the help of Mr. Emilio Estrada, an hacienda at Salango (Figures 9, 10) was made available for headquarters.

Since communication between the *Explorer* and the shore was by means of bongos, native dugout canoes which are paddled through the surf, and since the best ground for billfish was at La Plata Island, about 30 miles offshore, several days at a time were spent at sea, with short intervals at

FIGURE 6. Giant nerve fibers of large squid taken in the Humboldt Current off Iquique, Chile.

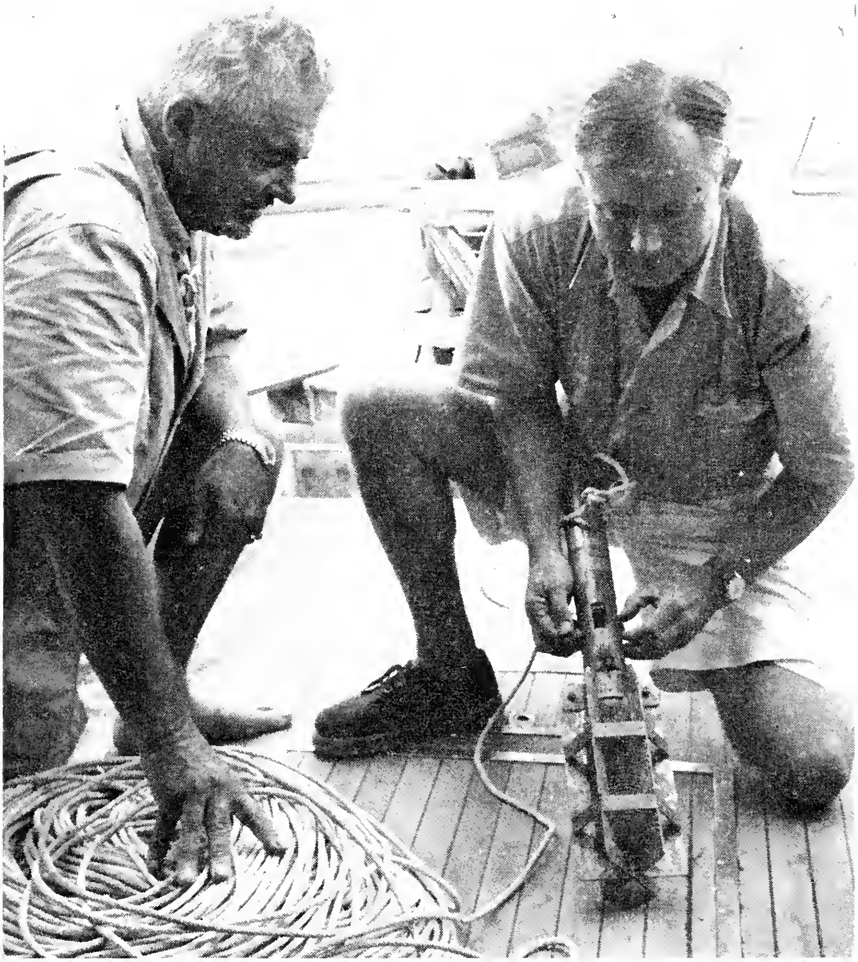

FIGURE 7. Mr. Lou Marron and Dr. F. G. Walton Smith, setting bathythermograph for recording of subsurface temperatures off the coast of Ecuador.

Salango for refueling and an occasional rest. From September 29 the field work was under the supervision of Dr. F. G. Walton Smith.

While at La Plata the opportunity was taken to run offshore for a further distance westward in order to take bathythermograph data and plankton samples from waters beyond the continental shelf.

During the stay in Ecuador a number of fishes caught by natives from their bongos in the course of commercial operations were examined but fishing in general was poor. Of 9 black marlin sighted, only 1 was caught and of 7 striped marlin, only 2 were landed. Two sailfish were also captured. No broadbill swordfish were seen.

At the termination of this work the *Explorer* was shipped to Panama for refitting and storage until plans could be made for work during the following year.

ICHTHYOLOGICAL STUDIES

In order to obtain specimens for study a total of 123 days were actually spent at sea in angling operations from April 27 through October 12. In addition to 54 days fishing from the *Explorer* in northern Chile (April 27 through July 6) a chartered cruiser, the *Marlin*, was used for the same purpose during 31 days. During the period of work off northern Peru, 45 days were devoted to angling operations, from July 24 through September 10. Off Ecuador, 24 days were devoted to angling from September 19 through October 12.

During the angling operations (54 days) off northern Chile (Figure 10), 361 striped marlin (*Makaira mitsukurii*) were sighted. Baits were presented to 185 and 107 strikes were obtained. Only 75 fish were hooked and 45 were actually landed. During the same period, 93 broadbill swordfish (*Xiphias gladius*) were sighted, baits presented to 56 and 27 strikes obtained. Only 17 fish were hooked and 11 were actually landed. No black marlin (*Makairi marlina*) or sailfish (*Istiophorus greyi*) were seen during the expedition's operations off northern Chile (April 27 through July 6) The area covered in northern Chile (about 16,000 square miles) comprised about 160 miles of coastline, from Arica to Punta Lobos, and up to 100 miles offshore. Visibility and sea conditions were generally good, and no rough seas encountered. No blind trolling for billfishes was conducted in Chilean waters. Baits were presented only after the fish had been sighted.

Off northern Peru, only 3 striped marlin were sighted during the angling operations in these waters (45 days). Baits were presented to only one, and although a strike was obtained, the fish was not landed. During the same period 34 black marlin were sighted, baits presented to 19 and 8 strikes obtained. Only 6 fish were hooked and 2 were actually landed. Only 4 swordfish were sighted in Peruvian waters and baits presented to three with no strikes obtained. No sailfish were seen from the *Explorer* during the expedition's stay in Peruvian waters (July 24 through September 10) but 2 specimens captured by commercial fishermen were seen at the Port of Mancora on August 15. The area covered in northern Peru (about 2450 square miles) comprised about 70 miles of coast line from Talara to Zorritos and up to about 35 miles offshore. Most of the angling activities, however, were conducted in the vicinity of Cabo Blanco where marlin appeared to be most abundant. In addition, continued heavy seas prevented the expedition activities from covering more extensive grounds. With very few exceptions, no blind trolling for billfishes was conducted in Peruvian waters. In Chile, baits were presented only after the fish had been sighted.

In Ecuadorian waters, 7 striped marlin were sighted during the angling operations (24 days) from September 19 through October 12. Baits were presented to 4 of these, all of which struck, but only 3 were hooked and 2 actually landed. Only 9 black marlin were sighted and baits were presented to 8. Strikes were obtained from all of these, but only 6 were hooked and only 1 was actually landed. All of the 4 sailfish sighted took the bait, but only 3 were hooked and 2 were actually landed. No broadbill swordfish were sighted in Ecuadorian waters. Blind trolling, rather than waiting until the fish were sighted, was the method employed in Ecuador. Most of the angling activities were conducted in the vicinity of La Plata Island.

Of the 45 specimens of striped marlin landed in northern Chile, 41 were measured and dissected. Vertebrae were obtained for age studies and the gonads and stomach contents analyzed. These specimens ranged from 170 to 396 pounds in weight (average 255 pounds) and 2260 to 2850 mm. in fork length (measured from tip of lower jaw). Of the 27 specimens sexed, 12 (44 per cent) were males, and 15 (56 per cent) females. All the gonads examined appeared to be in a resting condition, far from the ripe or recently spent stage. This would seem to indicate that striped marlin were not in the process of spawning off northern Chile during the period of operations of the expedition. Females were considerably heavier (average 289 pounds) than males (average 236 pounds). The striped marlin occurring in the waters off northern Chile appear to be much heavier than those occurring off the west coast of Mexico and Southern California. In these more northern waters, specimens rarely reach a weight of more than 250 pounds and usually average less than 200 pounds. The reasons why this species is so much heavier in Chilean waters than in the north are as yet unknown, but the oceanographic and biological data obtained during the expedition may throw some light towards the solution of this problem. The biometric data obtained will help determine whether or not the striped marlin occurring in the eastern Pacific represent one or more races or populations.

It is interesting to note that during the angling operations in northern Chile, striped marlin were more interested in the bait and took it more readily at higher surface temperatures and showed little or no interest when

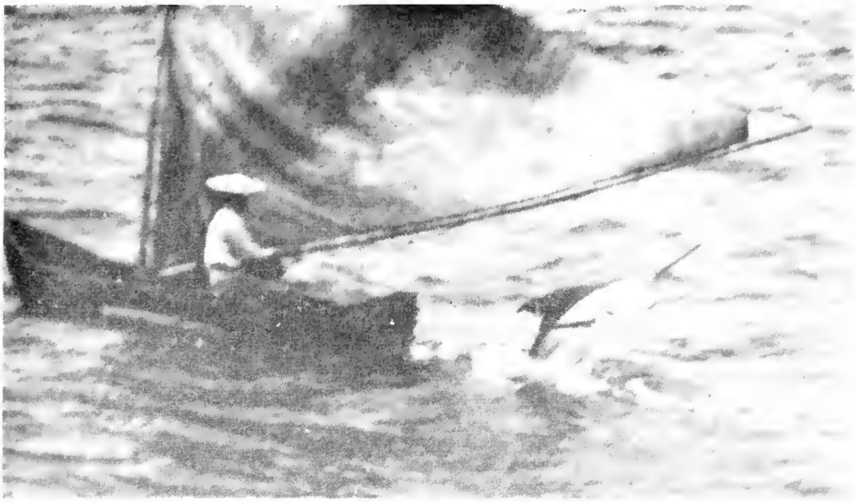

FIGURE 8. Striped marlin jumping close to boat after being hooked by native fisherman off the coast of Ecuador.

surface temperatures were lowest. Surface temperatures during the angling operations ranged from 16.2 to 20 degrees Centigrade.

The only other specimen of striped marlin studied during the expedition was a small female 85 pounds in weight, and 1955 mm. in length, captured off La Plata Island, Ecuador, on October 6. The size and condition of the ovaries indicated that this specimen was probably immature.

Examination of the stomach contents of the striped marlin studied in Chilean waters, showed that these fish were feeding almost exclusively on squid.

Although only 3 striped marlin were sighted (none taken) during the angling operations off northern Peru (July 24 through September 10) interviews with local commercial fishermen and anglers familiar with the area indicate that these fish are much more abundant during the summer months comprising December through June. In connection with this, it is interesting to note that although striped marlin are taken in Chilean waters practically the year round, the species is much less abundant during the winter months (late June through September). During the expedition's angling operations in Chilean waters 284 individuals were sighted and 34 landed during the 35 day period comprising April 27 through May 31, whereas only 77 were sighted and 11 landed during the 36 day period comprising June 1 through July 6. The abundance of fish definitely decreased with the approach of winter and the lowering of the water temperature. Striped marlin are called "pez aguja" by the Chileans.

As already indicated no black marlin were seen in Chilean waters and so far as known none have been taken there by anglers. However, interviews with commercial fishermen revealed that at least a few specimens are taken by them every year. These men can distinguish well between the striped and black marlin and refer to the latter as "pez zuncho."

Twenty-six specimens of black marlin were measured by the expedition in Peruvian (Cabo Blanco) waters, thanks to the splendid cooperation of various other anglers whose catches were kindly donated for study.

All of the 26 specimens of black marlin available for study in Peru were measured and dissected. Vertebrae were obtained for age studies and the gonads and stomach contents analyzed. These specimens ranged from 418 to 1085 pounds in weight (average 770 pounds) and 2755 to 3475 mm. in fork length (measured from tip of lower jaw). Of the 26 specimens sexed, only 1 (4 per cent) was a male, and 25 (96 per cent) females. All the gonads examined appeared to be in a resting condition far from the ripe or recently spent stage. This would seem to indicate that black marlin were not in the process of spawning off northern Peru during the period of operation of the expedition. The females were considerably heavier (average 783 pounds) than the single male (445 pounds).

The sex ratio found in black marlin from Cabo Blanco and the apparent much larger size of the females suggest that the latter might not occur in company with the males except during the as yet unknown spawning season. In this connection, it is interesting to note that three specimens examined in Panama during July 14-16, 1953, ranged in weight from 200 to 366 pounds and were all males. In addition, interviews with local commercial fishermen and anglers familiar with the area, reveal that black marlin are much more abundant in the Cabo Blanco area during June through November, and very scarce or absent the rest of the year. The simultaneous occurrence of mostly females in Peru and mostly males in Panama during July is suggestive.

Whether or not the black marlin occurring in Peru form part of the same race or population as those occurring in more northern waters has not as yet been established. It is hoped that the biometric data obtained in Cabo Blanco may help in the solution of this problem. In addition, the oceanographic data obtained correlated with the occurrence of the fish in Peruvian waters and nearby areas, is expected to throw light on their migratory movements.

Examination of the stomach contents of the black marlin studied revealed a wide variety of food. Jack crevalle (*Caranx hippos*) were found in 7 stomachs and was the fish most frequently occurring in the stomach contents. Sometimes the stomachs would contain only this species and as many as 4 large jacks would be found in a single stomach. It is interesting to note that the occurrence of jack crevalle in Cabo Blanco waters was spasmodic and that the degree of abundance of the species in the commercial catch in the area, appeared to be correlated with the abundance of black marlin. Small sharks and manta rays (unidentified) were found to occur in 4 stomachs. Black skipjack (*Euthynnus lineatus*), yellowfin tuna (*Thunnus albacares*) and sierra mackerel (*Scomberomorus sierra*) were found in 4 stomachs. Bonito (*Sarda chilensis*) and cojinova (*Neptomenus crassus*) were found in 2 stomachs. Squid were found in only one stomach. Two stomachs were found to be empty and 3 were "thrown" by the fish during the fight. Seven stomachs were not examined.

The only other specimen of black marlin studied during the expedition was a female 552 pounds in weight and 2860 mm. in length, captured off La Plata Island, Ecuador, on October 3. The ovarian condition of this specimen was similar to those observed in the Cabo Blanco area and discussed above.

FIGURE 9. House utilized as headquarters by the expedition at Salango, during the period of work off the coast of Ecuador.

Only one sailfish was studied during the expedition. This specimen, a female 2370 in length (weight not taken), was captured off La Plata Island, Ecuador, on September 21. The ovaries were found to be in a resting condition not near the ripe or recently spent stage.

As already indicated, no sailfish were seen in Chile or Peru during the expedition. Interviews with commercial fishermen in Chile indicate that this species does not occur in that area. A number of specimens, however, have been taken in the Cabo Blanco area by anglers and commercial fishermen during the summer and indications are that the species is much more abundant there during that time of the year.

Of the 11 specimens of broadbill swordfish landed in northern Chile, 10 were measured and dissected. Vertebrae were obtained for age studies and to gonads and stomach contents analyzed. A small specimen 1960 mm. in fork length was skeletonized and brought back to the laboratory for osteological study. These specimens ranged from 231 to 772 pounds in weight (average 523 pounds) and 1960 to 2820 in fork length (measured from tip of lower jaw). All of 9 specimens sexed were females. The ovaries appeared to be in a resting condition, not nearly ripe or recently spent, thus indicating that spawning was not taking place in the area during the period of work of the expedition. The biometric data obtained will help determine whether the swordfish occurring off the coast of Chile forms part of the same race or population as those in more northern waters or represents an independent unit.

Although only 4 swordfish were sighted (none taken) during the angling operations off Cabo Blanco (July 24 through September 10) interviews with commercial fishermen and technologists of various fishing companies revealed that swordfish should have been much more abundant during July through October. In fact many commercial fishermen and fishing companies located in the vicinity of Cabo Blanco (Mancora) derive their livelihood almost entirely from swordfishing. A study of the statistics on monthly swordfish production in the area comprising the years August, 1948, through May, 1954, shows that the period of greater abundance has occurred during August through October with a peak in September. The expected run for the area in 1954 had not materialized when the expedition left in the middle of September. The statistics also show another period of abundance, to a lesser degree, during March. The periods of least abundance appear to occur during May through July with a peak in June, and during November through January, with a peak in December. Swordfish are present in northern Peruvian waters the year round but the statistics do not show the prevailing sizes of fish during the periods of greater and lesser abundance.

Statistics on swordfish production issued by the Chilean government for about the same period (1948-1952) as those covered by Peru, indicate a well marked period of abundance during May and June and a well marked period of least abundance during November through February with a peak in December and January. As further confirmative evidence, it is interesting to note that swordfish were very abundant off northern Chile during May and June, 1954, and that abundance decreased towards July. During the expedition angling operations in Chilean waters, 29 individuals were sighted during the period comprising June 1 through June 17, whereas only 18 individuals were sighted during the period comprising June 18 through July 6. On June 1, 9 broadbill were sighted in 1 hour and 15 minutes, between 1245 and 1400. A number of anglers operating out of

Iquique during the week of August 1 through the 8th, were unable to sight any swordfish.

Comparison of Chilean and Peruvian statistics show that the period of greatest abundance (May, June) in northern Chile corresponds with the period of least abundance in northern Peru, and that as abundance decreases in Chile from late June on, it increases at the same time in northern Peru, reaching its peak in September. On the other hand, the period of least abundance in northern Chile (November through February) also corresponds with another period of least abundance for northern Peru.

It may be tentatively inferred from the above that perhaps the Chilean and Peruvian swordfish may belong to the same population and that they may move towards the north, from Chile to Peru, during late June through September. It may be pointed out here, that commercial fishermen operating in northern Chile state that the schools of swordfish move from south to north (Tocopilla towards Iquique and Arica) during late June and July and that the commercial fishermen operating out of Mancora, northern Peru, have known for years that the September run comes from the south. The fish arrive first off Paita, about 65 miles south of Mancora and a few days later they show up off the latter locality. The coincidence of periods of least abundance for Chile and Peru during November through February may mean that the fish have moved into as yet unknown spawning grounds during that time before returning south. This period (November through February) comprises late spring and early summer in the southern hemisphere and it is interesting to note that Atlantic swordfish spawn during that season of the year in the northern hemisphere. As already indicated, the gonads of the swordfish examined in northern Chile during April through July, and in northern Peru during August, appeared to be in a resting condition, thus indicating that spawning must take place sometime between September and April.

In addition to billfishes, yellowfin tuna, bonito, mackerel, and other scombrid fishes were studied in northern Chile, Peru and Ecuador.

Other Biological Observations

During the period of work in Chilean waters, arrangements were made to cooperate with Dr. Francis O. Schmitt, head of the Department of Biology, Massachusetts Institute of Technology, in connection with studies of the giant nerve fibers of the squid (Figure 6). These are among the largest single nerve fibers in the animal kingdom and are being used in the above institution in the investigation of the chemistry of the squid nerve axoplasm.

Since the giant squid (Figure 3) occurring in the Humboldt current off Chile were expected to possess even larger nerve fibers, the expedition undertook to collect and dissect specimens in order to obtain material for study. Two specimens were collected and the dissected material sent to Massachusetts.

Observations on whales, incidental to the billfish work, were conducted on several occasions. The only species positively identified was the sperm whale which appeared to be rather abundant off Chilean waters.

COMMERCIAL FISHERY SURVEY

General

Acknowledgement is gratefully accorded to the various government agencies and commercial fishery operators for the data and statistics on commercial fisheries which have been used in compiling this report.

THE MAJOR SEA fisheries from Chile to Panama are for the tunas, which are found during every month of the year. Billfishes are also caught in some quantity and swordfish account for nearly 80% of the billfish catch in the area from northern Chile to southern Ecuador. This area now ranks third in the world's production of billfish, after Japan and its mandated islands, and the northwestern Atlantic from Cuba to Nova Scotia.

In northern Chile the billfishery has provided fish for local consumption for over half a century but no serious attempt has been made to export outside of minor quantities to a few neighboring countries and a small amount picked up at sea by an occasional refrigerator ship from the United States.

In Peru, commercial swordfishing started in the last years of World War II when the loss of the Japanese supply encouraged American fishing interests to search for new sources. American tuna vessels had reported large schools of swordfish off the northwestern coast of Peru for many years, and the first organized fishery was established at Mancora and Paita soon after the end of the war. No local industry had ever been built up, as in Chile, because the native fishermen have a superstition against eating the flesh of swordfish.

The Wilbur-Ellis Company of San Francisco has pioneered the Peruvian swordfishing, along with their tuna operation, and have been very successful. Modern harpooning methods and equipment are used and their rate of catch per man-boat for the number of fish seen is vastly higher than in Chile, where an older method is used.

The entire swordfish catch of Peru is exported, principally to the United States, either unprocessed or as steaks and fillets, by refrigerated vessels. A fair amount of black and striped marlin are harpooned each year, along

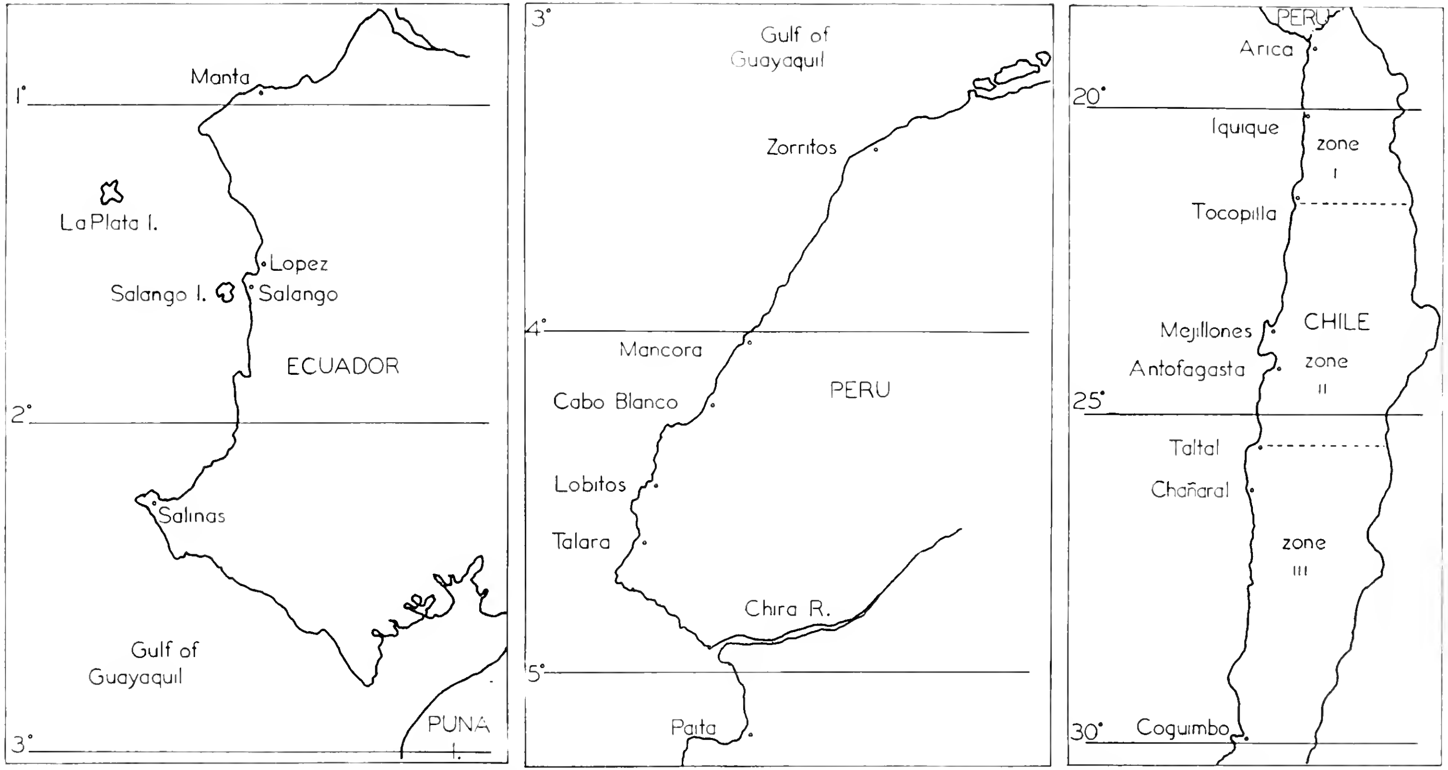

FIGURE 10. Map of Ecuador, Peru and Northern Chile, showing commercial fishing zones and area covered by the expedition.

with swordfish, in the area from Paita to Mancora. It is impossible to estimate the quantity since the fish are cut up on the beach and consumed locally. Due to the great demand for fish locally, all types of surface sharks are also harpooned.

The expedition introduced the first experimental work ever attempted on the west coast of South America in the use of the Japanese long or flag line fishing gear. Due to shipping delays of necessary equipment, it was impossible to start this experimentation in Chile. It was not until the establishment of the base at Talara and with the cooperation of the Wilbur-Ellis Company, that the first sets were made. This company very kindly conducted all the organization and operation of the expedition's equipment under the able direction of Mr. Donald Bates, Jr., their fisheries research expert. The results so far have exceeded all expectations as will be shown in the section under Peru.

From Peru northward across the Gulf of Guayaquil and along the Ecuadorian coast, commercial billfishing rapidly diminishes. A few swordfish are reported from twenty to sixty miles off the Salinas area during September and October and occasionally in February and March but apparently the large schools that touch the coast a few hundred miles south in the Mancora to Paita section, swing far offshore here, if they do migrate this far north at all.

The only commercial fishery in Ecuador is out of the Port of Manta. This town is unique in that it is the only area of the world, as far as is known, where the principal fishing operation is for black marlin. These fish are caught in substantial numbers during the months of June through October and in smaller quantities during other months, from Manta southwestward to La Plata Island. Along with the black marlin some Pacific silver or blue marlin, striped marlin and a few sailfish are caught. They are shipped in the frozen state, principally to Puerto Rico. Marlin fishing is done on the relatively shallow coastal shelf, but it is possible that they might also occur farther offshore.

Chile

The expedition's observations in Chile covered a period of three months, from April 22, to July 14, 1954. During that time the base was maintained at Iquique, the largest commercial fishing port in northern Chile (Figure 10). About 80% of the entire Chilean swordfish catch is landed here. The city also has the largest tuna canneries in South America and leads the country in total capital invested in fisheries. While the entire field operation of the expedition was devoted to the study of Zone I (Iquique) some data were compiled concerning Zone II (Antofagasta) and Zone III (Coquimbo). This information was very generously provided by the government and the local companies. (See Tables 1-4).

TABLE 1

NUMBER OF PEOPLE EMPLOYED IN THE CHILE FISHING INDUSTRY-1952

	Number of Fishermen	Crews on Cannery Vessels	Employees in Canneries	Total
Iquique	823	467	652	1,942
Antofagasta	538	113	340	991
Coquimbo	711	—	127	838
	2,072	580	1,119	3,771

NUMBER OF FISHERMEN IN VARIOUS ZONES AND % OF CHILE'S TOTAL-1943; 1951; 1952

	1943 — %		1951 — %		1952 — %	
Iquique	239	4.3	780	10.7	823	10.7
Antofagasta	294	5.3	492	6.8	538	7.8
Coquimbo	604	11.0	678	9.3	711	9.1

NUMBER OF FISHING VESSELS AND BOATS USED IN VARIOUS ZONES STUDIED, 1951 - 1952

	Over 10 Tons 1951	1952	Under 10 Tons (Motor Vessels) 1951	1952	Average 4 Tons (Row Boats)* 1951	1952	Total 1951	1952
Iquique	17	20	202	170	240	203	461	393
Antofagasta	4	4	100	110	212	203	316	317
Coquimbo	1	4	71	73	268	277	340	354
	22	28	273	353	720	683	1,117	1,064

*Note: Row boats and skiffs average less than 1 ton

ZONE I—IQUIQUE. This Zone is in the State of Tarapaca and includes the ports of Arica, Pisagua, Iquique and Cavancha. Arica, on the border of Peru and Chile, has a local swordfishing fleet of about twenty-five boats. The number of vessels is not constant in any one port since the boats shift from port to port, following the schools of fish. Arica has a small cannery and freezing plant. The cannery processes anchovies, sardines and bonito (Figures 12, 13). Most of the swordfish are frozen and exported to La Paz, Bolivia, by rail.

Southward, Pisagua is a shelter used by the fleets of Arica and Iquique when the fish are in that vicinity. Iquique, one hundred and twenty miles south of Arica, is the principal fishing port of the Zone. The main swordfishing fleet of Chile, roughly about one hundred boats, is based here, as are the principal tuna canneries. The latter are three in number and include large freezing capacity. One, Pesquera, Iquique, is the largest in South

America. In the southern end of the Zone there is a sheltered harbor at Pt Lobos which is used when the fish are coming from the south. Zone I includes about 250 miles of coast line.

TABLE 2
COMPARATIVE PRODUCTION OF FISH IN CHILE
(By Species)

	1945 x	1956 x	1947 x	1948 x	1949 x	1950 x	1951 x	1952*
Anchovies	253	416	273	927	689	570	436	427,680
Tuna	2069	918	479	274	454	412	570	773,658
Bonito	592	409	1679	2426	4250	2927	3973	4,886,415
Swordfish	1455	2166	1701	1209	690	786	870	570,113
Sardines	2872	3346	3259	1211	7397	14261	7588	4,436,757

(By Zones)

1952	I Iquique	II Antofagasta	III Coquimbo
Anchovies	95,400	31,635	21,750
Tuna	139,600	925	6,948
Bonito	4,499,050	387,365	——
Swordfish	481,800	44,590	43,723
Sardines	348,100	1,894,710	12,430
1951			
Anchovies	289,600	71,560	32,625
Tuna	151,900	——	3,684
Bonito	3,510,100	461,300	1,558
Swordfish	560,250	244,140	65,734
Sardines	134,400	1,752,135	8,000

x in tons
* in kilos

ZONE II—ANTOFAGASTA. This Zone includes the entire State of Antofagasta and the ports of Tocopilla, Mezillones, Antofagasta and Taltal. Tocopilla, at the north end of the Zone, is the main swordfishing area. There the fleet comprises from thirty to thirty-five boats. These at times overlap with the Iquique fleet, depending on where the main body of fish lie and which port is paying the higher price. Next to the south is Mejillones, situated on a long headland north of Antofagasta which port is too far southeastward in a deep bay to be able to reach swordfish grounds. The last port south in the Zone is Taltal. Because it is rather remote not much information is available. About a dozen boats fish swordfish, plus, probably, a few more from the smaller villages adjacent to it. It is well to note that in all Zones, every little village has a few craft available for harpooning when the fish are in the vicinity. The fish are consumed locally and since no government inspectors are available it is impossible to estimate the catch accurately. For this reason no catch figure is included for this area in the totals in the table. Zone II ranks second in swordfish production. Its coast line is about 250 miles long.

ZONE III—COQUIMBO. The States of Atacama and Coquimbo comprise this Zone. It is the longest of the three, being about 400 miles in extent.

TABLE 3
CANNERY PRODUCTION IN CHILE, ZONE I—1951*

Companies and Products	Raw Material	Total	Finished Prod.	Total
Pesquera Iquique S.A.				
El Colorado—Iquique				
Tuna in Oil	20,399		9,233	
Tuna Natural	20,413		8,463	
Bonito in Oil	1,598,611		636,657	
Bonito Natural	473,678		197,678	
Shark—Dried	24,511		5,802	
Industrial Oil			3,221	
Fish Meal		2,137,612		1,015,988
Sociedad Ind. Pesquera				
De Tarapach Ltda.—Cavancha				
Anchovies in Oil	58,590		17,597	
Anchovies Natural	1,760		137	
Anchovies in Tomato	87,355		36,023	
Tuna in Oil	49,079		14,597	
Tuna Natural	32,045		9,234	
Bonito in Oil	454,378		120,040	
Bonito Natural	593,709		151,512	
Swordfish in Oil	1,420		148	
Swordfish Fillets	1,124		557	
Sardines in Oil	11,418		3,115	
Sardines in Tomato	3,092		920	
Shark—Dried	39,666		10,415	
Fish Meal		1,333,636	227,022	591,317
Sociedad Pesquera Ind.				
Ltda. Pacifico—Iquique		343,686		102,853**
Jorge Cerda "Buen Gusto"				
Arica		579,306		202,516**

* in kilos ** (No Swordfish)

Table 4

Cannery Production in Chile—Zones II & III—1951*

Companies and Products	Raw Material	Total	Finished Prod.	Total
II Zone: Antofagasta				
Compania Ind. Pesq. De Antofagasta—Cipa				
Bonito in Oil	2,800		1,129	
Bonito Natural	300		184	
Sardines in Oil	453,455		101,778	
Sardines Natural	96,930		42,381	
Sardines in Tomato	6,475		2,425	
Fish Meal	240,170	800,130	51,686	199,583
Mateo Zlatar O. "El Cobre"—Caleta				
Anchovies in Oil	11,760		2,940	
Bonito in Oil	42,390		12,906	
Bonito Natural	63,505		21,779	
Bonito Meal	9,340		1,868	
Sardines in Oil	118,015		19,916	
Sardines Natural	357,632		115,543	
Sardines in Tomato	145,850		39,890	
Fish Meal	89,073	837,565	17,814	232,656
III Zone: Coquimbo				
Industrias Pesqueras Guayacan				
Anchovies in Oil	21,325		11,575	
Anchovies in Tomato	11,300		6,818	
Bonito Natural	1,558		861	
Mackerel Natural	46,392		25,558	
Red Snapper in Oil	16,425		12,779	
Red Snapper Natural	69,461		35,695	
Fish Meal	54,610	229,092	31,725	131,337**

* in kilos ** (No Swordfish)

No reliable reports of swordfish have been received south of Coquimbo The two major swordfish ports are Chañaral and Caldera. Chañaral is probably the major producer since more boats are reported fishing from here. About twenty to twenty-five boats fish from this port during a relatively short season. A short distance to the south is Caldera, apparently the next best producer in this Zone. No figure is available on the number of boats, but it probably is about that of Chañaral. A few fish are reported taken from Coquimbo north, and this area is assumed to be the southern boundary of the swordfish migration on the coast of Chile.

Fishing Methods and Procedures. Swordfishing in Chile is a primitive operation. The harpoon is used and aside from slightly larger boats and improvements in the motors used, there has been no material advance in the last twenty-five years. This can be attributed to a lack of organized fishing and adequate financing. Generally, northern Chile can be considered virgin territory for the development of modern techniques in this type of fishing.

Boats. The craft used in swordfishing are of one general pattern. They are of a double-ended sea-skiff design, from 22 to 28 feet in length. They were formerly powered by oar and sail. However, by the mid-twenties conversion to power had started. By 1940, the entire fleet was motorized. Due to the Import Tax and to the cost of motors the boats are vastly underpowered. The motors are of British or German design and manufacture. The average horsepower is about 20-30 with a very few as high as 60 H.P. The boats are of heavy hard-wood construction and the average cruising speed of the fleet is 5 knots, with a top of 7 knots. The boat design is a completely open cockpit and flush deck, divided into four to six sections for storage of gear, fish and a shelter for the crew. The freeboard, at bow and stern, is about three and one-half to four feet, with roughly two feet midships. The use of a pulpit for harpooning has never been tried in Chile, primarily due to lack of example, plus the small size and slow speed of the craft. In general it is apparent that any future expansion in this field will require a complete redesign of the present type of boat, coupled with the necessary increase in power. This can be achieved in Chile only by the active support of the commercial companies. It would be financially impossible for an individual crew or group of crews to acquire the desired equipment.

Fishing Equipment. The gear employed in the commercial harpooning of the billfishes is as obsolete and inefficient as the boats, because of the lack of organized backing to fishing, and because each boat and its crew operates as an independent unit, living a hand to mouth existence. Fishermen have never had commercial or government encouragement in developing efficient equipment.

The cost of good gear is beyond fishermen's means. Instead of longline manila or cotton rope for their harpoon lines they manufacture their line themselves, from any old marine rope. This is destranded, blended with raw, long manila fiber. The final result is a line of low tensile strength. A rough ¼″ native line will break at about 175 to 225 pounds in comparison with a 450 pound test of machine made cotton. Many large and active fish are lost because of this.

The harpoons or darts used are of the conventional American design and

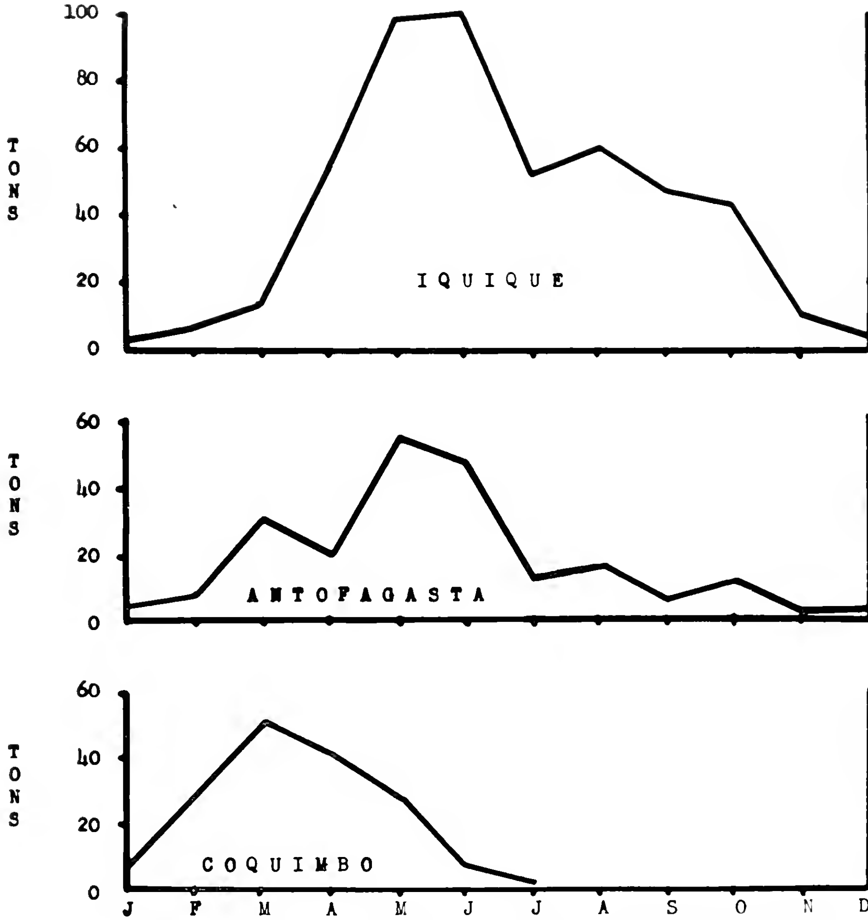

FIGURE 11. Production of swordfish in northern Chile by zones, during 1948-1952. Monthly averages.

are manufactured locally. The metal used is copper or raw iron, and the dart is shorter and has less surface area than the American model. Also, there is less angle at the tail flanges. The chance of pulling or ripping the dart out is thus increased.

Darts are connected to the line by 3 to 5 feet of cable or twisted wire. Some fishermen use a 1/8 to 5 32 nylon or dacron connection, which has less tendency to tear the flesh of the fish than metal. No key or barrel is connected with the line to restrict the movements of the fish after it is harpooned. The standard Chilean procedure today is to handplay the fish. Should all available line be taken out with a strong fish any buoyant material in the vessel is tied on with the hope that the fisherman can follow gear and fish.

Harpoon poles are of a heavy wood, 2″ to 2½″ dia., length 10′ to 12′ They are short and heavy because of the low freeboard of the boat and its lack of pulpit necessitating the striker throwing in a high arc to reach the fish before it sinks.

From a study of billfish production in Chile, it appears that the accepted concept that the swordfish migration to this part of the continent come from the South, touching Chile about at its mid-point (roughly the Coquimbo area) and progressing northward with the flow of the Humboldt or Peru Current, is substantially correct. The figure (Figure 11) showing monthly average production from 1948 to 1952 supports this. Zone III,

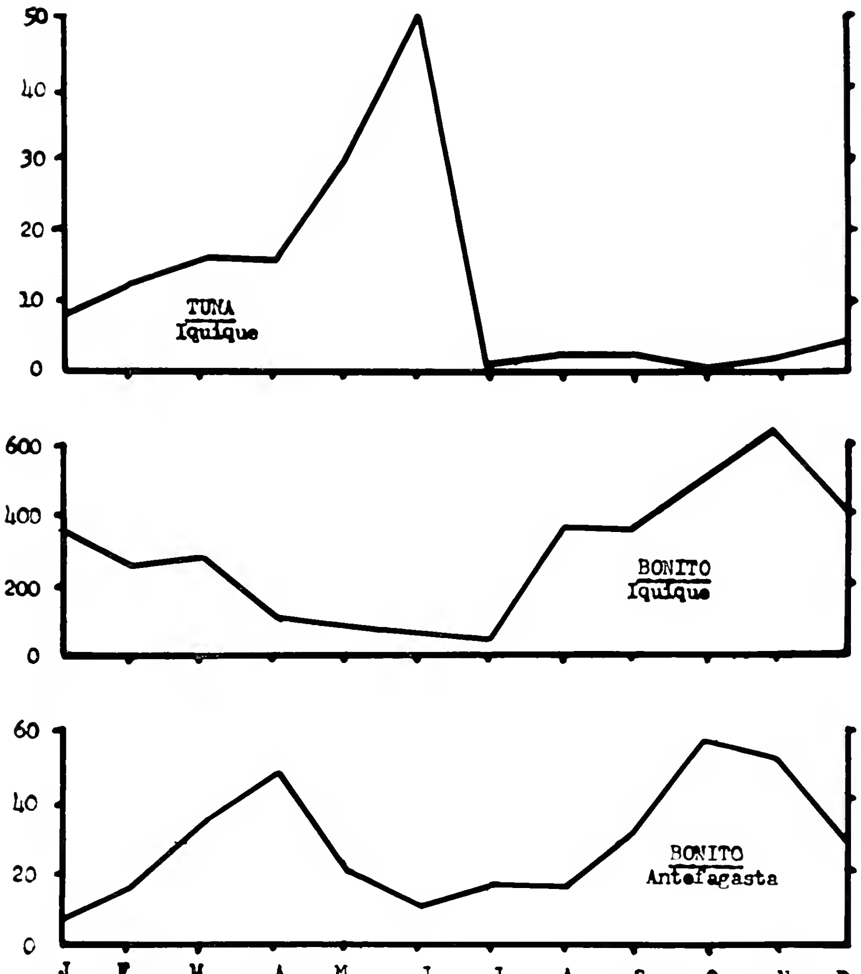

FIGURE 12. Production of tuna and bonito in northern Chile by zones, during 1948-1952. Monthly averages.

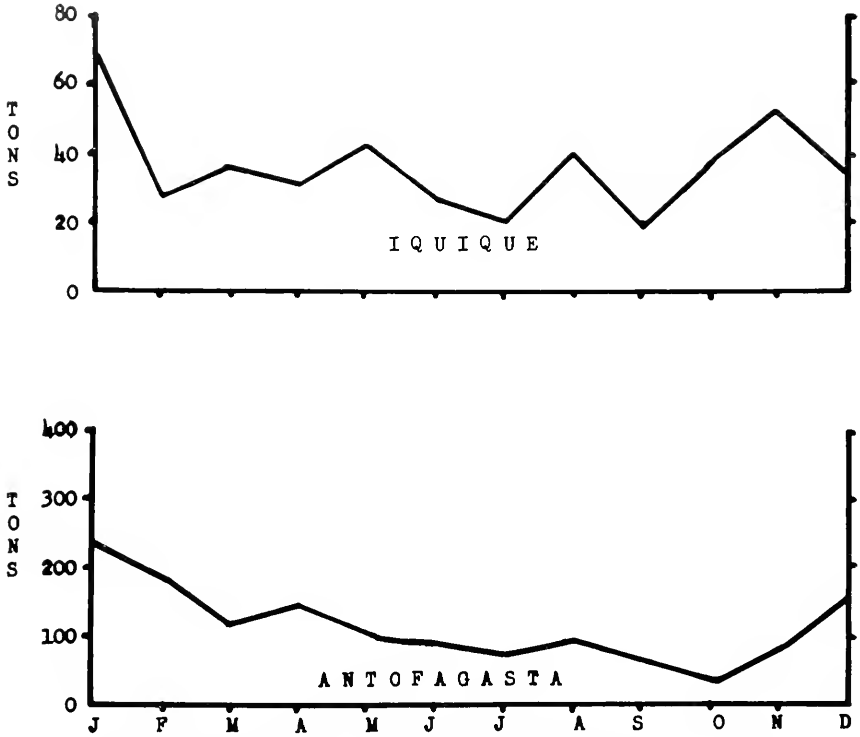

FIGURE 13. Production of sardines in northern Chile by zones, during 1948-1952. Monthly averages.

Coquimbo, shows the major production of the year. It also shows the least, but in all probability, if the same number of boats operated here as in the Iquique area, the catch would be more than doubled.

As the schools flow northward or slant in from the ocean, there is increased production in the Antofagasta Zone, and its peak is about two months later than Coquimbo. Again the number of boats and fishermen involved is far less than Iquique. The fish here seem to swim farther offshore; due to oceanographical features, the clear blue water does not come in as close as in the Iquique Zone and it is in this water that the bulk of the fish are found. In Zone I (Iquique) heavy production occurs for the longest period of the year, the majority of the fleet operating from four to five months.

At Arica, the coastal shelf of Peru is encountered and the fish swing out to sea. No production is found in central and southern Peru. While it is evident in all three zones that swordfish do travel from south to north, it seems possible that additional fish are constantly arriving from the outer ocean, especially in Zone I (and due to warmer water and better feeding conditions, hold closer to the coast for longer periods).

The extent of the marlin migration is far more limited than that of swordfish. Their range is throughout Zone I and somewhat south of Antofagasta in Zone II. None are reported in the northern part of Zone III. The duration of their stay is quite short, roughly the months of March, April, May and early June. However, in some years a few marlin are in evidence as early as February in the Tocopilla-Iquique area. They are practically non-existent in these waters after July 1. It is assumed that they proceed from south to north, following the current. The marlin range much closer to shore than the swordfish, preferring the belt of green water inside the clear blue. The expedition also discovered that they seem to occur in greatest numbers in the areas of warmer water, and feed more actually here. In some years the catch of marlin may be as much as a third that of the swordfish, but the average is about 20%. The selling price is 40 to 45% that of swordfish.

One hydrographic feature of Chile must be remembered in considering the fisheries. There is no continental shelf, since the coastal range of the Andes enters the sea at a steep angle, and from the border of Peru southward for nearly 600 miles the 100 fathom curve will be found about one-half to three miles offshore. In this stretch, uninterrupted by banks or islands, it is natural to assume that the swordfish and marlins will follow a pattern of temperature, salinity and food conditions most suitable to their needs.

Peru

General. This expedition, during its two and a half months operation in the waters of Peru, was based at Talara (Figure 10), which is the principal refining and oil shipping port of that country.

This area was chosen for the study of billfish in Peruvian waters because it is the heart of that type of commercial fishing and the black marlin caught here are the average largest in size found in any part of the world. Both the black and the striped marlin occur here every month of the year, and the area has also two distinct runs of swordfish, in the summer and the winter seasons.

Since 1947 several seafood companies have been established at Mancora on the north of Talara, and at Paita on the south. These enterprises are primarily devoted to the catching of swordfish and tuna. This industry has flourished rapidly in recent years. It appears now with the tremendous demand for fish sticks and fillets in the United States that it may be commercially profitable to develop bottom fishing on a large scale. Both Mancora and Paita have very modern refrigeration and packing plants. The leading company is the Wilbur-Ellis Corporation of San Francisco, which initiated the first commercial swordfishing operation in 1947, and has steadily expanded ever since.

There are two separate runs of swordfish in these waters, one which arrives in the summer season just after the first of the year and remains until the end of March, and the second which appears the end of August and remains until the end of October. The entire catch of these fish is exported by the American Company in Manta to the United States.

It is interesting to note that swordfish have been reported in these waters for many years, yet no commercial fishing for them was practiced until the Wilbur-Ellis enterprise was started, owing to a native superstition. While the marlin and sharks are in constant demand, the native, even today, is very reluctant to eat swordfish.

This section of Peru is the only area of commercial swordfishing. Farther south, through central and southern Peru, an extensive coastal shelf is encountered, and consequently the fish are beyond the reach of the small type of boats employed. Along with the deep water and the strong ocean current found here, an added inducement for swordfish is a series of banks northwest of Ancora. These banks have a high concentration of bottom fish, which is the favorite food of the swordfish.

The population of fish in the two schools that migrate to this area are far more extensive and concentrated than any found off the coast of Chile. Here, a marked decrease was noted in the size of the fish. The average Chilean swordfish weighs slightly in excess of 500 pounds, while the Peruvian fish will run above a 350 pound average. This difference in size between two areas more than 1,000 miles apart, may possibly indicate the entirely separate populations of fish.

The yearly production in this relatively small area of Peru is nearly as great as that of the entire three zones of Chile previously described; in fact, there were good years when it actually exceeded the production of Chile. All available production figures for swordfish and tuna are given in Table 5. Along with the swordfish there is a large population of black and striped marlin. Also a few sailfish are seen in the summer months.

The black marlin caught here are by far the largest found in any part of the world. Since the start of sport fishing at Cabo Blanco and the fairly extensive harpooning of the black marlin by the sword fishermen, the average weight has been close to 800 pounds. During 1954, the fish were exceptionally large and the average went up to 850 pounds. It is not known why these fish should be so large here in comparison with other black marlin populations in Australia, New Zealand, Ecuador and the Gulf of Panama. It also seems odd that a small fish in the vicinity of 400 pounds is rarely seen here. All the world's records of black marlin fish recorded in the past five years have been caught at Cabo Blanco. The present record is 1560 pounds and it seems possible that the maximum size may be in excess of 2,000 pounds. There have been some extremely large fish harpooned but, unfortunately, they were never weighed before being dressed.

The black marlin, while present every month of the year, seem to predominate in the winter season, during the months from June through October. This is the windiest season of the year, having an average daily velocity of 20 knots. Its prevailing direction is from south to southwest. This course of the wind holds generally from northern Chile through southern Ecuador. The black marlin seem to prefer to surface, traveling with the wind when the weather is the roughest. In the calm summer months, or on any relatively calm day few fish are seen on the surface. It is interesting to note that this is the only part of the world where this fish is seen on the surface in any great numbers.

The striped marlin off northern Peru are much smaller than those off Chile. The average is not more than 150 to 160 pounds. They appear in the greatest numbers during the late summer; the months of February, March and April appear to be the height of their season. During this period there are also a few sailfish in the Cabo Blanco to Mancora area. This point is probably the southern-most limit of the sailfish migration from the north. As far as could be ascertained, there is no concrete evidence of the so-called Pacific silver marlin being caught here, though the fish do occur a relatively short distance north off southern Ecuador. The entire catch of these fish is exported, according to the records provided by the Wilbur-Ellis Company.

The principal commercial fish of Peru are the tuna and the bonito. The greatest concentration of the yellowfin tuna is in the vicinity of Mancora and the adjacent banks on the northwest. Farther south, from Paita to central Peru, is the main range of the bonito, both the common and the oceanic varieties being caught in quantity.

The main bulk fish canned in Peru are the two varieties of bonito. This production of canned fish is done by six domestic and two foreign companies, both of which are American controlled and operated. Their yearly production by the month is illustrated in the government Fisheries Reports appended to this section on Peru.

Geography. The area studied encompasses the northwest section of the coast line of Peru (Figure 10). This area is the most westerly point of the South American continent. It is bounded on the north by the Gulf of Guayaquil, the center of which is 3° south of the equator and extends to the vicinity of Paita, 6° south. The principal commercial fishing ports are at Mancora at the north end of the area and Paita on the south. The distance separating these two points is only about ninety miles, but generally speaking, they have opposite seasons and different fishing conditions in relation to the production of swordfish. This is due, to a great extent, to the separate and rather unrelated geographical features. Paita on the south is still affected by the Humboldt current sweeping up from Chile. For reasons not ascertained this produces an early school of swordfish in the months of February, March and April. When the southerly inshore Niño current is fairly strong here, these fish penetrate it in quantity and are caught relatively close to the coast line. As there are no settlements or villages of any importance south of Paita, nothing is known concerning the first contact of this particular group of fish with the continental shelf. The 100 fathom curve from Talara, which is the center of the area, is distant from five to thirty miles offshore, increasing in distance in going southward from Talara. During the run of swordfish in the southern part of the area, very few are caught in the vicinity of Mancora. This port, at the southern end of the Port of Guayaquil, has its peak production from a second school of fish in the months of August, September and October. At the same time the production in the vicinity of Paita is light. Why two adjacent ports should have such different periods of productivity, is a mystery still to be solved.

It is the general supposition that the early season school of fish in the vicinity of Paita arrives from a southwesterly direction, similar to the movement of fish off northern Chile. At the height of production off Mancora the swordfish seemed to drift towards the coast from a westerly or northwesterly direction, first arriving on the banks between Mancora and Zorritos about thirty miles to the north. These banks, as before mentioned, are from 25 to 40 miles offshore. The average size of the fish, in both cases, seems to be about the same, though the Wilbur-Ellis Company reports that there are more very small fish produced in the Paita area. These little fish run as low as 25 or 30 pounds in weight and there are many caught weighing about 60 to 80 pounds. This, apparently, is the only point on the west coast of South America where the small swordfish are in evidence. Southward from Paita there are reports of swordfish from American tuna clippers and Grace Line freighters. These fish are seen from 40 to 100 miles offshore and generally from the months of April through October. In the northern end of the area, from Zorritos across the Gulf of Guayaquil to Salinas, Ecuador, there is very little recorded about the fish. While a few have been taken from 40 to 60 miles offshore in the vicinity of Salinas, it would seem logical to assume that the vast majoriy of fish in the Mancora area retreat to the westward and toward the range of commercial fishing observation.

The migration of marlin to these waters, both the black and the striped, is as complex as that of the swordfish. The striped marlin have an early year run, roughly from January through May. Their greatest concentration is from Talara to Mancora with a fair scattering of fish extending southward to the vicinity of Paita. There are occasional fish caught every month of the year but they are most plentiful in this particular period of time which is the summer season and the calmest period of the year. The greatest predominance of black marlin is in the winter season and also the roughest. Why these two species should be so different in their seasonal occurrence along this coast is not known. Food conditions are excellent in any season of the year, so apparently this has little or no bearing on the question.

FISHING METHODS. The commercial production of billfish off the coast of Peru is solely through harpooning. Due to American training and equipment since the war, fishing methods are the best encountered along the west coast of South America. Before the war there was little, if any, swordfishing, and the fishermen concerned themselves with casual harpooning of marlin and sharks in the course of their general bottom fishing operations.

While the fishermen have not been harpooners by nature, they have developed skill rapidly in the past seven or eight years through the operations of the Wilbur-Ellis Company. The primitive methods encountered off northern Chile have never been used here and consequently the fishermen have readily adopted modern techniques.

The average size of craft employed is from 25 to 30 feet in length. It is equipped with a conventional harpooning pulpit or plank of about 8 to 12 feet in length. The length of the plank is restricted because of the rough water encountered in the winter season. These boats are powered with two or four cylinder engines and have relatively low horsepower. They do not have the required speed for full efficiency, but are fairly adequate. All the gear and equipment relative to harpooning is of local manufacture but of American design, the only exception being that most of the line is imported. This reduces considerably the number of fish broken off, in comparison with Chile.

Methods of approaching the swordfish are strictly conventional and differ from those employed in Chile. The fish is approached from the rear, and the vessel is kept on the outside of the fish if it shows a tendency to circle. The only apparent weakness observed in this operation is that the harpooners show a tendency to throw the pole a little prematurely instead of waiting an extra few seconds until they are in effective striking range The fishermen are rather light and small in stature, but seem to prefer a very long, heavy, wooden harpoon pole. Probably their efficiency could be much improved if they were provided with one of hollow metal construction. They show a strong inclination to start hand lining the fish from the vessel as soon as he has been struck, instead of allowing it to tow a float with a flag attached until it is tired. This wastes a sizeable amount of the vessel's time which is obliged to deal with individual fish rather than having several harpooned at the same time during a good day in the peak of the season.

The fishermen harpoon anything that shows on the surface. Consequently, a considerable amount of black and striped marlin, and sailfish are killed. Along with all types of sharks they are much in demand for local consumption. There is no export of the marlin such as that encountered in Ecuador, due to the lack of sufficient quantity. A small amount of all types of billfish are killed by the fleets of sailing craft operating from the various ports in the production of bottom fish. They all carry harpooning equipment and sailing back and forth from their fishing grounds have an opportunity occasionally to strike a fish on the surface. There was no evidence of attempts at drift fishing for the billfish, as practiced off Cuba. Occasionally the hand line fishermen on their balsa rafts, or from their small sailing craft, hook a swordfish or a marlin, but due to the light line used these fishes are almost always lost. In some seasons of the year, especially in the months of February, March and April, numbers of big-eye and larger sized yellowfin tuna are hooked by the drifting fishermen. A few are caught but the result is about the same as that with the billfish.

The Wilbur-Ellis Company has shown the possibility of producing markets for white meat fish, fillets and fish sticks. This is just approaching the commercial production stage. Production of a large volume of bottom fish would seem doubtful, due to the lack of a coastal shelf.

TABLE 5

EXPORTS OF FROZEN FISH FROM PERU

In Net Tons

	1948	1949	1950	1951
TUNA*				
Ilo	——	——	——	127
Mancora	——	——	533	1248
Paita	279	897	2808	5044
Talara	10	320	3172	311
SWORDFISH				
Mancora	——	——	386	——
Paita	274	200	446	1035
Talara	140	1114	1652	86
TOTAL	703	2531	8997	7851
SOLES	898,200	6,956,800	22,761,800	17,348,900
U. S. $	44,910	347,840	1,138,090	867,180

* All exported to U.S.A. except for 10.3 tons of tuna to Italy in 1950.

From the Port of Talara to Cabo Blanco, a section of the coast line controlled by the International Petroleum Company and the Lobitos Oil Company, there is a serious shortage of food. Both companies subsidize the local fishermen, providing them with living quarters and other necessities of life. This is done at a considerable cost, without any attempt to train the fishermen or provide them with modern equipment. The entire operation of the fishing fleet from these various ports is by sail. It is obvious that much can be done to improve the production and the efficiency in this section.

The expedition unfortunately did not have enough time, or the opportunity, to examine fully the commercial tuna industry of the country. The results of the Wilbur-Ellis Company operation, both of swordfish and tuna are in the appended figures.

Experimental Longline Operations. Longlining operations were conducted by the expedition from the Port of Mancora, aboard the motor vessel *Corsario,* owned by the Wilbur-Ellis Company. The longline was constructed and operated under the supervision of Mr. Donald Bates, Jr., fishery technologist for the Company (Figure 5). The following information has been prepared from periodic progress reports sent by Mr. Bates.

The gear employed consisted of 8 baskets of Italian hemp line, 3/8″ in diameter. Oxygen tanks of 2100 cubic inches of capacity were used as floats, 5/64″ wire was used for leaders, and size 8/0 Japanese tuna hooks. Each basket comprised 6 hooks with 7 on the end basket making a total of 49 hooks fished. Drop lines were standardized at 8 fathoms, including one fathom of leader wire. The mainline was made up of 20 fathom sections, with a total of 100 fathoms to each basket.

Since the Italian hemp line is soft lay, setting and retrieving times were somewhat slow, averaging one-half hour and one hour respectively. Furthermore, the vessel's winch slowed the retrieving operations because of the direct drive from the main engine. By allowing the *Corsario* to drift during favorable weather, this handicap was somewhat overcome as the engine RPM could be increased with the drive clutch disengaged.

The gear, set downwind, floated well on all occasions, with little tendency to bunch and tangle. A combination of a strong current setting to the south with a strong wind from the southwest accounts for the baskets remaining in virtually the same positions. The entire gear, however, drifted southward. In general, during the period of operations, winds were slight during the night and early morning hours, increasing to about 35 knots during mid-afternoon. The choppy seas would make retrieving the gear extremely difficult for a small boat but not impossible.

One problem in introducing new fishing methods into an area is the fishermen acceptance and adaptability in handling it. The *Corsario* crew was apparently enthusiastic about fishing the longline and the men were able to understand the procedure with only two days of direct supervision.

The bait used for the longline tests comprised sardines and mullet from 6 to 8 inches long.

The abundance of giant squid in Peruvian waters presents a problem in connection with the feasibility of longlining in that area. Many baits were taken from the gear by these animals during the tests, but in general they were not as bothersome as expected. Apparently the squid occur in belts and in colder waters. Daily drops of a squid "test" line before setting the gear did not prove too helpful in detecting their presence. Even though squid might have been present as shown by the loss of baits, it was encouraging to note that the majority of tuna captured on the longline were unharmed. Also, the lack of shark-eaten tuna was encouraging.

The area covered by the longlining operations (about 160 square miles) comprised a zone between 3 and 30 miles from shore and extending from Cabo Blanco to Zorritos, a distance of about 60 miles.

Longline fishing tests were begun on August 13 and continued through October 15. Although the expedition left Peruvian waters about the middle of September, longlining operations continued until the above date. A total of 27 fishing days were devoted to the investigation and 29 sets were made. The baits were fished at depths ranging from 20 to 110 fathoms. During the period of operations, surface temperatures ranged from 17 to 22 degrees Centigrade (average 20.5° C.).

A total of 80 fish were obtained from the 29 sets made corresponding to an average of 2.75 fish per set. Since 49 hooks per set were fished, this means that an average of 5.6 fish per 100 hooks was obtained. No catch was obtained in 8 sets and the number of fish obtained per set ranged from 2 to 9.

The 80 fish obtained comprised one skipjack (1.2 percent), 2 broadbill swordfish (2.5 percent), 3 cojinova (3.7 percent), 4 big-eye tuna (5 percent), 22 shark (27.5 percent) and 48 yellowfin tuna (60 percent). The only skipjack taken weighed 6 pounds and was hooked at a depth of 30 fathoms. The 2 broadbill swordfish weighed 400 pounds each and were hooked at depths of 30 and 50 fathoms. The 3 cojinova were all taken on a single set and no weights or depths were reported. Two of the big-eye tuna weighed 250 pounds each and were taken on the same set at a depth of 70 fathoms. The other two weighed 240 and 270 pounds and were taken on separate sets at depths of 110 and 30 fathoms respectively. The sharks ranged in size from small to large (not weighed) and were taken in depths ranging from 20 to 90 fathoms. Yellowfin tuna comprised more than half of the catch and ranged in size from 10 to 70 pounds (average 23 pounds). More than half of the specimens weighed 15 pounds; only

6 weighed less, and only 2 weighed 50 pounds or more. It is interesting to note that with one exception, all of the specimens were taken in depths ranging from 20 to 60 fathoms and most were taken between 30 and 50 fathoms. There is no apparent correlation between size and depth of capture.

The results of the preliminary experimental longline sets indicate that longlining for yellowfin and big-eye tuna, both important commercial species, may be profitable in Peruvian waters. Although only two swordfish were taken, it must be remembered that as already indicated, the expected run for that time of year had not materialized during the period of operations.

ECONOMY. Peru has a commercial fishing organization far in advance of the Chilean industry. The domestic companies are well organized, and joined with a cooperative organization in Lima are doing an excellent job. Foreign capital and enterprise in the commercial fishing field has been more successful, due to the modern training and improved types of equipment provided.

The country itself has a stable currency and strong government control and organization. Because of the availability of fishing labor, the average income per day is only slightly higher than that encountered in northern Chile, roughly 15% to 20% more. The yearly average income is about a third higher than Chile, due to more constant employment. This can be directly attributed to a better organization of the fishing interests, both foreign and domestic.

Peru has partial price control on ocean fish production but it is not as rigidly controlled as in Chile.

The fishermen are about equally skillful and energetic as those of Chile. They are kept much closer to the coastal line in their operations, due to adverse weather encountered, and to the fact that the fish are encountered closer to the coast because of the oceanographic features of that part of South America.

Ecuador

GENERAL. In the short time of one month that this expedition spent in Ecuador, operating in the vicinity of La Plata Island and Salango (Figure 10), very little opportunity was offered to study the commercial fishery. The greater part of the information available concerned the history of the fishery. Ecuador and its adjacent waters have been very potent in the past as regards the tuna industry of the United States. The area is the most southerly limit of operational tuna fleets from Southern California. It was not until 1949 that any American enterprise became established in Ecuador.

Since the primary purpose of this expedition was the study of billfish in the southeastern Pacific area, it was natural that interest should be concentrated upon them in this particular section of the coast line of Ecuador. The area investigated by the expedition included Manta on the north to Salinas in the south and was primarily devoted to the area surrounding La Plata Island. This site was chosen because it is probably the only area in the world where black marlin are caught commercially in a well defined season. These marlin, both black and striped, have been caught here for many years, but it was not until 1950 that they supported a commercial operation.

As a result of research by an American seafood corporation, it was deemed practical to establish a refrigeration plant and a cannery at Manta. In the course of the establishment of the original operation of this enterprise, it was discovered that marlin in the vicinity of La Plata Island and Manta, the adjacent part on the mainland, could be caught in profitable commercial quantity. This situation developed primarily because of the demand for large bulk fish in the West Indies. The operation arose from a contract with the Ecuadorian government to collect and process the bottomfish from the Galapagos Islands and the coastal shelf of Ecuador. When it was determined that billfish could be caught in quantity in the vicinity of Manta, the local fishermen were encouraged to expand their operation and were supplied with the necessary equipment to increase the production of this type of fish. This experiment has proven to be very successful since its inception.

The area for commercial marlin fishing around Manta is undoubtedly the largest in the world, and it is our opinion that the production possibilities have barely been scratched, if the demand for this type of seafood continues to exist. With training in the improved modern methods of fishing and equipment, the catch of these billfish could be vastly increased.

This area of the southeastern Pacific is not productive of swordfish. The Gulf of Guayaquil appears to be the northernmost limit of the swordfish schools. Possibly due to the extensive coastal shelf and the meeting point of the Humboldt and the south equatorial current, the schools of swordfish may be driven far offshore in the vicinity of Ecuador. From all reports, only a few fish are ever seen, and only in the latitude of Salinas, from 40 to 60 miles from the coast.

The principal billfish caught off the coast of Ecuador are the black marlin, the striped marlin, the so-called silver marlin and the sailfish.

Since there are no accurate governmental records available, it is impossible to estimate the yearly production of the various species. A conservative estimate of the yearly export of these fish from the port of Manta, would be between 150 and 200 tons. Practically all of this export of fish is picked up by refrigeration vessels and sold in Puerto Rico. It is interesting to note that this area appears to be the southern-most limit of the migration of the so-called silver marlin of the Pacific. While this fish is caught in most of the tropical and subtropical areas of the Central Pacific, its range along the western coast line of North and South America appears to be limited to the mouth of the Gulf of Lower California on the north and south to the area under consideration. There have been a few reportedly caught south of the Gulf of Guayaquil in the vicinity of Mancora, Peru but no definite records were available to substantiate this.

Black marlin were found to be predominant in about the same season as in the northern part of Peru on the south side of the Gulf of Guayaquil. Again, the fish appears in the greatest abundance from June through October. The only marked difference in the fish is its size. While the average fish caught in the Mancora area of Peru is between 700 and 800 pounds, the average fish caught off southern Ecuador run less than 500. Also, it is interesting to note that 1,000 pound black marlin are rarely caught in Ecuador but are fairly common 200 miles south in Peru. A small fish in the 200 to 300 pound class is seldom seen in the Peruvian waters studied, yet they are very common in the adjacent Ecuadorian waters. According to the ichthyological studies conducted during the expedition, the size of the fish appears to be correlated with sex, the females being the larger.

The striped marlin in this vicinity of Ecuador arrive in their greatest quantity much earlier in the year than the blacks. From the information available, it appears that they arrive at their peak in the months of March, April and May, which are roughly the best months for the same fish off the northern coast of Chile. As in the case of the black marlin, there is a reduction in the size. It appears that they weigh 120 to 140 pounds. The few caught during the period of the expedition in these waters were very small, averaging around 100 pounds. It is interesting to compare the three zones in which the expedition studied the striped marlin. In northern Chile the fish averaged very close to 300 pounds. From central to northern Peru the average was about 180 to 200 pounds and finally they declined to the above mentioned weights in southern Ecuador. From morphometric standpoint these fish are similar in every respect.

A third species of marlin is recorded from this area. It is possible that this fish may be identical with the blue marlin of the Atlantic. It is hoped to clarify this in the near future. The fish itself is not common in this particular part of the Pacific or any other area with the exception of the Hawaiian Islands. This marlin may occur any month of the year off the coast of Ecuador and on an average the few caught run considerably larger than those recorded northward in the Gulf of Panama. During the month the expedition was based at Salango, two specimens were observed that had been caught commercially. One was very large, probably in excess of 700 pounds, but unfortunately it had been dressed before it could be carefully examined. The second was a specimen of about 350 pounds. From the reports given by the local fishermen these fish average in weight almost that of the black marlin.

The predominant sailfish run here is in the summer months, roughly from the end of November through March, although (as in the case of the three marlin) they are caught every month of the year.

The general tuna situation is similar to that off the coast of northern Peru. The principal species is the yellowfin tuna which is caught every month of the year, but predominates in December, January and February. In the winter season the fishermen have the same heavy runs of the oceanic bonito that were encountered off Peru. The common bonito is rather scattered, and its production does not compare with that of central and northern Chile.

GEOGRAPHY. The operational site for the Ecuadorian phase of the expedition was the village of Salango (Figure 10). This was chosen because it was adjacent to the Island of La Plata and just southwest of the city of Manta which is the principal commercial fishing port of Ecuador. This area is 60 miles north of the mouth of the Gulf of Guayaquil. The city of Salinas is at the northwestern tip of the port of Manta. The Island of La Plata, our principal point of fishing research, lies about 18 miles off the coast and 5 miles inside of the 100 fathom curve of the coastal shelf. From Iquique, Chile, northward through the Peruvian areas studied, we found that this is the first place in which a definite coastal shelf is encountered where billfish exist in quantity during the migratory cycle. From this point northward, it is apparent that the schools of marlin and sailfish touch all prominent coastal points northward to the Gulf of Panama. Possibly these fish constitute a single population, while the sailfish, to some extent, migrate across the Gulf of Guayaquil and in summer season range as far south as Talara, Peru. Generally, the main group never migrates farther south than Salinas, Ecuador.

The expedition received only vague reports of billfish north of the port of Manta. By the close proximity of the 100 fathom curve to the coast line in the vicinity of Cape San Francisco, just south of the port of Esmeraldas, it is logical to assume that similar fishing conditions would exist. There are no governmental reports available for this area and only future exploration will determine the potential of billfish in the northern part of Ecuador and Colombia.

The area that this expedition studied from Manta on the north to Salinas on the south lies between one and two degrees south of the equator, with the Island of La Plata slightly in the northern part. Here, the coastal shelf, which we shall consider to end with the 100 fathom curve, averages about 20 to 25 miles offshore. The predominant points along this coast line lie very nearly in a north and south line and the 100 fathom curve follows about the same pattern until Cape San Lorenzo is reached, then the coast line and the coastal shelf swing toward the northeast. The coastal shelf in the vicinity of La Plata Island extends about 25 miles offshore and is of very uniform depth, averaging from 25 to 35 fathoms. Practically all of the commercial fishing in this section of Ecuador is done in this relatively shallow water. During our stay at Salango we found the current to run generally in a southerly direction. From all reports this seems to hold true in every season of the year. This flow of water apparently comes from the southern equatorial current and possibly there is some influence from the Gulf of Panama on the north. From the mouth of the Gulf of Guayaquil to the equator the Humboldt Current is far offshore and rapidly diffuses to the westward. This southerly inshore current that we experienced, coupled with the flow of water out of the Gulf of Guayaquil may be the origin of the so-called Niño current that occasionally reaches as far south as central Peru.

FISHING METHODS. Generally, fishing procedures here, especially for billfish, were the most primitive that we encountered in our preliminary examination of the west coast of South America: Chile, Peru and Ecuador. The fishermen in the area are predominantly bottom or reef fishermen. Before the expansion of marlin fishing in the last ten years, only a few of the hardier men indulged in shark fishing. Today, in the vicinity of Manta, there are less than 10% of the local fishermen who have had experience and practice in marlin fishing in Manta and the surrounding area, principally La Plata Island.

Due to the lack of swordfish in these waters, there is very little employment of the harpoon and very few vessels are equipped for this type of fishing. While all the species of billfish are inclined to surface, the local fisherman has never equipped himself with power in his boat so that he could make any adequate use of the harpoon. All the commercial fishing boats we encountered that were used in marlin and shark fishing were powered by sail and oar. The only fishing vessels encountered that were equipped with motors were those used either as a pickup boat for the catch of the sailing craft or were employed in bottom fishing, where power was necessary to haul the long set lines.

In the entire world of commercial billfishing, Ecuador is probably the most unique. This is the only place in our experience where the fish are predominantly caught by the use of live bait. All the marlins and sailfish are caught by slowly trolling a live bonito or a mackerel from a boat under sail (Figure 8). The native craft employed in this type of fishing is primitive.

It consists of a dugout canoe, or, as it is called in Ecuador, a "bongo." This craft averages about 16 feet to 18 feet in length and is manned by one or two fishermen. It is generally constructed out of a single large log with a side panel added on to give additional freeboard above the surface of the water. Most of the boats employed in marlin fishing lash a split balsam log on either side just above the water line to provide additional stability. In the fore part of the craft is a mast of about 14 feet to 16 feet in height, which carries a single lateen sail. Occasionally, in the calmer seasons of the year a plain foresail is used. The steering of these craft is done by a single oar seated in a notch in the stern. In the summer months, around the first of the year, when the periods of calm are encountered, the natives will either row or slowly scull. Due to the lack of power in these boats, the fisherman is forced to operate in courses that will set him most advantageously in relation with his home port and the prevailing tradewind is from the south to the southwest and only occasionally in the summer season is a light blow encountered from the northerly quadrants. These summer winds from the north only last a day or two at a time. This obvious limitation imposed by sail and wind probably has restricted these fishermen in the development of the potential in their waters as there has never been any serious exploration here with the proper facilities. It is impossible to predict where the best billfishing might be encountered.

As stated before, the main area of operation is from the north and northeast port of La Plata Island, northeast across the channel to Cape San Lorenzo, which is just southwest of the Port of Manta. While the waters off the northern part of La Plata Island are very productive of billfish, it is probably a chosen spot more because fishing is close to shore and their small sailing craft always have the lee side of the Island and its consequent shelter for protection. It is very seldom that they operate if the wind force is in excess of 15 knots.

A typical day's commercial marlin fishing is as follows: The homes of nearly all these fishermen are on the mainland side. In the peak of the fishing season during their winter months, the little sailing craft are towed over to La Plata Island by the pick-up boats that return the fish to the refrigeration plant at Manta. During the season these fishermen camp out on the beach at the Island. As a rule they depart from their sheltered cove at 4:00 to 5:00 o'clock in the morning. The small village and the best anchorage is at the northeastern end of La Plata and a scant mile from the principal fishing ground at the northwestern end. The fisherman either sails or rows up the shore in the early morning, trolling a feather on a hand line until he catches a bonito, or large mackerel. This is carefully hooked through the upper lip and the second or trailing hook is inserted horizontally through the skin about the middle of the first dorsal fin of the bait.

Some fishermen even employ a third hook on the leader, allowing it to trail just past the tail of the bonito. As soon as the bait is attached, it is paid out on the heavy hand line about 100 feet to 125 feet of stern. This live bait is trolled very slowly, either under sail or by rowing from the shore of the northern coast out to about a distance of two miles, in a north or northwesterly course. This course sets the fisherman at the most advantageous angle in relation with the prevailing wind. They fish this limited area of about two miles of coast line to a limit of not more than three miles from shore, until the early afternoon. It was our observation that the majority of the fish are caught in the early hours of the morning and the majority within a mile from shore. Quite often the black marlin are hooked within 100 yards of shore around the rocky points. Unless the fishing is exceptionally good, a fisherman seldom operates in the middle or the late afternoon. During the marlin run most of these craft have two men aboard. They take turns fighting fish on the hand line while the other man steers or paddles the boat. Occasionally, if the black marlin are not too prevalent, a single man fishes.

Generally speaking, the oceanic bonito is a hardy bait and when carefully hooked will swim very actively when trolled slowly. As a rule, it tends to troll about 8 to 12 feet below the surface, and in consequence the marlin and the sharks are seldom observed when they strike. The general procedure is to give the fish a fairly substantial amount of line when it takes the bait, in order to hook it as deeply as possible. This, of course, will vary with the speed of the strike. Due to the extreme shallow water in the vicinity, the fish are very active on the surface. Both the black and the striped marlin will jump immediately when hooked. Large black marlin will jump as many times and show as much activity as small stripers or sailfish. Each boat carries about 200 fathoms of hand line and it is very seldom that a large fish will take out the full amount, or any great part of it. If this should occur, a balsa float is attached and thrown overboard. The only great loss of the larger fish seems to be due to inferior and weak line.

On black marlin the average killing time is about two hours. When the fish is brought alongside it is killed with a club, or as in Cuba, if it is very active, it is lanced or knifed in the gills and allowed to bleed.

The method of bringing a large fish aboard in these small dugouts is interesting and amusing. A fish of 800 to 1,000 pounds is almost as long as the boat itself, so the procedure is to pull its head and shoulders over the combing, at the same time allowing the craft to fill with water, and then it is a rather simple procedure to float it in. When the fish is secured, the boat is bailed out. Since their capacity is one fairly large fish, boats immediately return to the village to deposit the fish either in the pick-up boat or on the beach. During a large fishing period a boat will catch as many as three or four fish in a day.

The size of the fishing fleet that operates in the vicinity of La Plata Island and Cape San Lorenzo varies in size, depending on how good the fishing is. In a very good marlin year, there will be about 25 to 30 boats fishing in this area. It was recorded two years ago that this fleet, fishing off La Plata Island caught 47 marlin in a single day. Of these, over 50% were black marlin. Considering the size of the fish and the boats used, this is remarkable, since this is an average of more than a fish and a half per boat. Generally speaking, it was found that during a good run the fleet caught between 15 and 20 fish a day. During our stay in these waters, the fishing was very poor and the best day observed was a catch of eight fish, with about ten or eleven boats fishing. Until the time we left Salango, which was the 14th of October, no great concentration of fish had yet arrived. This area was experiencing the coldest winter season in about fifteen years and the worst billfishing in the last ten.

The equipment employed by these fishermen is far from adequate. While these marlin fishermen in an average year have the highest earning power of any fishermen along the west coast of South America, very little of their income is reinvested in improvement and the modernization of their gear. The hand lines used are about the same quality as the harpoon line used off Chile. Most of it is handmade out of the strands of old rope or line. Consequently, its strength is very low in comparison with the diameter of the line. Much of it probably would test no more than the strength of a new 39 strand fishing line. Because of this many of the very large black marlin are lost. The leaders are constructed of old cable or heavy wire. Most of the leaders are shorter than an average black marlin, being about ten feet in length. This also contributes to the loss of many fish, since the tail has the opportunity to chafe the line. The hooks are of any size and type available. Most of them run from 10/0 to 14/0, the largest sizes being preferred. Fishing gear is very expensive and not much is imported into Ecuador. In consequence the fisherman generally has to beg and borrow most of his needs.

American interests now established at Manta are bringing in modern equipment, so in the future the area should see a steady increase in the production of these fish. In all probability, we shall also see the introduction of small engines in boats of a slightly larger size. This new equipment, when it is in operation, could probably double or treble the yearly catch.

Economy. Unfortunately, Ecuador has no good production figures on the catch of billfish at the present time. The best estimation, as has been pointed out before, is the production of between 600 and 1,000 tons of marlin yearly shipped out of the port of Manta. It is a safe assumption that about the same amount is probably consumed by the small fishing villages up and down the coast. The local fishermen will not bother to bring a fish into Manta for sale at the refrigeration plant if he is any distance away.

With a stable currency and no price control set by the government, the fishermen receive the highest unit price in the three countries that we have studied. The average black marlin of 400 to 600 pounds will return $15.00 to $20.00 American. An exceptionally large fish will sell for as high as $30.00. The average of striped marlin and sailfish runs from $5.00 to $7.00 each, and medium size sharks about the same.

This entire area of Ecuador is extremely rich in bottom fish, and since fish are the main staple of life, any type of fish is constantly in demand.

This is the only country examined where no price control is employed and consequently price is solely based on supply and demand. The demand is always high and the average income of a fisherman is about 30% more than that of Peru or Chile. With the abundance of fish these natives are at sea far less than those to the southward. This situation develops a lack of aggressiveness and a lack of desire on the part of the men to improve their fishing methods and equipment. In the off years of fishing the native, instead of ranging farther from his home base and working more hours and days, is inclined to say on the beach eking out an existence by minor agricultural pursuits.

CONCLUSIONS. The waters of Ecuador are as rich in sea life as any area that we encountered along the west coast of South America. Due to its location at the meeting points of the Humboldt and the South equatorial currents, there is a far greater number of species of fish found here than off the countries to the south. The only large food fish apparently scarce is the swordfish. The territorial waters farther offshore and surrounding the Galapagos Islands probably contain the largest population of tunas found anywhere in the eastern Pacific Ocean.

Due to the lack of organized commercial fishing in the coastal waters and the lack of refrigeration and processing plants, the potential of this area has probably only been touched. When modern facilities are expanded here and proper training techniques and equipment introduced, the fishery production should multiply rapidly. To achieve this, Ecuador should encourage foreign capital and technology.

PLANKTON STUDIES

PLANKTON STATIONS were occupied during the months of June through October, off the western coast of South America, the earlier stations carried out off Chile, gradually moving northwards to Ecuador in October. Fifty bottles of plankton were taken and examined. The area studied proved to be rich in plankton, as exemplified by the appended list of stations, giving the volumes of each bottle. Upon reading the volumes of the individual hauls, it was noted that the richest bottles were usually obtained farther away from shore, during the hours of darkness.

The main constituents of many of the bottles were euphausiids, copepods, salps, chaetognaths, and stomatopod larvae. For example, LM 1, mainly contained copepods; LM 4, copepods and chaetognaths; LM 5, salps; LM 6, salps and euphausiids; LM 7, stomatopod larvae; LM 13, euphausiids and stomatopod larvae; LM 14, copepods, euphausiids, chaetognaths, and stomatopod larvae; LM 15, copepods and diatoms; LM 17, salps; LM 18, stomatopod larvae; LM 20 provided a very good cross section of various phyla represented in the plankton, although the major portion of the contents were salps, medusae, chaetognaths, and stomatopod larvae; LM22 and 23, copepods; LM 25, copepods and medusae; LM 26, 27 and 28, copepods; LM 29, siphonophores, copepods, and euphausiids; LM 30, copepods and medusae; LM 32, copepods; LM 35 and 36, chaetognaths, and copepods; LM 38, chaetognaths and diatoms; LM 39, salps and siphonophores; LM 41, copepods, and colonial siphonophores; LM 43, copepods and diatoms; and, LM 44, chaetognaths, copepods, and salps. The richness of plankton samples collected in these waters should indicate an excellent fishing area since many larval, juvenile, and adult fish feed solely on plankton.

The main purpose of the plankton hauls made by the Marron Expedition was to acquire billfish larvae of the families Istiophoridae (sailfish and marlin) and Xiphiidae (swordfish) but none were found. The absence of billfish larvae is probably seasonal. The expedition reported adults in the collecting areas, none of which were in spawning condition. In general, few larval fish were collected, but many different eggs were noted, covering a wide range of groups. The major families of larval fish present were the Synodidae (lizard fish), Clupeidae (herrings), Myctophidae (lantern fish), and Nomeidae. Those stations having larval fish were LM 1 (1 fish), LM 6 (1), LM 9 (1), LM 12 (20), LM 13 (10), LM 14 (5), LM 18 (13), LM 19 (5), LM 20 (6), LM 24 (4), LM 27 (2), LM 32 (2), LM 33 (141 Synodontidae), LM 35 (5), LM 36 (3), LM 37 (1), LM 39 (8), LM 40 (2), LM 42 (15), LM 44 (4), LM 45 (7), LM 46

(25), LM 48 (14), LM 49 (15), and LM 50 (3).

In summarizing the information obtained from the Marron Expedition, it is a seasonal factor that seems to be the main cause of the few fish collected in spite of the rich plankton present. If the area were again studied in the months of December and January, a greater quantity of fish larvae might be obtained. This supposition is based on the early spawning period of many fish in the Northern hemisphere.

List of Plankton Stations

LM 1 20°12′ S., 70°32′ W.; 20 miles W of Iquique, Chile; June 15, 1954; 0740-0810; 10 cc. vol.

LM 2 20°12′ S., 70°53′ W.; 40 miles W of Iquique, Chile; June 15, 1954; 3 cc. vol.

LM 3 20°12′ S., 71°14′ W., 60 miles W of Iquique, Chile; June 15, 1954; 2 cc. vol.

LM 4 20°12′ S., 71°36′ W.; 80 miles W of Iquique, Chile; June 15, 1954; 1525-1555; 33 cc. vol.

LM 5 20°12′ S., 71°57′ W.; 100 miles W of Iquique, Chile; June 15, 1954; 1740-1810; 123 cc. vol.

LM 6 20°00′ S., 71°53′ W.; about 100 miles WNW of Iquique, Chile; June 15, 1954; 96 cc. vol.

LM 7 19°36′ S., 70°21′ W.; 5 miles W of Punta Pichalo, Chile; June 20, 1954; 0115-0145; 68 cc. vol.

LM 8 18°27′ S., 70°28′ W.; 5 miles W of Cabo Lobos, Chile; June 19, 1954; 0640-0710; 34 cc. vol.

LM 9 18°30′ S., 70°42′ W.; 20 miles W of Arica, Chile; June 23, 1954; 1030-1100; 93 cc. vol.

LM 10 18°30′ S., 71°3′ W.; 40 miles W of Arica, Chile; June 23, 1954; 1415-1445; 19 cc. vol.

LM 11 18°30′ S., 71°25′ W.; 60 miles W of Arica, Chile; June 23, 1954; 1720-1750; 173 cc. vol.

LM 12 18°30′ S., 71°46′ W.; 80 miles W of Arica, Chile; June 23, 1954; 2005-2035; 316 cc. vol.

LM 13 18°30′ S., 72°7′ W., 100 miles W of Arica, Chile; June 23, 1954; 2250-2320; 156 cc. vol.

LM 14 18°51′ S., 71°31′ W., 70 miles WSW of Arica, Chile; June 24, 1954; 0400-0430; 41 cc. vol.

LM 15 19°12′ S., 70°55′ W., 47 miles NW of Pisagua, Chile; June 24, 1954; 0945-1015; 6 cc. vol.

LM 16 19°42′ S., 70°41′ W., 25 miles WSW of Pisagua, Chile; June 25, 1954; 1200-1230; 1 cc. vol.

LM 17 20°28′ S., 70°43′ W.; 35 miles SW by W of Iquique, Chile; June 30, 1954; 1700-1730; 175 cc. vol.

LM 18 20°43′ S., 71°17′ W.; 70 miles SW by W of Iquique, Chile; June 30, 1954; 2135-2205; 60 cc. vol.

LM 19 21°04′ S., 72°02′ W.; 105 miles W. of Punta Lobos, Chile; July 1, 1954; 0315-0345; 70 cc. vol.

LM 20 21°04′ S., 71°41′ W.; 85 miles W of Punta Lobos, Chile; July 1, 1954; 0610-0640; 70 cc. vol.

LM 21 21°04′ S., 71°20′ W.; 50 miles W of Punta Lobos, Chile; July 1, 1954; 0900-0930; 3 cc. vol.

LM 22 21°04′ S., 70°59′ W.; 45 miles W of Punta Lobos, Chile; July 1, 1954; 1230-1300; less than 1 cc. vol.

LM 23 21°4′ S., 70°37′ W.; 25 miles W of Punta Lobos, Chile; July 1, 1954; 1545-1615; 2 cc. vol.

LM 24 21°4′ S., 70°16′ W.; 5 miles W of Punta Lobos, Chile; July 2, 1954; 0835-0905; 3 cc. vol.

LM 25 20°38′ S., 70°18′ W.; 5 miles W of Punta Barracos, Chile; July 2, 1954; 1630-1700; 6 cc. vol.

LM 26 20°2′ S., 70°40′ W.; 30 miles WNW of Iquique, Chile; Ju'y 5, 1954; 0850-0920; BT sample No. 1; 13 cc. vol.

LM 27 19°54′ S., 71°5′ W.; 55 miles WNW of Iquique, Chile; July 5, 1954; 1235-1305; 4 cc. vol.

LM 28 19°46′ S., 71°30′ W.; 75 miles WNW of Iquique, Chile; July 5, 1954; 1620-1650; 3 cc. vol.

LM 29 19°35′ S., 72°1′ W.; 110 miles WNW of Iquique, Chile; July 5, 1954; 2030-2100; 113 cc. vol.

LM 30 19°35′ S., 71°42′ W.; 80 miles W of Pisagua, Chile; July 6, 1954; 0400-0110; 27 cc. vol.

LM 31 19°35′ S., 71°15′ W.; 55 miles W of Pisagua, Chile; July 6 1954; 0815-0845; 5 cc. vol.

LM 32 19°35′ S., 70°48′ W.; 35 miles W of Punta Pichalo, Chile; July 6, 1954; 1145-1215; 6 cc. vol.

LM 33 19°53′ S., 70°16′ W.; 5 miles W of Punta Ballenas, Chile; July 6, 1954; 1845-1915; 25 cc. vol.

LM 34 4°10′ S., 81°23′ W.; about 10 miles WNW of Cabo Blanco, Peru; July 29, 1954; 11 cc. vol.

LM 35 4°00′ S., 81°12′ W.; about 12 miles WNW of Mancora, Peru; July 29, 1954; 28 cc. vol.

LM 36 4°00′ S., 81°1′ W.; about 1.5 miles W of Pta. Sal., Peru; July 29, 1954; 27 cc. vol.

LM 37 4°14′ S., 81°15′ W.; about 1 mile W of Cabo Blanco, Peru; July 30, 1954; 0910-0940; 1 cc. vol.

LM 38 4°26′ S., 81°24′ W.; about 7 miles WNW of Lobitos, Peru; July 30, 1954; 1230-1300; 4 cc. vol.

LM 39 3°45′ S., 81°12′ W.; 30 miles N. of Cabo Blanco, Peru; August 2, 1954; 0950-1020; 149 cc. vol.

LM 40 3°30′ S., 81°10′ W.; 45 miles N of Cabo Blanco, Peru; August 2, 1954; 1225-1255; 37 cc. vol.

LM 41 3°37′ S., 80°54′ W.; 14 miles W of Zorritos, Peru; August 2, 1954; 1510-1540; 100 cc. vol.

LM 42 3°41′ S., 80°40′ W.; Zorritos Anchorage, Peru; August 2, 1954; 2045-2115; 23 cc. vol. + 1 large medusae.

LM 43 3°50′ S., 80°52′ W.; 12 miles NE of Pta. Sal., Peru; August 3, 1954; 0915-0945; 27 cc. vol.

LM 44 4°3′ S., 81°26′ W.; August 11, 1954; 0715-0745; 63 cc. vol.

LM 45 Near La Plata; 1340-1510; 19 cc. vol.; September 30, 1954.

LM 46 Near La Plata; 1830-1900; September 30, 1954; 105 cc. vol.

LM 47 15 miles NW of Salango; October 3, 1954; 1700-1730.

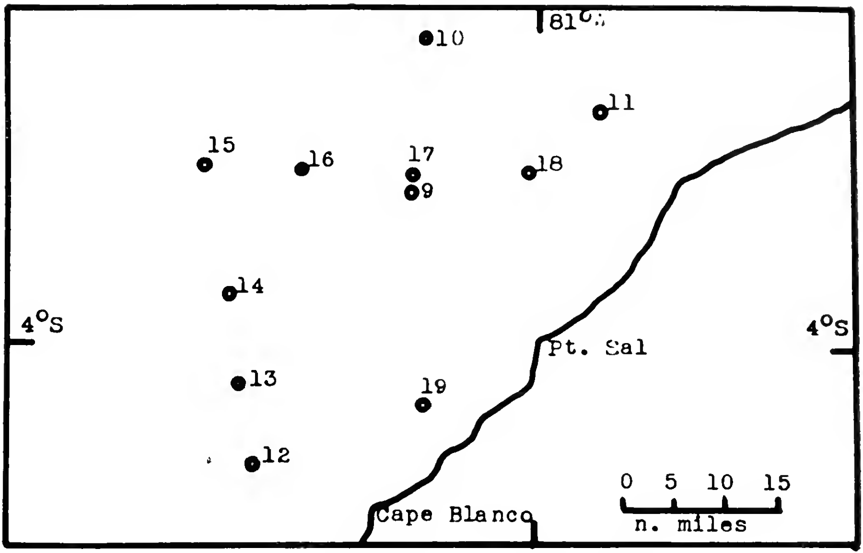

FIGURE 14. Station Plan. August, 1954.

LM 48 20 miles WSW of La Plata; October 4, 1954; 1300-1330; 207 cc. vol.
LM 49 Inside Salango Island; October 6, 1954; 1300-1340; flood; 53 cc. vol.
LM 50 15 miles NW Salango; October 6, 1954; 1620-1650; 95 cc. vol.
15 miles NW Salango; 30 min. 1605-1635; October 7, 1954.
Off La Plata; October 9, 1954; 1230-1300.
15 miles NW Salango; October 9, 1954; 1645-1715.

HYDROGRAPHIC DATA

THE DISCUSSION of the hydrographic environments will be made in three sections according to their geographic locations: Cabo Blanco, Peru; Iquique, Chile; and Salango, Ecuador.

Cabo Blanco

The location of the BT lowerings made off Cabo Blanco are given in Figure 14. Six of the BT stations were occupied on the same day and all ten stations within a ten day period. This is fairly synoptic.

The temperature characteristic of the water mass is a good indicator of its source in this region of juxtaposition of the water masses from the Peru Current and Equatorial Countercurrent and for the depths presently dealt with. This applies even to the surface temperature as the initial temperature difference of the two water masses is large—much too large to be masked by the relatively slow boundary processes of radiation and sea-air interchange.

The two vertical temperature sections, Figures 16 and 17, clearly show the water mass of the Equatorial Countercurrent (hereafter ECC) occupying the surface layer. This surface layer presumably rests on the subtropical component of the Peru Current, which according to Gunther (1936:160) flows north beyond Pt. Santa Elena and, as will be seen in a later section, probably at least as far north as the Isla La Plata. As the ECC crosses the geographic equator and flows toward the south it will, on the basis of conservation of angular momentum, acquire anticyclonic vorticity and tend to hug the South American shores. This would tend to lead to a greater thickness of the ECC nearer shore. But the observed thickness of this water mass, as defined by the depth of the thermocline, is clearly shown in Figure 17 to be smaller near shore than offshore. Since the observed winds made at the time of BT lowerings as well as the climatological winds as given by charts published by Compania Administradora del Guano (Lima, Peru) are stronger offshore than near shore, it is possible that the greater thickness offshore may be due to stronger wind mixing. However, although there are no salinity data to corroborate this and the situation is further complicated by upwelling, the greater warming of the subtropical water beneath the ECC at stations 17 and 18 implies that differential wind mix-

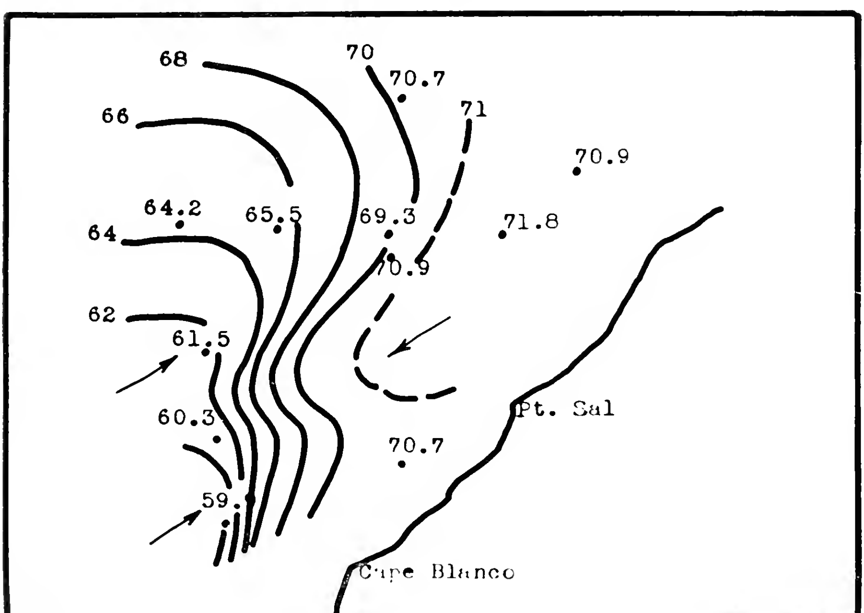

FIGURE 15. Surface Temperature in degrees Fahrenheit. August, 1954.

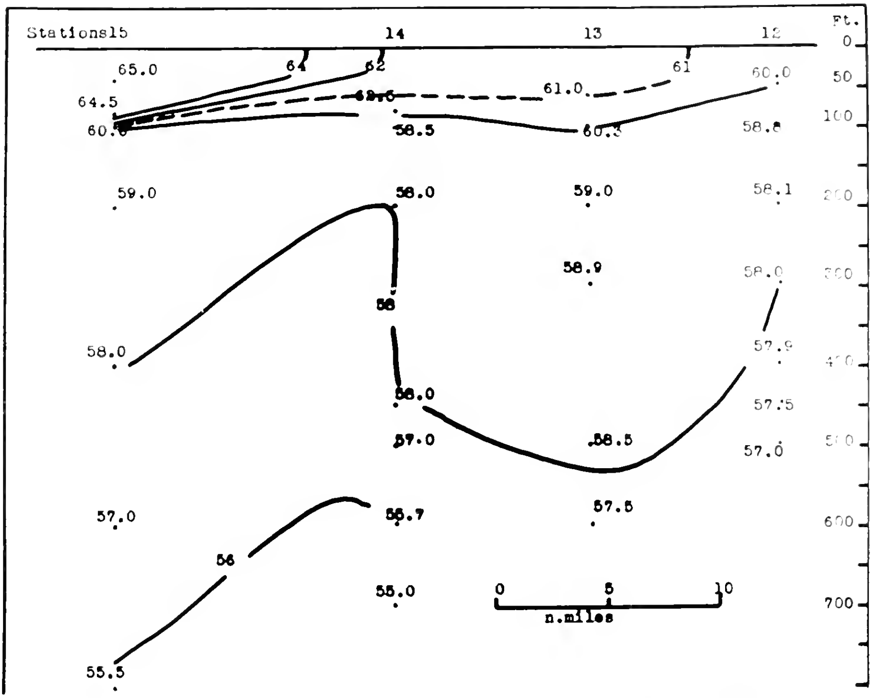

FIGURE 16. The N-S Vertical Temperature Section in degrees Fahrenheit. August 11, 1954.

ing is not the major cause for the greater thickness of ECC farther offshore. More probably the varying thickness of the ECC is better explained in terms of the varying wind stress westward. For qualitative indication of this relationship one may use the Ekman wind transport equation (see e.g. *The Oceans*, 1946:498):

$$Tr = \int w \, dz = (1/f)\, T_a$$

where T_a is the wind stress at right angle to the current speed, w, and transport, Tr, while f is the Coriolis parameter and the integration is taken to large depth.

Take

$$T_a = kv^2 \qquad (2)$$

where k is the product of the density of the air immediately above the water surface and a resistance coefficient (Taylor, 1916). If the wind stress is a sole function of x, then differentiating (1) with respect to x and considering (2) one has

$$\frac{dTr}{dx} = \frac{1}{f}\frac{dT_a}{dx} = \frac{k}{f}\frac{dv^2}{dx} \qquad (3)$$

For simplicity, suppose

$$v^2 = a \sin(2nx/L) + b \qquad (4)$$

where a and b are positive and where b is of such magnitude that v^2 is always positive. Then

$$\frac{dv^2}{dx} = \frac{2an}{L} \cos \frac{2nx}{L} \qquad (5)$$

For arbitrary values of k, a and b equations (3) and (5) are plotted in Figure 18. Regions of divergences are seen centered at $x = O$ and $x = L$, while convergences are seen centered at $x = L/2$, and $x = \frac{3L}{2}$. It is probable that the southerly winds observed at the time of the BT stations partake of equivalent variation while roughly steadily increasing in the offshore direction. The wind observations are shown below. Since the wind force was estimated on the Beaufort scale, a superposing of a relatively small amplitude wind variation of the kind equivalent to Figure 18 can be easily overlooked.

Observed Winds at BT Stations

Stations	Observed Winds In Beaufort Force	Wind Direction
15	5	S
16	5	S
17	4	S
18	2	S

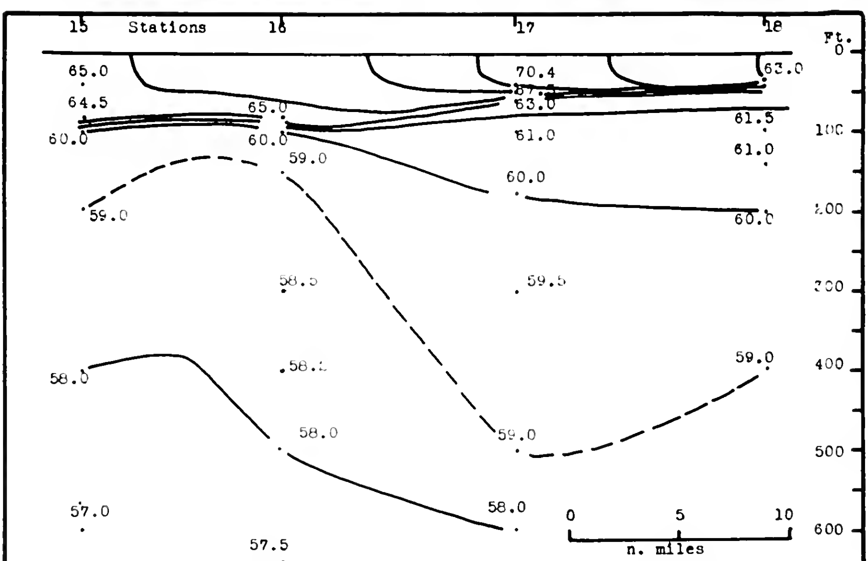

Figure 17. E-W Vertical Temperature Section in degrees Fahrenheit. August 11, 1954.

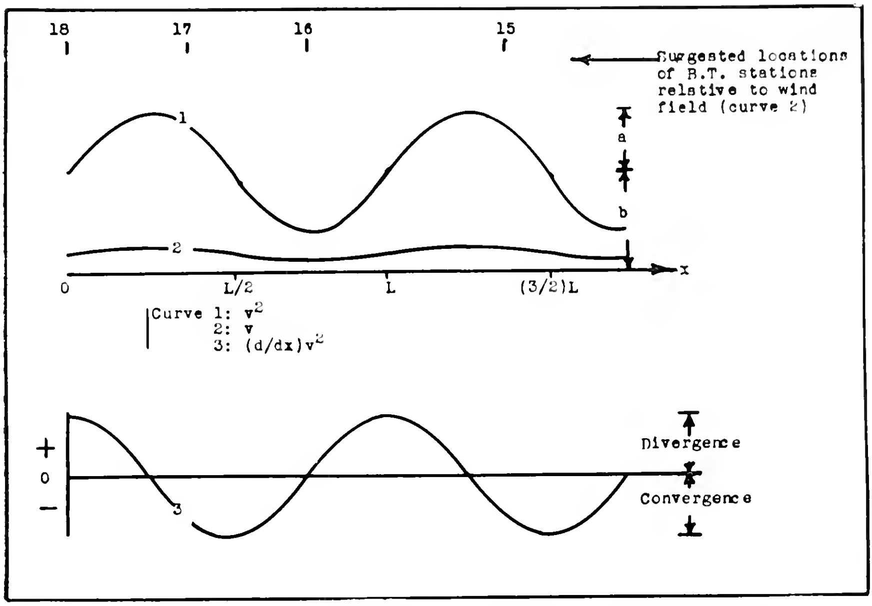

FIGURE 18. Hypothetical Wind Distribution and Consequent Divergence.

Thus it is reasonable to conclude that the thickness of the ECC water mass is caused primarily by varying wind and that the positions of the BT stations relative to the southerly winds are as suggested in Figure 18.

While it is doubtful that the geostrophic relation will hold for this region more than very approximately because of the certain existence of frictional and inertial forces, no other approach is possible with the present data. Nevertheless, use of the hydrostatic and geostrophic relations suggests a current pattern that is consistent with that of the surface temperatures. The probable current directions are indicated by arrows in Figure 15.

The thermocline depth, defined as the depth of the top of the layer of rapid temperature change, is given in Figure 20; this presentation does not show the deep upwelling evident between stations 15 and 16 in Figure 17.

Salango

Four BT lowerings were made at nearly the same station at Lat. 1°22′ S., and Long. 80°59′ W., 15 n. miles NNW of Isla La Plata. Two characteristics are common to the 5 lowerings: The first is the small cool layer some 20 to 40 feet deep overlying a warmer and thicker layer; the second is the very sharp thermocline, the temperature decreasing from 75 to 76° F to the neighborhood of 60° F in some 30 feet or less. The cool thin layer is most probably due to the cold southwesterly wind observed blowing in Beaufort force 3-4 at that time. The sharp thermocline separates the

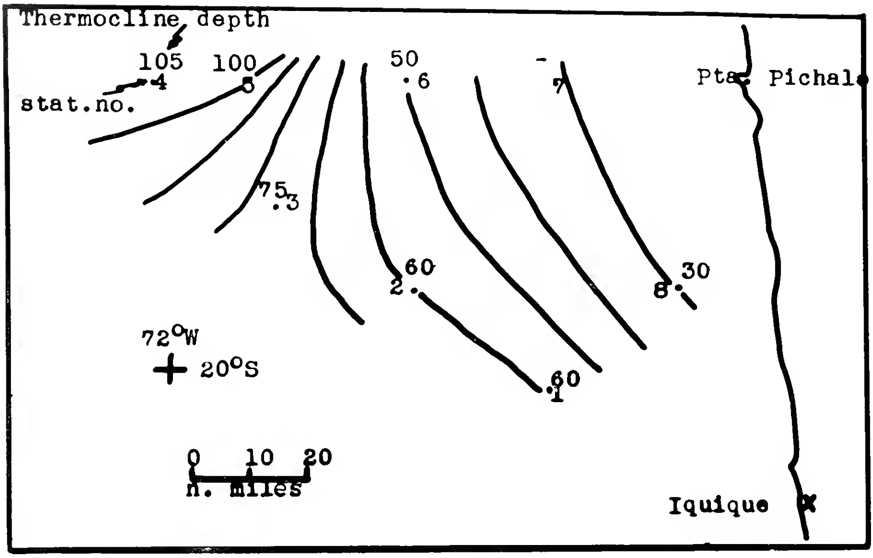

FIGURE 19. Depth of Thermocline in feet; defined as top of layer of rapid temperature change. Iquique. July 5, 6, 1954.

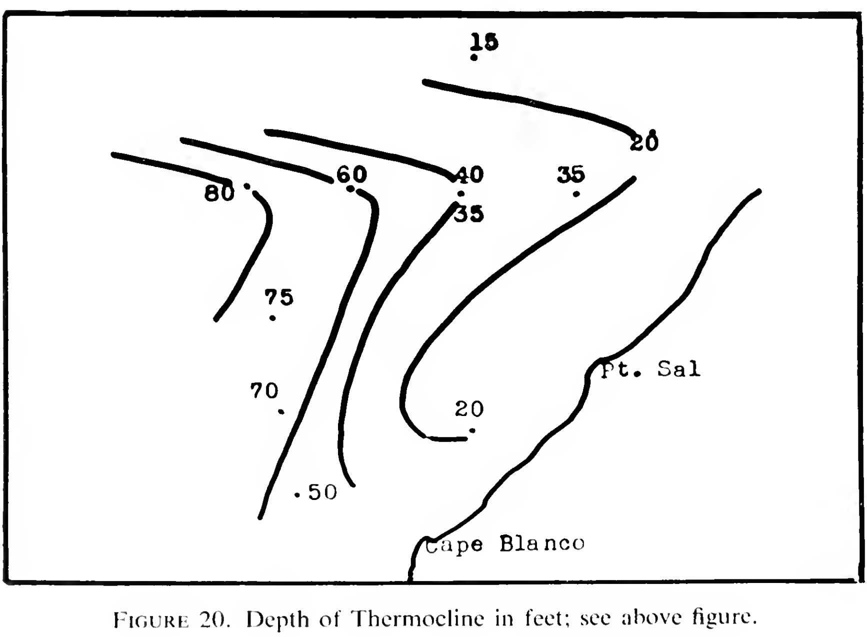

FIGURE 20. Depth of Thermocline in feet; see above figure.

warm ECC water from what is very probably the cooler subtropical component of the Peru Current; no subsurface salinity data are available to support the identification of the cooler water as the subsurface northerly extension of the Peru Current, but the temperature data are very suggestive. The existence of the sharp thermocline in the face of moderate wind stirring and other turbulences such as due to bottom friction and internal wave to efface it, requires that there be continuous supply of the two water masses. Hence, for a steady state, the maintenance of the low temperature near the topographic bottom requires a cold bottom current to carry away the heat diffused from above. The relative thicknesses of the water masses of the ECC and of the Peru Current further implies that the Peru Current is flowing there at a greater speed than that of the ECC. The causes for the varying depth of thermocline which changed from 100 to 170 feet are uncertain.

Iquique

In this southerly location the ECC water mass is absent. The surface temperatures rise steadily from the coast out to the open Pacific as is generally observed. But the presence of a relatively strong thermocline indicates that no upwelling was in progress and that the warmer water above the thermocline must have been advected into the region since it is

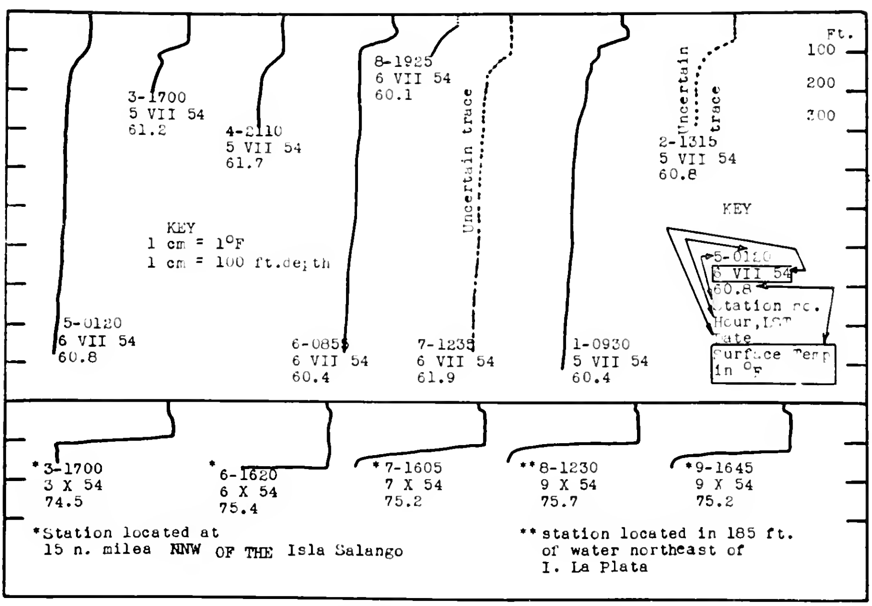

FIGURE 21. Bathythermograph Traces.

quite improbable that summer heating in the face of predominantly southerly winds (and hence upwelling tendency) can effect thermoclines of such magnititude (see Figure 21). Gunther (1936) showed, in his Figure 17, a warm tongue advecting from the ocean Pacific into the region south of Arica, about 100 n. miles north of Iquique. It is likely that the eddy, whose warm branch forms the water mass above the thermocline, is bounded geographically to this area because of the abrupt change in the direction of the coast line at Arica.

The depth of the thermocline, defined as the top layer of rapid temperature change, is given in Figure 19. The thermocline depth deepens seaward and southward indicating that the warm branch of the eddy is south of the approximate line drawn WNW of Iquique at this time.

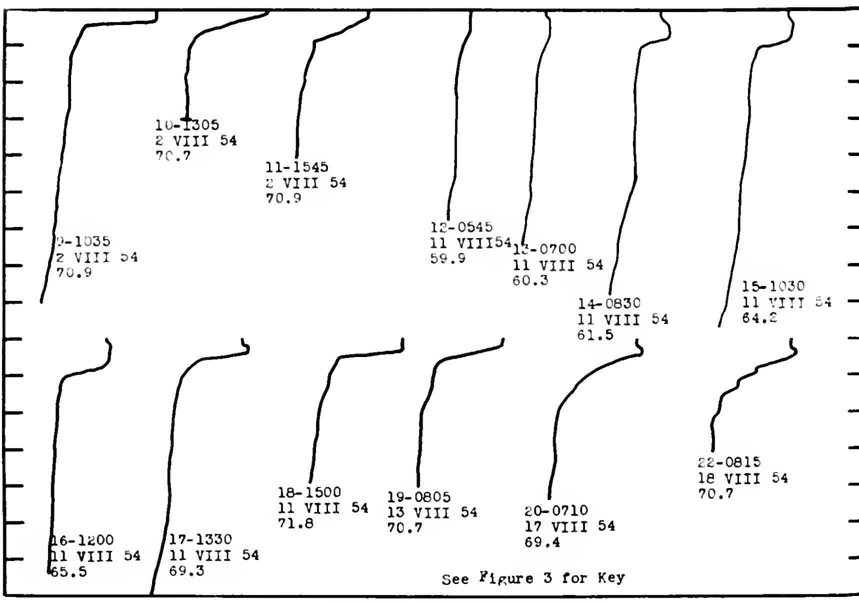

FIGURE 22. Bathythermograph Traces.

Summary and Recommendations

The surface boundary between the Peru Current and Equatorial Counter Current was located by the bathythermograph at north of Cabo Blanco and the subsurface northern extension of the Peru Current was thought to extend as far north and near shore as the Isla La Plata, Ecuador. The warm branch of the eddy, first observed by Gunther, off Arica, was found to extend as far as Iquique and south.

In this region of interplay of water masses each with distinctive temperature characteristic, the bathythermograph is a valuable instrument particularly north of 10° S. However, for more complete analysis and more positive conclusions, BT lowerings should be supplemented with salinity samplings and rigorous meteorological observations. A more complete and detailed oceanographic coverage of area surveyed is another desirable that must be fitted into the biological plans of any future studies.