COMMERCIAL FISHERIES REVIEW

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PRELIMINARY FISHERIES SURVEY OF THE HAWAIIAN-LINE ISLANDS AREA[1/]

PART II - NOTES ON THE TUNA AND BAIT RESOURCES OF THE HAWAIIAN, LEEWARD, AND LINE ISLANDS[2/]

By Fred C. June*

PREFACE

The present report is a digest of the miscellaneous information gathered on the tunas[3/] and tuna bait-fish resources of the Hawaiian, Leeward, and Line islands; together with related information on the physical characteristics of the various land masses and surrounding seas. The data have been assembled from available literature, discussions with fishermen, and field observations made at various islands in the region. In many instances, desired data could not be obtained without additional field work, which conditions did not permit. However, it is hoped that this summary will be of some aid to those interested in commercial tuna fishing in these waters.

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THE HAWAIIAN ISLANDS

INTRODUCTION: The Hawaiian Islands proper consist of eight major islands: Hawaii, Maui, Molokai, Kahoolawe, Oahu, Kauai, and Niihau; comprising a total land area of approximately 6,450 square miles, of which the island of Hawaii comprises about 62 percent. The islands are all mountainous and of volcanic origin. Their coastlines are indented by numerous bays and coves, and in many places long stretches of white sand beaches, alternating with rocky shores and headlands, rise from the shallow waters inside the reefs. At other places there are no beaches at all; the steep cliffs often drop directly into deep water, or their bases are strewn with

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1/PART I - THE HAWAIIAN LONG-LINE FISHERY BY THE SAME AUTHOR APPEARED IN COMMERCIAL FISHERIES REVIEW, JANUARY 1950, PP. 1-23; ALSO AVAILABLE AS SEPARATE NO. 244.

2/DR. SIDNEY SHAPIRO, FISHERY RESEARCH BIOLOGIST, U. S. FISH AND WILDLIFE SERVICE, COLLABORATED IN THE PRELIMINARY PHASES OF THIS INVESTIGATION.

3/THE VARIOUS TUNA SPECIES CONSIDERED HERE INCLUDE: YELLOWFIN TUNA (NEOTHUNNUS MACROPTERUS), BIG-EYED TUNA (PARATHUNNUS SIBI), ALBACORE (THUNNUS GERMO), OCEANIC SKIPJACK (KATSUWONUS PELAMIS), AND "KAWAKAWA" (EUTHYNNUS YAITO).

lava rocks. In general, the fringing reef extends only a few hundred yards from shore.

Climate is fairly uniform through the year. Mean monthly air temperature at Honolulu varies from 71° F. in January to 78.4° F. in August. Northeast trade winds prevail throughout the year, but from October to April they are occasionally interrupted by "Kona" (southerly or southwesterly) winds. "Kona" weather is often accompanied by rainstorms which may last from a few hours to three or four days.

SEA TEMPERATURES: The average annual sea-surface temperature in the Hawaiian area is about 77° F. Maximum and minimum monthly averages are shown in table 1.

Table 1 - Maximum and Minimum Monthly Average Sea Temperatures (°F.) in the Hawaiian Area[1]

Month	Sea Temperature							
	Maximum				Minimum			
		Feet				Feet		
	Surface	100	200	300	Surface	100	200	300
January	80	79	78	78	68	68	66	64
February ...	79	78	78	77	67	66	65	64
March	78	77	77	76	66	67	64	64
April	78	77	77	76	68	68	64	64
May	79	78	78	77	70	69	66	64
June	80	80	79	77	74	71	68	64
July	82	80	80	78	76	73	66	64
August	82	81	81	79	77	75	68	66
September ..	82	82	81	80	77	76	67	67
October	82	82	82	80	76	75	68	66
November ...	82	81	81	80	72	72	68	67
December ...	80	80	80	79	70	70	67	66

1/Reproduced from Oceanographic Rept. No. 12, June 1948, Scripps Inst. of Oceanography, Univ. of Calif.

It is at once apparent that, at the surface, the differences between the monthly maximum and minimum temperatures become smaller during the summer season and larger during the winter. The same condition exists at a depth of 100 feet, while at 200 and 300 feet, the differences appear to remain relatively constant. The horizontal distribution of sea temperatures at the surface, 100 feet, 200 feet, and 300 feet, at the two extremes of the year (February and August), is shown in figure 1. The thermocline, therefore, generally lies between 250 and 300 feet during the winter months, rising to roughly 150 feet during the summer (figure 2).

Since the tunas are primarily warm-water forms, it is to be expected that the vertical and horizontal distribution of the various species is to some extent governed by sea temperature conditions. The results of the Japanese exploratory investigations in the region of the Inner South Seas, for example, indicate that sea temperature had a close bearing on the occurrence of skipjack and yellowfin tuna, especially in the region of the equatorial countercurrent, where the main fishing grounds for these species were located. Their findings indicate that when temperatures in this zone were below normal, a marked decrease in the catches of skipjack and yellowfin tuna occurred, followed by an increase in the long-line catches of big-eyed tuna and albacore.

Although no basic studies on the relation of sea temperatures to the occurrence and abundance of tunas in Hawaiian waters have been completed, the Territorial Division of Fish and Game has been gathering data on the relation of subsurface temperatures to tuna long-line fishing. The commercial catch records indicate a marked increase in the landings of yellowfin tuna and skipjack, as the waters in this region become progressively warmer during the summer months. As the season advances and the waters again become cooler, the numbers of these two species entering the commercial catches show a decided decline. Big-eyed tuna and albacore, which may be less tolerant of the higher summer temperatures, occur in the catches in fewer

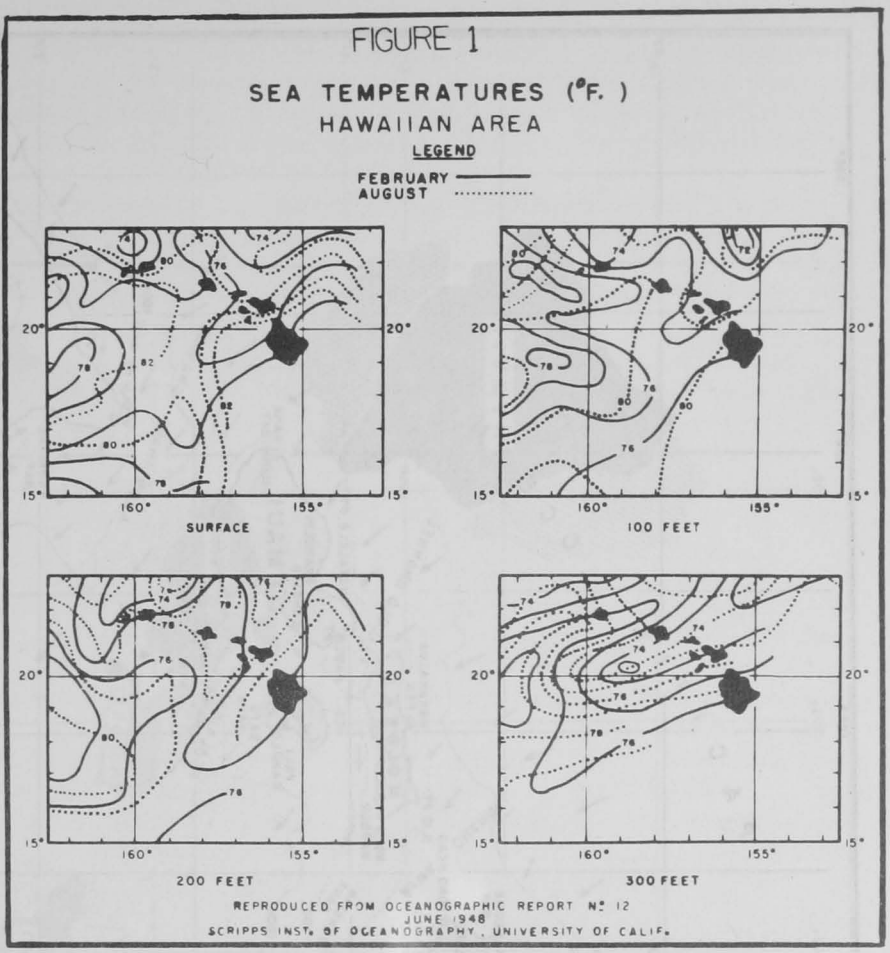
numbers during the summer season. These two species enter the catches in the greatest abundance during the winter months, and their increased appearance follows closely the decline of the yellowfin and skipjack.

OCEAN CURRENTS: The waters surrounding the Hawaiian Islands are subject to strong and variable currents through the year (figure 3). In general, currents run southwesterly and westerly offshore, due to the influence of the northeast trade winds. Close inshore, however, the flow is northward along the coastlines, except off the Puna (southeast) coast of Hawaii, where the inshore current flows in a southwesterly direction. In the channels between the islands, the currents are tidal, but to some extent, are influenced by the prevailing winds and the position of the islands with respect to each other.

FIGURE 1

SEA TEMPERATURES (°F.)

HAWAIIAN AREA



REPRODUCED FROM OCEANOGRAPHIC REPORT Nº 12
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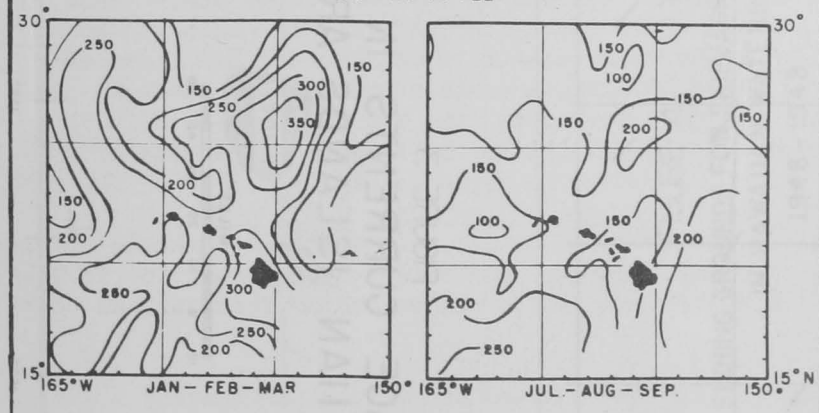
FIGURE 2

AVERAGE THERMOCLINE DEPTH

HAWAIIAN AREA

DEPTHS IN FEET



REPRODUCED FROM OCEANOGRAPHIC REPORT Nº 12
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SCRIPPS INST. OF OCEANOGRAPHY, UNIVERSITY OF CALIF.

In Kauai Channel, the main current approaches from the northeast, but abruptly changes its direction of flow to the northwest as it strikes the shallow water bank that extends northwestward off Kaena Point, Oahu. It continues northwestward until it reaches the east coast of Kauai; here it divides in the vicinity of Nawiliwili Bay. North of the bay it follows the coastline and joins the main current north of the island. South of Nawiliwili Bay it joins a large eddy movement that exists south and west of Kauai. This eddy rotates in a clockwise pattern, extending a maximum of about 30 miles offshore. The north-

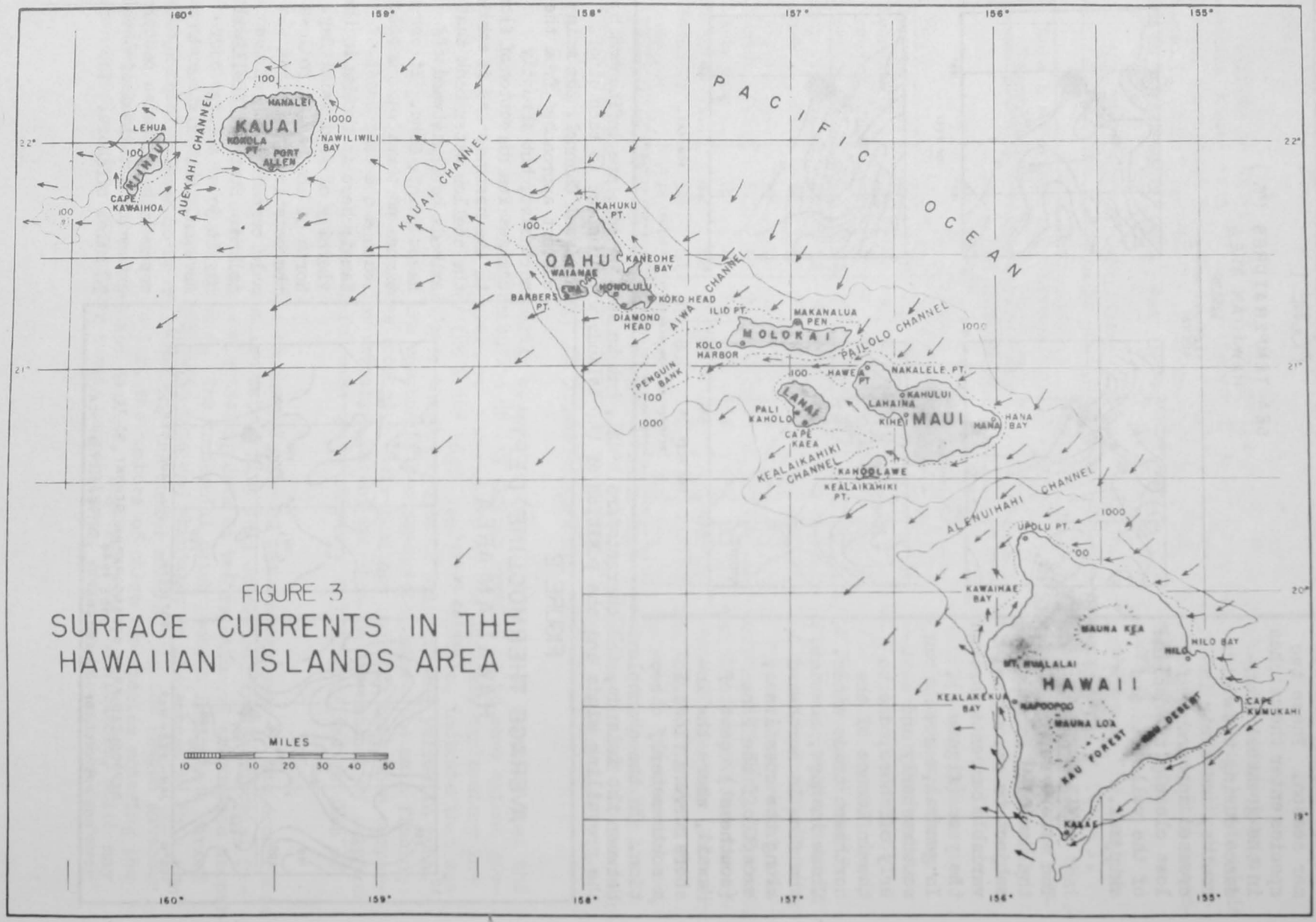


FIGURE 3
SURFACE CURRENTS IN THE HAWAIIAN ISLANDS AREA

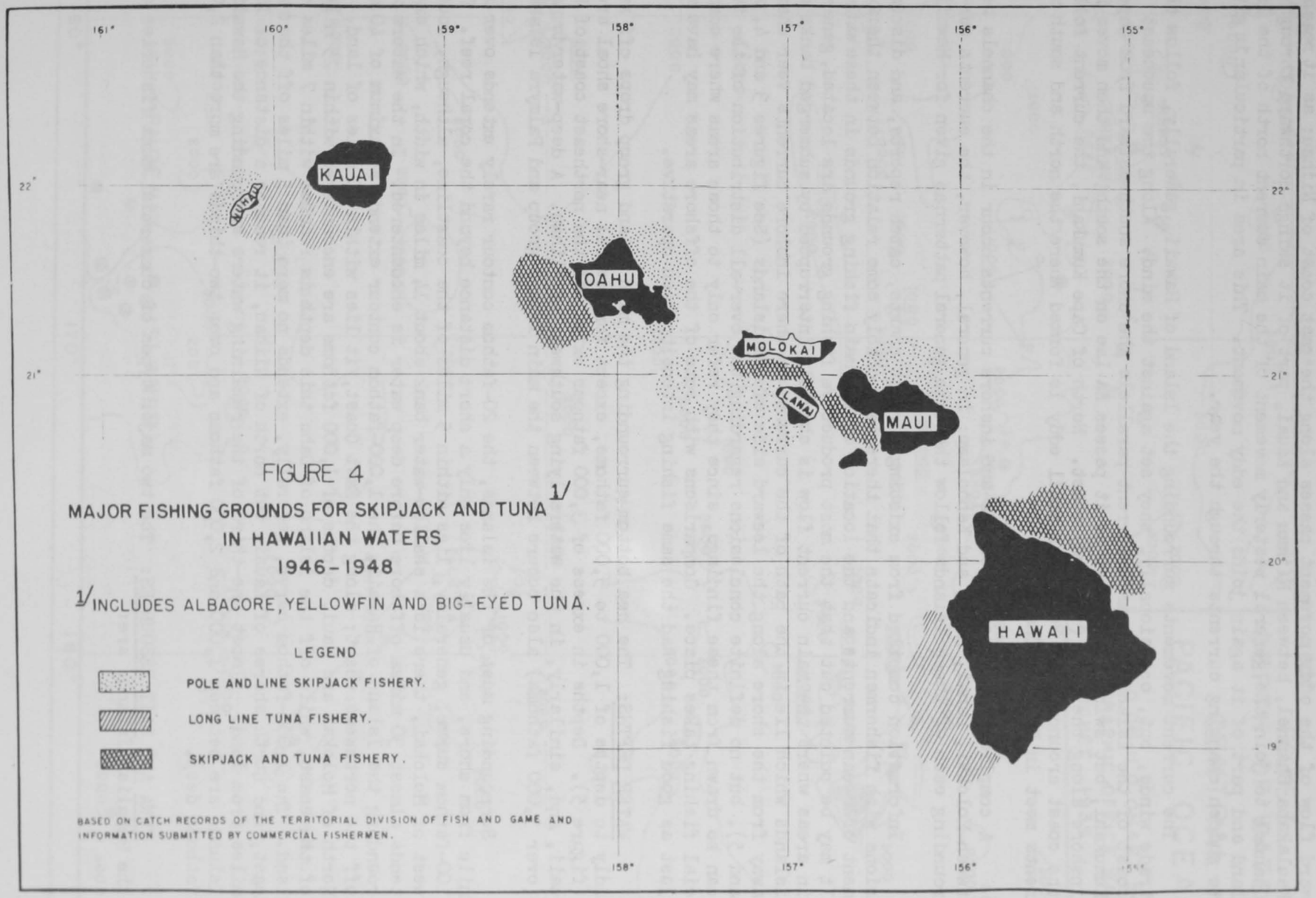


FIGURE 4

MAJOR FISHING GROUNDS FOR SKIPJACK AND TUNA 1/
IN HAWAIIAN WATERS
1946-1948

1/ INCLUDES ALBACORE, YELLOWFIN AND BIG-EYED TUNA.

ward flow of the eddy movement passes along the east coast of Niihau; as it reaches Kaulakaha Channel, between Niihau and Kauai, part of it swings northward through the Channel to join the general westerly movement of the main current north of the Island and part of it again joins the eddy movement. This area in particular is given to sudden changing currents through the year.

The current movements surrounding the Island of Hawaii, generally, follow the trade winds, but, occasionally, they set against the wind. Along the southeast coast of the Island, the main current parallels the shore southwestward from Cape Kumukahi, but swings northwest as it passes Ka Lae on the south, and then moves close inshore along the Kona (leeward) coast. North of Cape Kumukahi, the current follows the coast around Upolu Point. A small eddy is formed where the north and south currents meet in Kawaihae Bay.

A complicated system of eddies and inshore currents occur in the channels between Molokai, Lanai, Maui, and Kahoolawe; in general, however, the currents surrounding each of these islands follow the same general patternas given for Hawaii.

Information compiled from existing current charts, catch reports, and discussions with fishermen indicate that there is probably some relation between the movement of ocean currents and the location of the main fishing grounds in these waters. It may be pointed out that the most productive fishing grounds are located, generally, in areas where the main current flow is abruptly interrupted by submerged banks or islands which lie in the path of the current, or where inshore currents veer sharply away from the shore along the leeward side of the islands (See figures 3 and 4, pp. 4 and 5), but no definite conclusions regarding the over-all distribution of the tunas can be drawn from these findings, since they refer only to those areas where commercial fishing takes place. Comparisons with some of the offshore areas may have shown just as good fishing had the same fishing intensity been operative.

WATER DEPTHS: The sea bottom surrounding the main island group drops off rapidly to depths of 1,000 to 3,000 fathoms, except for several near-shore shoal areas (figure 5). Depths in excess of 3,000 fathoms exist off the northeast coast of Hawaii, and, similarly, in the waters lying southwest of Niihau. A deep-water trough (over 3,000 fathoms) also occurs between the main island group and Palmyra Island.

Surrounding most of the islands, the 20-fathom contour rarely extends over one mile from shore, and usually lies only a short distance beyond the coral reef. The 100-fathom curve, generally, lies within 5 miles of the coastline, although, southwest of Molokai, there is a shallow-water bank about 14 miles in width, which extends almost 30 miles offshore before deep water is encountered. In the waters surrounding the Island of Hawaii, the 1,000-fathom contour extends a maximum of 40 miles off the northwest coast; along the East Coast, it lies within 10 miles of land. North of Molokai and Maui, depths of 1,000 fathoms are encountered within 25 miles of the coast, while off the island of Oahu this depth is reached within 7 miles of land. The 1,000-fathom curve, generally, extends no more than 5 miles off the south, east, and north shores of Kauai, but north of Niihau, it reaches a distance of 14 miles from land. Almost one-third of the remaining waters surrounding the Hawaiian Islands are between 1,000 and 2,000 fathoms and over two-thirds are more than 2,000 fathoms deep.

TUNA AND BAIT RESOURCES: The two major types of commercial tuna fisheries of the Hawaiian Islands are:

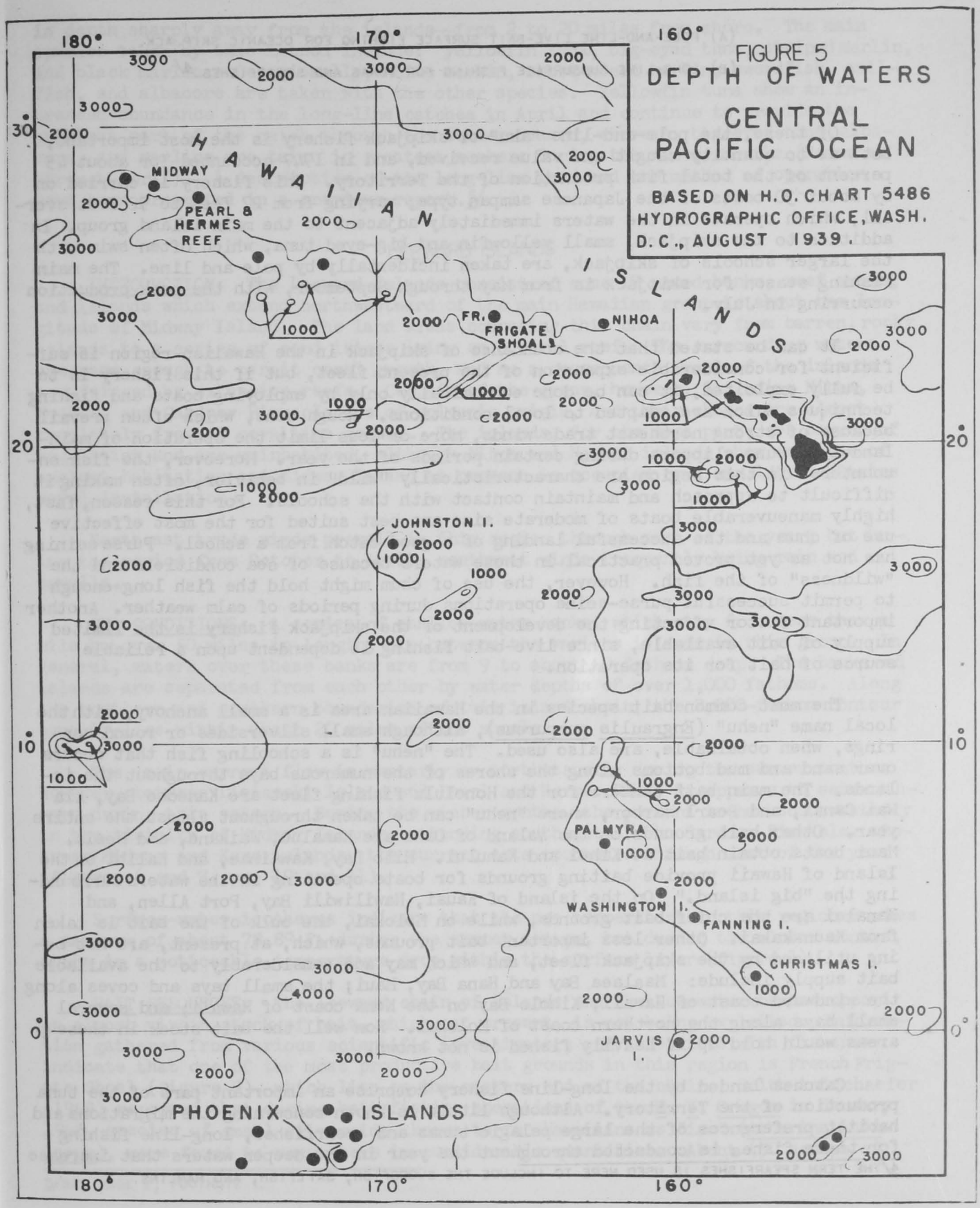


FIGURE 5
DEPTH OF WATERS
CENTRAL
PACIFIC OCEAN
BASED ON H.O. CHART 5486
HYDROGRAPHIC OFFICE, WASH.
D.C., AUGUST 1939.
180°
170°
160°
30°
20°
10°
0°
HAWAIIAN ISLANDS
MIDWAY
PEARL & HERMES REEF
FR. FRIGATE SHOALS
NIHOA
JOHNSTON I.
PALMYRA
WASHINGTON I.
FANNING I.
CHRISTMAS I.
JARVIS I.
PHOENIX ISLANDS

(A) POLE-AND-LINE LIVE-BAIT SURFACE FISHING FOR OCEANIC SKIPJACK.

(B) LONG-LINE SUBSURFACE FISHING FOR TUNAS AND SPEARFISHES.4/

Of these, the pole-and-line "aku" or skipjack fishery is the most important, both as to quantity caught and value received, and in 1947 accounted for about 45 percent of the total fish production of the Territory. This fishery is carried on by about 30 boats of the Japanese sampan type, varying from 27 feet to 92 feet overall, which operate in the waters immediately adjacent to the main island group. In addition to the skipjack, small yellowfin and big-eyed tuna, which often swim with the larger schools of skipjack, are taken incidentally by pole and line. The main fishing season for skipjack is from May through September, with the peak production occurring in July.

It can be stated that the abundance of skipjack in the Hawaiian region is sufficient for considerable expansion of the present fleet, but if this fishery is to be fully exploited, it can be done economically only by employing boats and fishing techniques which are adapted to local conditions. Rough seas, which often prevail because of strong northeast trade winds, more or less limit the operation of mainland-type tuna clippers during certain periods of the year. Moreover, the fish encountered in this region are characteristically "wild" in behavior, often making it difficult to approach and maintain contact with the schools. For this reason, fast, highly maneuverable boats of moderate size are best suited for the most effective use of chum and the successful landing of a good catch from a school. Purse seining has not as yet proved practical in these waters because of sea conditions and the "wildness" of the fish. However, the use of chum might hold the fish long enough to permit successful purse-seine operations during periods of calm weather. Another important factor affecting the development of the skipjack fishery is the limited supply of bait available, since live-bait fishing is dependent upon a reliable source of bait for its operation.

The most common bait species in the Hawaiian area is a small anchovy, with the local name "nehu" (Engraulis purpureus), although small silversides or round herrings, when obtainable, are also used. The "nehu" is a schooling fish that occurs over sand and mud bottoms along the shores of the numerous bays throughout the islands. The main bait centers for the Honolulu fishing fleet are Kaneohe Bay, Ala Wai Canal, and Pearl Harbor, where "nehu" can be taken throughout almost the entire year. Other bait grounds on the island of Oahu are Kahaluu, Waikane, and Heeia. Maui boats obtain bait at Kihei and Kahului. Hilo Bay, Kawaihae, and Kalihi on the Island of Hawaii provide baiting grounds for boats operating in the waters surrounding the "big island." On the island of Kauai, Nawiliwili Bay, Port Allen, and Hanalei are the chief bait grounds, while on Molokai, the bulk of the bait is taken from Kaunakakai. Other less important bait grounds, which, at present, are not being utilized by the skipjack fleet, and which may add considerably to the available bait supply include: Maalaea Bay and Hana Bay, Maui; the small bays and coves along the windward coast of Hawaii; Kiholo Bay on the Kona coast of Hawaii; and several small bays along the northern coast of Molokai. How well the bait stock in these areas would hold up if heavily fished is not known.

Catches landed by the long-line fishery comprise an important part of the tuna production of the Territory. Although little is known concerning the migrations and habitat preferences of the large pelagic tunas and spearfishes, long-line fishing for these fishes is conducted throughout the year in the deeper waters that increase

4/THE TERM SPEARFISHES IS USED HERE TO INCLUDE THE SWORDFISH, SAILFISH, AND MARLINS.

in depth sharply away from the islands—from 2 to 20 miles from shore. The main species taken by this method include: yellowfin tuna, big-eyed tuna, striped marlin, and black marlin. Occasionally, white marlin, short-nosed marlin, swordfish, sailfish, and albacore are taken with the other species. Yellowfin tuna show an increased abundance in the long-line catches in April and continue to provide the greatest part of the catch through the summer season, whereas, big-eyed tuna, albacore, and marlins are taken in greatest numbers during the winter months (November through April). A description of the long-line gear and the method of operation have been presented in a previous report.5/

LEEWARD ISLANDS

INTRODUCTION: The Leeward Islands consist of some 17 named banks, reef areas, and islands which extend northwestward of the main Hawaiian group to about the longitude of Midway Island. The land areas composing this chain vary from barren, rocky islands to a series of sand islets lying on a coral reef. The surrounding waters are warm enough to permit coral growth, and as a consequence, most of the islands are fringed by extensive reefs. Certain of the group, however, including Nihoa, Necker, and Gardner Pinnacle are of volcanic origin, and their shores are almost completely free of coralline growth. The islands, for the most part, are barren of vegetation and are uninhabited, although Nihoa and Necker islands show evidence of ancient habitation and Midway Island at present is occupied by a small United States Naval installation.

Northeast trade winds prevail in this region through most of the year; but during the period from October to April, southwest winds frequently bring rain and squalls.

SEA CONDITIONS: A series of shallow-water banks, which vary from less than a mile to over 50 miles in length, lie between the various islands in this group. In general, waters over these banks are from 9 to about 40 fathoms deep. The banks and islands are separated from each other by water depths of over 1,000 fathoms. Along the northern and southern boundaries of this island chain, the 2,000-fathom contour usually lies within about 20 miles of the shoals.

The main current flow is westerly or northwesterly during the summer months. However, between Lisianski Island and Pearl and Hermes Reef, it appears to set northward during this season. During the winter months, the current trends southeasterly in the vicinity of Midway Islands, extending southeastward to Gardner Pinnacle. Between Midway and Kure islands, the current sets southward through most of the year (figures 6 and 7, pp. 10 and 11).

Surface-water isotherms indicate that the sea temperature in this region reaches a maximum of about 78.8° F. during the summer season, but during the winter months, there is a noticeable temperature drop within the surface layer (figure 1).

BAIT RESOURCES: The leeward chain of islands and shallow-water banks support an almost virgin stock of bait, which, at present, is not being exploited. Information gathered from various scientific investigators and interviews with fishermen indicate that one of the most productive bait grounds in this region is French Frigate Shoal (figure 8), which lies on the eastern end of the chain. Smith and Schaefer (1949) reported that during bait-fishing operations of the M. V. Oregon in January 1948, species of small silverside, known to the Hawaiians as "iao" (Atherina insularum), were found to occur here in considerable quantities. About 450 scoops of

5/SEE PAGE 1, FOOTNOTE 1.

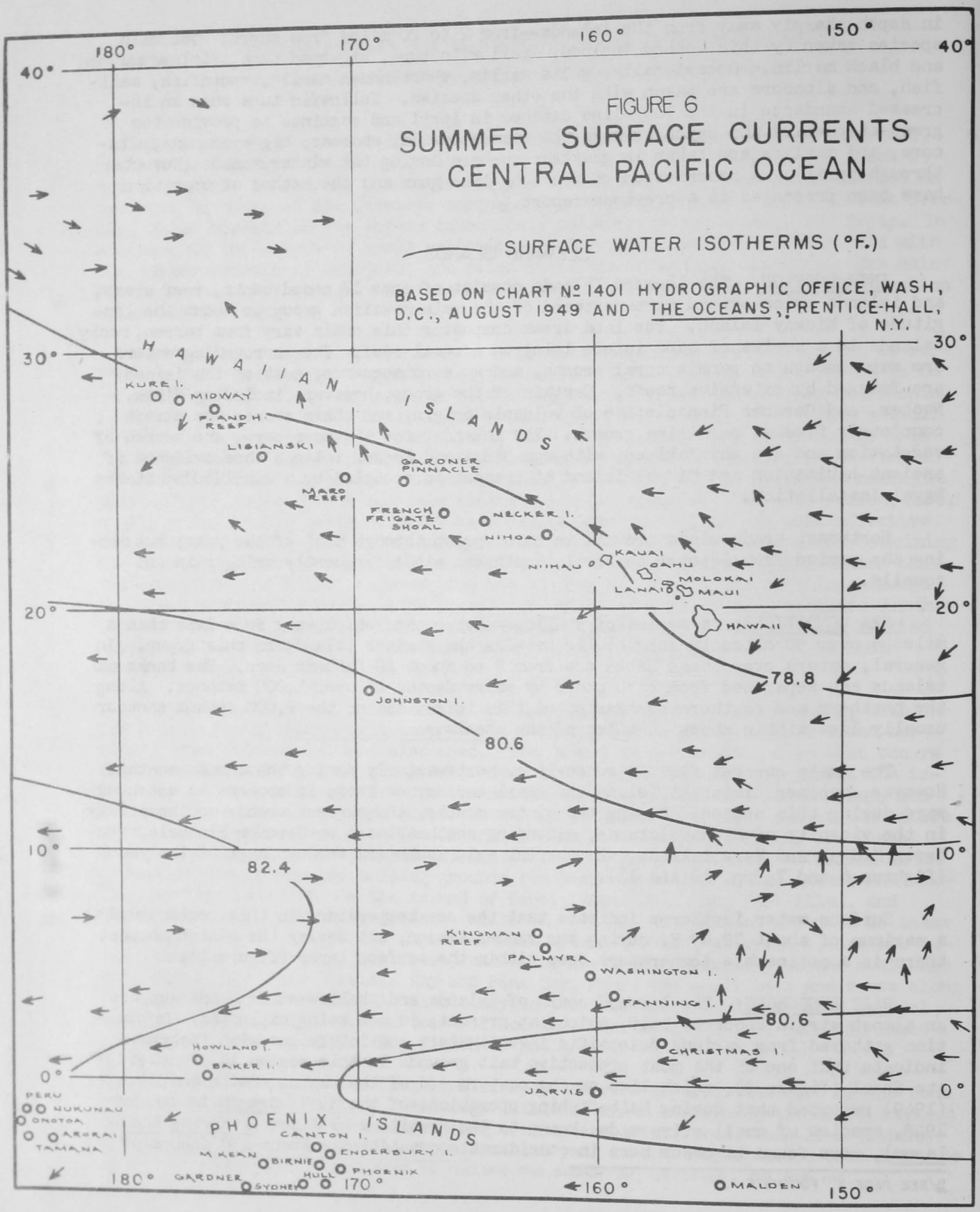


FIGURE 6
SUMMER SURFACE CURRENTS
CENTRAL PACIFIC OCEAN
SURFACE WATER ISOTHERMS (°F.)
BASED ON CHART Nº 1401 HYDROGRAPHIC OFFICE, WASH, D.C., AUGUST 1949 AND THE OCEANS, PRENTICE-HALL, N.Y.
180°
170°
160°
150°
40°
30°
20°
10°
0°
HAWAIIAN ISLANDS
KURE I.
MIDWAY
P. AND H. REEF
LISIANSKI
GARDNER PINNACLE
MARO REEF
FRENCH FRIGATE SHOAL
NECKER I.
NIHOA
NIIHAU
KAUAI
OAHU
LANAI
MOLOKAI
MAUI
HAWAII
78.8
JOHNSTON I.
80.6
82.4
KINGMAN REEF
PALMYRA
WASHINGTON I.
FANNING I.
HOWLAND I.
BAKER I.
CHRISTMAS I.
JARVIS
PERU
NUKUNAU
ONOTOA
ARORAI
TAMANA
PHOENIX ISLANDS
CANTON I.
M'KEAN
BIRNIE
ENDERBURY I.
HULL
PHOENIX
GARDNER
SYDNEY
MALDEN

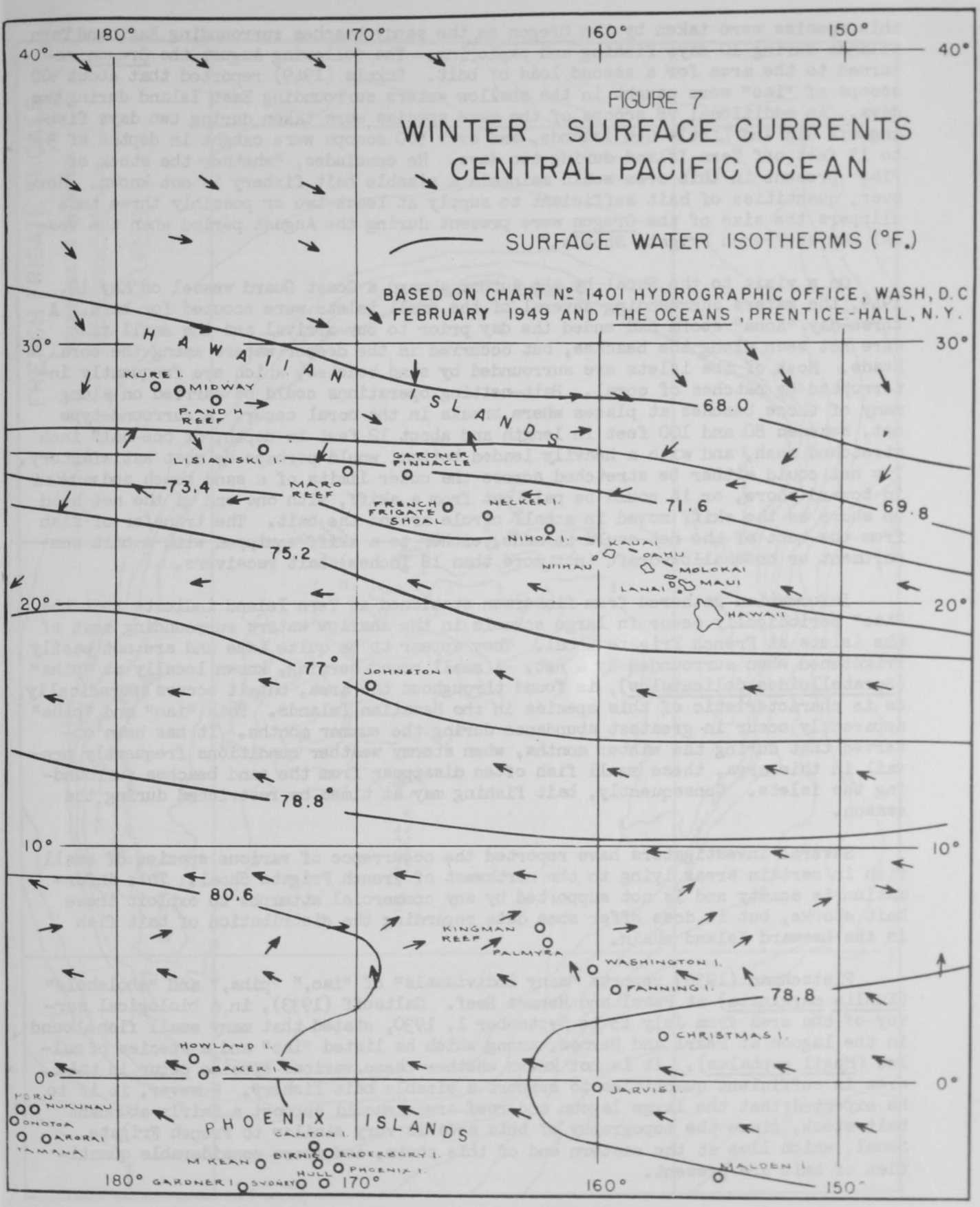


FIGURE 7
WINTER SURFACE CURRENTS
CENTRAL PACIFIC OCEAN
SURFACE WATER ISOTHERMS (°F.)
BASED ON CHART Nº 1401 HYDROGRAPHIC OFFICE, WASH, D.C
FEBRUARY 1949 AND THE OCEANS, PRENTICE-HALL, N.Y.
180°
170°
160°
150°
40°
30°
20°
10°
0°
HAWAIIAN ISLANDS
KURE I.
MIDWAY
P. AND H REEF
LISIANSKI I.
GARDNER PINNACLE
MARO REEF
FRENCH FRIGATE SHOAL
NECKER I.
NIHOA I.
KAUAI
OAHU
NIIHAU
MOLOKAI
LANAI
MAUI
HAWAII
68.0
69.8
71.6
73.4
75.2
77°
78.8°
80.6
JOHNSTON I.
KINGMAN REEF
PALMYRA
WASHINGTON I.
FANNING I.
78.8
CHRISTMAS I.
HOWLAND I.
BAKER I.
JARVIS I.
PHOENIX ISLANDS
CANTON I.
ENDERBURY I.
PHOENIX I.
HULL
MCKEAN
GARDNER I.
SYDNEY
MALDEN I.
PERU
NUKUNAU
ONOTOA
ARORAI
TAMANA

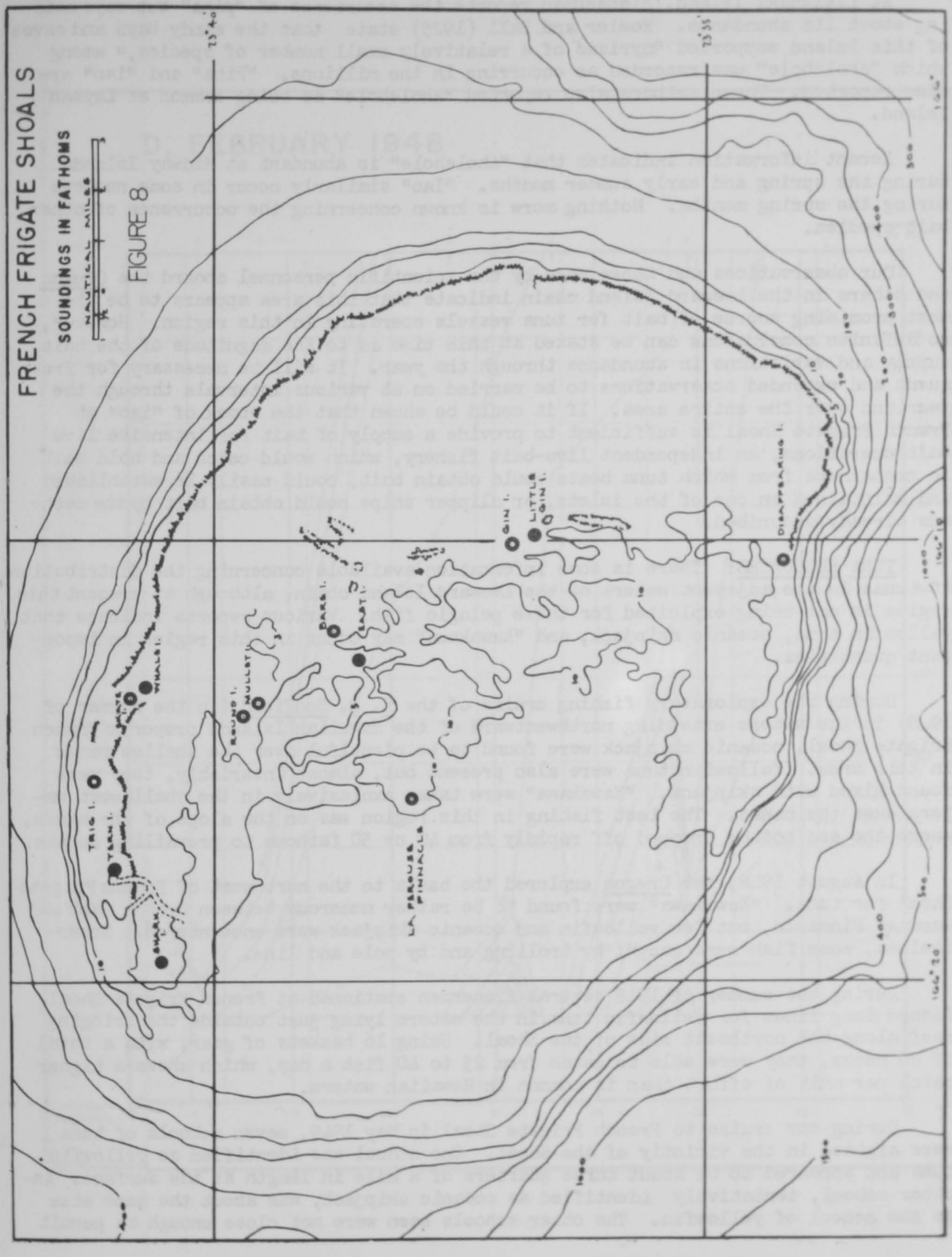
this species were taken by the Oregon on the sandy beaches surrounding East and Tern islands during 10 days fishing and exploring. The following August the Oregon returned to the area for a second load of bait. Eckels (1949) reported that about 300 scoops of "iao" were caught in the shallow waters surrounding East Island during two days. An additional 78 scoops of the same species were taken during two days fishing off Gin and Little Gen islands, and over 500 scoops were caught in depths of 3 to 15 feet off Tern Island during two days. He concludes, "whether the stock of 'iao' present in this area would maintain a sizable bait fishery is not known. However, quantities of bait sufficient to supply at least two or possibly three tuna clippers the size of the Oregon were present during the August period when the vessel was at French Frigate Shoals."

On a visit to the Shoal by the author aboard a Coast Guard vessel on May 18, 1949, the waters surrounding several of the small islets were scouted for bait. A three-day "Kona" storm had ended the day prior to our arrival and the small fish were not seen along the beaches, but occurred in the deeper waters among the coral heads. Most of the islets are surrounded by sand beaches, which are frequently interrupted by patches of coral. Bait-netting operations could be carried on along many of these beaches at places where breaks in the coral occur. A surround-type net, between 80 and 100 feet in length and about 12 feet in depth, of one-half inch stretched mesh, and with a heavily leaded bottom, would perhaps be most satisfactory. The net could either be stretched across the outer limits of a sand beach and worked in toward shore, or it could be paid out from a skiff, with one end of the net held on shore as the skiff moved in a half circle around the bait. The transfer of fish from the bunt of the net could be made, either to a skiff equipped with a bait compartment or to shallow-draft (not more than 18 inches) bait receivers.

Information gathered from fishermen stationed at Tern Island indicate that the "iao" periodically occur in large schools in the shallow waters surrounding most of the islets at French Frigate Shoal. They appear to be quite tame and are not easily frightened when surrounded by a net. A small round herring, known locally as "piha" (Spratelloides delicatulus), is found throughout the area, but it occurs sporadically, as is characteristic of this species in the Hawaiian Islands. Both "iao" and "piha" apparently occur in greatest abundance during the summer months. It has been observed that during the winter months, when stormy weather conditions frequently prevail in this area, these small fish often disappear from the sand beaches surrounding the islets. Consequently, bait fishing may at times be restricted during the season.

Several investigators have reported the occurrence of various species of small fish in certain areas lying to the northwest of French Frigate Shoal. This information is scanty and is not supported by any commercial attempts to exploit these bait stocks, but it does offer some data regarding the distribution of bait fish in the Leeward Island chain.

Pietschman (1938) reports "many individuals" of "iao," "piha," and "aholehole" (Kuhlia marginata) at Pearl and Hermes Reef. Galtsoff (1933), in a biological survey of the area from July 15 to September 1, 1930, stated that many small fish abound in the lagoon at Pearl and Hermes, among which he listed "iao" and a species of mullet (Mugil cephalus). It is not known whether these various species occur in this area in sufficient quantities to support a sizable bait fishery. However, it is to be expected that the large lagoon and reef areas should support a fairly abundant bait stock, since the topography of this area is very similar to French Frigate Shoal, which lies at the eastern end of this chain, and where considerable quantities of bait are present.


FRENCH FRIGATE SHOALS
SOUNDINGS IN FATHOMS
NAUTICAL MILES
FIGURE 8
TRIG I.
TERN I.
SHARK I.
WHALE I.
ROUND I.
NULLET I.
BARE I.
EAST I.
GIN I.
LITTLE GIN I.
DISAPPEARING I.
LA PEROUSE PINNACLE

At Lisianski Island, Pietschman reports the occurrence of "piha" but says nothing about its abundance. Fowler and Ball (1925) state that the sandy bays and coves of this island supported "myriads of a relatively small number of species," among which "aholehole" was recorded as occurring in the millions. "Piha" and "iao" are also reported. These authors also reported "aholehole" as being common at Laysan Island.

Recent information indicates that "aholehole" is abundant at Midway Islands during the spring and early summer months. "Iao" similarly occur in some numbers during the spring months. Nothing more is known concerning the occurrence of other bait species.

Our observations and those made by the scientific personnel aboard the Oregon and others in the Leeward Island chain indicate that this area appears to be the most promising source of bait for tuna vessels operating in this region. However, no definite conclusions can be stated at this time as to the magnitude of the bait supply and variations in abundance through the year. It will be necessary for frequent and extended observations to be carried on at various intervals through the year and over the entire area. If it could be shown that the stock of "iao" at French Frigate Shoal is sufficient to provide a supply of bait for intensive live-bait operations, an independent live-bait fishery, which would catch and hold bait in containers from which tuna boats could obtain bait, could easily be established and maintained on one of the islets, or clipper ships could obtain bait by the methods already described.

TUNA RESOURCES: There is some information available concerning the distribution of tunas in the adjacent waters of the Leeward Island chain, although at present this region is not being exploited for these pelagic fish. Various reports indicate that yellowfin tuna, oceanic skipjack, and "kawakawa" may occur in this region in important quantities.

During the exploratory fishing cruise of the N. B. Scofield (in the summer of 1948) in the waters extending northwestward of the Hawaiian Islands proper to French Frigate Shoal, oceanic skipjack were found to be plentiful over the shallow banks in this area. Yellowfin tuna were also present but, almost invariably, they were found mixed with skipjack. "Kawakawa" were taken exclusively in the shallowest waters over the banks. The best fishing in this region was on the slope of the banks, where the sea bottom dropped off rapidly from 40 or 50 fathoms to prevailing depths.

In August 1948, the Oregon explored the banks to the northwest of French Frigate Shoal for tuna. "Kawakawa" were found to be rather numerous between Brooks Bank and Gardner Pinnacle, but few yellowfin and oceanic skipjack were encountered. Nevertheless, some fish were caught by trolling and by pole and line.

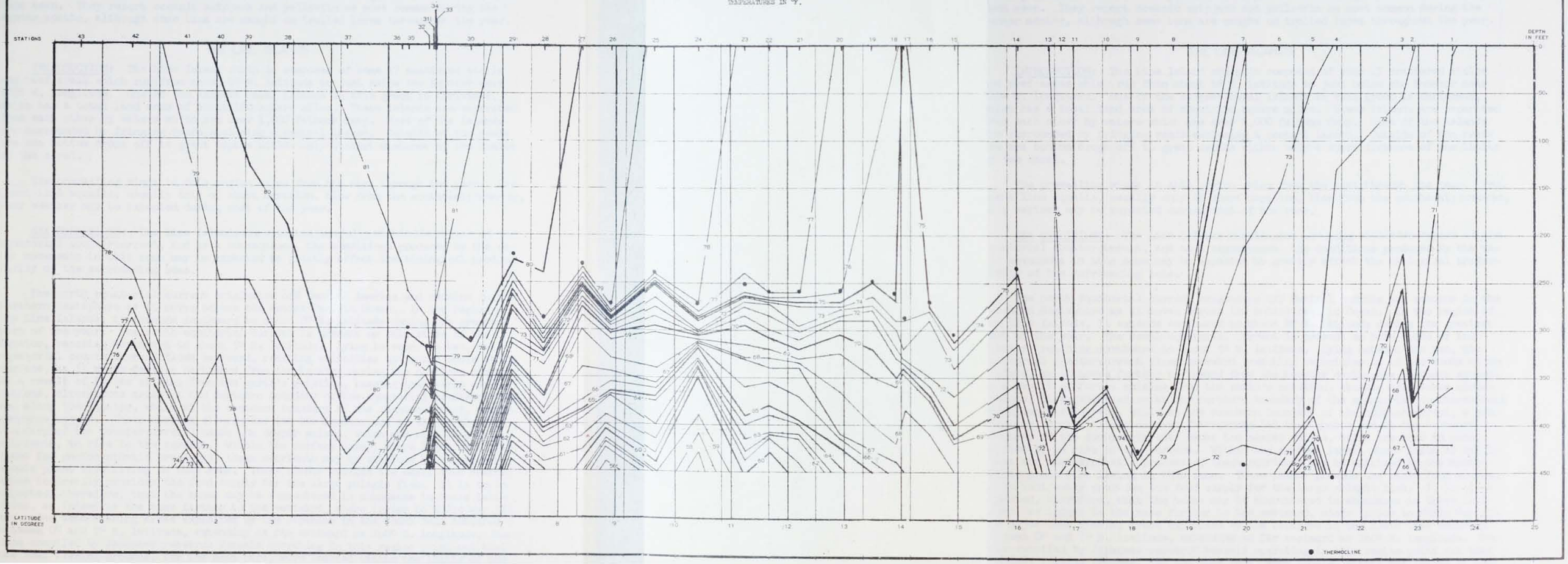
During the summer of 1948 several fishermen stationed at French Frigate Shoal fished long lines for yellowfin tuna in the waters lying just outside the fringing reef along the northeast side of the Shoal. Using 16 baskets of gear, with a total of 80 hooks, they were able to catch from 25 to 40 fish a day, which shows a higher catch per unit of effort than is common in Hawaiian waters.

During our cruise to French Frigate Shoal in May 1949, seven schools of tuna were sighted in the vicintiy of the Shoal. One school was identified as yellowfin tuna and appeared to be about three quarters of a mile in length at the surface. Another school, tentatively identified as oceanic skipjack, was about the same size as the school of yellowfin. The other schools seen were not close enough to permit

FIGURE 9

BATHYTHERMOGRAPH DATA--M. V. OREGON--FRENCH FRIGATE SHOALS TO JARVIS ISLAND, FEBRUARY 1948

TEMPERATURES IN °F.



identification. Six of these schools were seen under flocks of birds. In addition, about 15 flocks of birds, which appeared to be "working" over schools of fish, were sighted between Nihoa and French Frigate Shoal.

Discussions with Hawaiian fishermen (engaged in hand lining for bottom fish over the shallow-water banks in this region) indicate that schools of yellowfin, oceanic skipjack, and "kawakawa" are invariably seen on the cruises to and from the fishing grounds. Schools of yellowfin, a mile or so in length at the surface, have been seen. They report oceanic skipjack and yellowfin as most common during the summer months, although some tuna are caught on trolled lures throughout the year.

THE LINE ISLANDS

INTRODUCTION: The Line Island chain is composed of some 17 scattered atolls and reef areas which run from about 6° N. latitude to just below the Equator near 160° W. longitude. One of the largest coral islands in this group is Christmas, which has a total land area of about 160 square miles. These islands are separated from each other by waters which are over 1,000 fathoms deep. Most of the islands are surrounded by fringing reefs enclosing a central lagoon. Outside of the reefs the sea bottom drops off to great depths within only a short distance of the limits of the coral.

The prevailing winds in this region blow from the east through the year. Frequent line squalls, usually only of short duration, blow from the southeast; however, fair weather may be expected during most of the year.

SEA CONDITIONS: The Line Islands are situated partially within the region of the equatorial countercurrent, and as a consequence, the conditions produced by the water movements in this zone may be expected to greatly affect the biological productivity of the surrounding seas.

The north equatorial current originates off Central America and remains in the Northern Hemisphere as it moves across the entire Pacific Ocean. In the region of the Line Islands, it extends southward to about 8° N. latitude during the greatest part of the year. The south equatorial current is present on both sides of the Equator, reaching northward to about 5° N. latitude. Lying between the two, the equatorial countercurrent flows eastward, reaching velocities up to two knots at the surface, as it moves farther northward from the Equator during the northern summer. As a result of forces arising from the earth's rotation, causing transverse circulations, divergences arise at the northern boundary of the equatorial countercurrent and along the Equator, while at the southern boundary of the countercurrent, a convergence occurs. These current divergences (at the Equator and at the northern boundary of the countercurrent) cause the deeper waters, which are rich in plant nutrients, to rise to the surface. Within the surface layer, where light is sufficient for photosynthetic processes, these nutrients may be utilized by the microscopic plant life living in this zone. These plants provide the basic food source, which indirectly provides the food supply for the large pelagic fish. It is to be expected, therefore, that the tunas may be encountered in abundance in these latitudes, as indeed is the case farther to the westward, where (prior to World War II) the major tuna fishing areas exploited by the Japanese in the South Seas centered between 0° and 7° N. latitude, extending as far eastward as 160° E. longitude. The data compiled by Japanese research vessels operating in this region point out that the best fishing grounds, for the most part, were located within the limits of the equatorial countercurrent, with yellowfin tuna heading the list of species caught.

Surface water isotherms show little horizontal variation in sea temperatures in the region of the Line Islands; the only apparent difference occurs at the two extremes of the year (figures 6 and 7). The depth to the thermocline, however, varies greatly in this zone due to the upwelling associated with the equatorial countercurrent. The data recorded by the Oregon in February 1948 (figure 9) indicates that, near the Equator, the least depth to the thermocline was found to be about 270 feet, while the greatest depth was 400 feet at 1° N. latitude. The Carnegie's findings, similarly, indicate a great variation in depth to the thermocline in a north-south direction in the waters lying east of this island chain (figure 10). The thermocline lies closest to the surface, of course, where the upwelling occurs along the divergences.

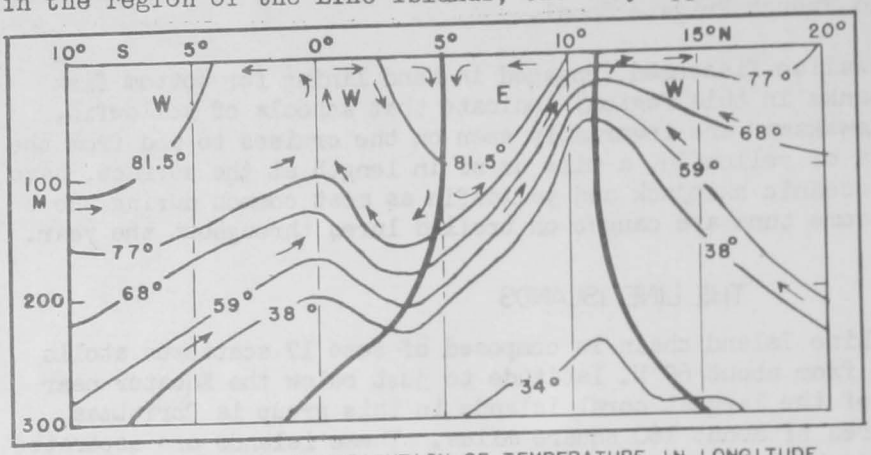


FIGURE 10 - VERTICAL DISTRIBUTION OF TEMPERATURE IN LONGITUDE 140° W., BETWEEN 10° S. AND 20° N. IN THE PACIFIC OCEAN. ACCORDING TO OBSERVATIONS MADE BY THE CARNEGIE, OCTOBER 192[illegible] (REPRODUCED FROM THE OCEANS, PRENTICE HALL, N. Y.).

The variations in thermocline depth must be taken into consideration with respect to long-line operations in this area, for in all likelihood, the vertical distribution of the tunas is influenced to a large extent by subsurface temperature conditions. The results of the Japanese exploratory investigations, for example, indicate that water temperature at the 100-meter stratum is most closely related to long-line fishing for yellowfin tuna in the equatorial regions lying to the westward of the Line Islands. Within the limits of the equatorial countercurrent (where yellowfin were found to be most abundant), the best catches were made when temperatures at a depth of 100 meters were over 20° C. (68° F.)

BAIT RESOURCES: The only definite information on the bait fish resources of this area is that pertaining to Palmyra Island (figure 11). On a survey trip to Palmyra by the author in June 1949, the entire island was scouted for bait. It was immediately obvious that fish of the size suitable for use as live bait were most plentiful in East Lagoon. These were primarily species of the mullet family (Mugil crenilabis, M. vaigiensis, and M. trichilus), varying from one inch to over 6 inches in length. The mullet occurs here in schools of varying size, from a few scoops to a hundred or more scoops, and could be seen swimming at the surface over the entire lagoon. Small milkfish (Chanos chanos), about 2 or 3 inches long, were also in evidence along the beaches. In West Lagoon, small goatfish, from one to 4 inches long, occurred in quantity along the north shore of the lagoon. According to several of the natives, the goatfish are fairly abundant along the sand beaches during June, July, and August; however, it is doubtful that they exist in quantities sufficient to supply anything but very limited fishing operations.

In February 1949, the commercial tuna clipper Calistar prospected Palmyra Island for bait. Using a Galapagos net in the shallow waters of East Lagoon, only about 8 scoops of 5-inch mullet were taken. From discussions with Civil Aeronautics Administration (CAA) personnel stationed on the island it was learned that the small mullet, which, apparently, are most abundant during the summer months, were not in evidence during the Calistar's explorations in the early part of the year.

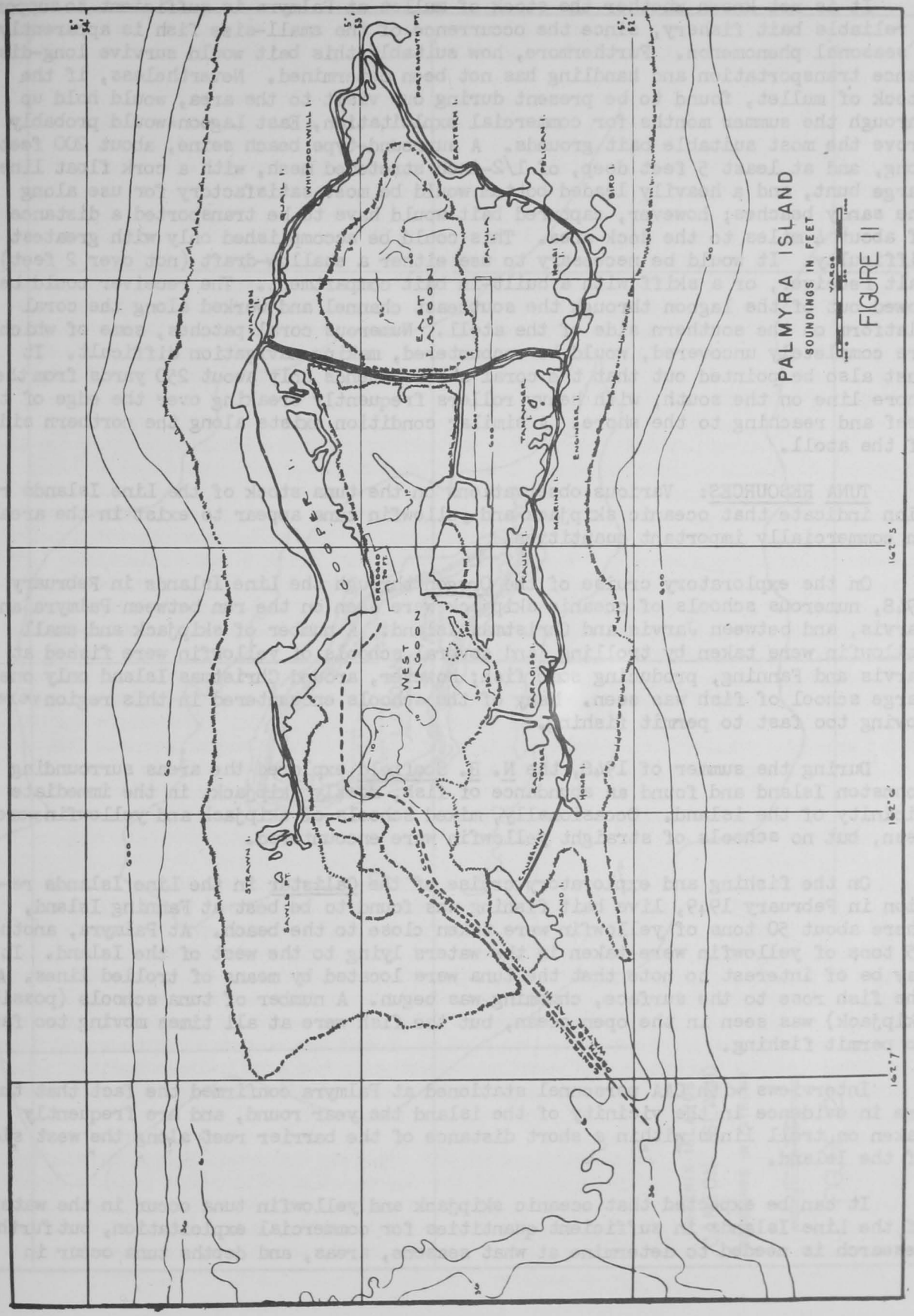

PALMYRA ISLAND
SOUNDINGS IN FEET
YARDS
EAST LAGOON
WEST LAGOON
PAPUA
PELICAN I.
BIRD I.
EASTERN I.
QUAIL I.
WHIPPOORWILL I.
AVIATION
MARINE I.
ENGINEER I.
RADIO TOWER
PARADISE I.
HOME I.
CAUSEWAY
BAND I.
STRAWN I.
SAVILE PT.
DREDGED
162° 5'
162° 6'
162° 7'

FIGURE 11

It is not known whether the stock of mullet at Palmyra is sufficient to support a reliable bait fishery, since the occurrence of the small-size fish is apparently a seasonal phenomenon. Furthermore, how suitably this bait would survive long-distance transportation and handling has not been determined. Nevertheless, if the stock of mullet, found to be present during our visit to the area, would hold up through the summer months for commercial exploitation, East Lagoon would probably prove the most suitable bait grounds. A surround-type beach seine, about 200 feet long, and at least 5 feet deep, of 1/2-inch stretched mesh, with a cork float line, large bunt, and a heavily leaded bottom would be most satisfactory for use along the sandy beaches; however, captured bait would have to be transported a distance of about 4 miles to the dock area. This could be accomplished only with greatest difficulty. It would be necessary to use either a shallow-draft (not over 2 feet) bait receiver, or a skiff with a built-in bait compartment. The receiver could be towed out of the lagoon through the southeast channel and worked along the coral platform on the southern side of the atoll. Numerous coral patches, some of which are completely uncovered, would be encountered, making navigation difficult. It must also be pointed out that the coral shelf extends only about 250 yards from the shore line on the south, with heavy rollers frequently breaking over the edge of the reef and reaching to the shore. A similar condition exists along the northern side of the atoll.

TUNA RESOURCES: Various observations on the tuna stock of the Line Islands region indicate that oceanic skipjack and yellowfin tuna appear to exist in the area in commercially important quantities.

On the exploratory cruise of the Oregon through the Line Islands in February 1948, numerous schools of oceanic skipjack were seen on the run between Palmyra and Jarvis, and between Jarvis and Christmas Island. A number of skipjack and small yellowfin were taken by trolling, and several schools of yellowfin were fished at Jarvis and Fanning, producing some fish; however, around Christmas Island only one large school of fish was seen. Many of the schools encountered in this region were moving too fast to permit fishing.

During the summer of 1948, the N. B. Scofield explored the areas surrounding Johnston Island and found an abundance of fish, mostly skipjack, in the immediate vicinity of the island. Occasionally, mixed schools of skipjack and yellowfin were seen, but no schools of straight yellowfin were encountered.

On the fishing and exploratory cruise of the Calistar in the Line Islands region in February 1949, live bait fishing was found to be best at Fanning Island, where about 50 tons of yellowfin were taken close to the beach. At Palmyra, another 15 tons of yellowfin were taken in the waters lying to the west of the Island. It may be of interest to note that the tuna were located by means of trolled lines. As the fish rose to the surface, chumming was begun. A number of tuna schools (possibly skipjack) was seen in the open ocean, but the fish were at all times moving too fast to permit fishing.

Interviews with CAA personnel stationed at Palmyra confirmed the fact that tuna are in evidence in the vicinity of the island the year round, and are frequently taken on troll lines within a short distance of the barrier reef along the west side of the Island.

It can be expected that oceanic skipjack and yellowfin tuna occur in the waters of the Line Islands in sufficient quantities for commercial exploitation, but further research is needed to determine at what seasons, areas, and depths tuna occur in

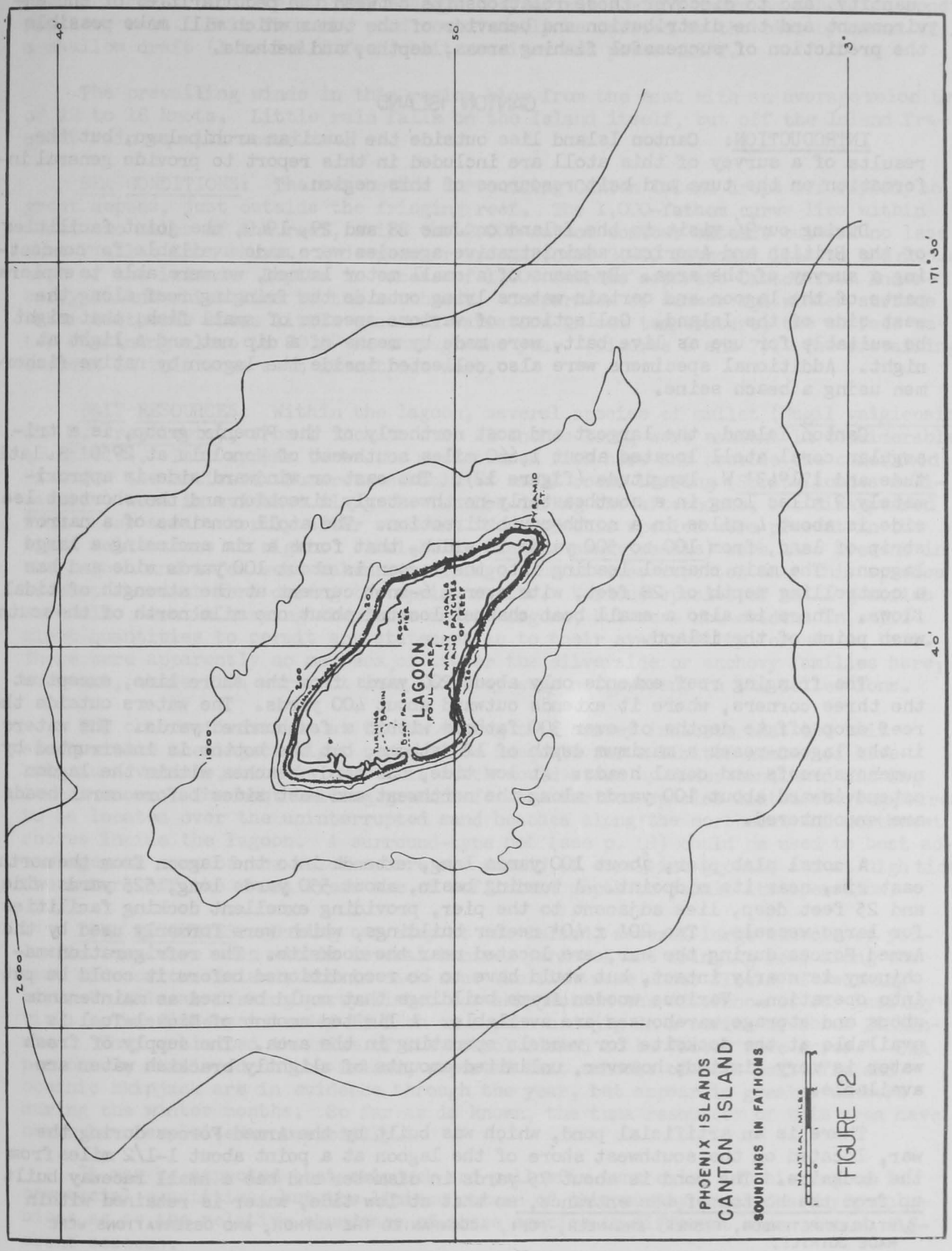

4'
50'
3'
171°30'
40'
LAGOON
POOL AREA
MANY SHOALS AND PATCHES OF REEF
ROCK PILE
PYRAMID PT.
TURNING BASIN
BOAT PASS
20
100
1000
2000
PHOENIX ISLANDS
CANTON ISLAND
SOUNDINGS IN FATHOMS
NAUTICAL MILES
0
1

FIGURE 12

quantity, and to discover those relationships between the peculiarities of the environment and the distribution and behavior of the tunas which will make possible the prediction of successful fishing areas, depths, and methods.

CANTON ISLAND

INTRODUCTION: Canton Island lies outside the Hawaiian archipelago, but the results of a survey of this atoll are included in this report to provide general information on the tuna and bait resources of this region.

During our[6/] visit to the Island on June 28 and 29, 1949, the joint facilities of the British and American administrative agencies were made available for conducting a survey of the area. By means of a small motor launch, we were able to explore parts of the lagoon and certain waters lying outside the fringing reef along the west side of the Island. Collections of various species of small fish, that might be suitable for use as live bait, were made by means of a dip net and a light at night. Additional specimens were also collected inside the lagoon by native fishermen using a beach seine.

Canton Island, the largest and most northerly of the Phoenix group, is a triangular coral atoll located about 1,660 miles southwest of Honolulu at 2°50' S. latitude and 171°43' W. longitude (figure 12). The east or windward side is approximately 9 miles long in a southeasterly-northwesterly direction and the shortest lee side is about 4 miles in a north-south direction. The atoll consists of a narrow strip of land, from 100 to 500 yards in width, that forms a rim enclosing a large lagoon. The main channel leading into the lagoon is about 100 yards wide and has a controlling depth of 28 feet, with over a 6-knot current at the strength of tidal flows. There is also a small boat channel located about one mile north of the southwest point of the island.

The fringing reef extends only about 200 yards from the shore line, except at the three corners, where it extends outward about 400 yards. The waters outside the reef drop off to depths of over 300 fathoms within a few hundred yards. The waters in the lagoon reach a maximum depth of 12 fathoms, but the bottom is interrupted by numerous reefs and coral heads. At low tide, the sandy beaches within the lagoon extend inward about 100 yards along the northwest and east sides before coral heads are encountered.

A coral slab pier, about 100 yards long, extends into the lagoon from the northeast rim, near its midpoint. A turning basin, about 550 yards long, 525 yards wide, and 25 feet deep, lies adjacent to the pier, providing excellent docking facilities for large vessels. Two 20' x 40' reefer buildings, which were formerly used by the Armed Forces during the war, are located near the docksite. The refrigeration machinery is nearly intact, but would have to be reconditioned before it could be put into operation. Various wooden frame buildings that could be used as maintenance shops and storage warehouses are available. A limited amount of Diesel fuel is available at the docksite for vessels operating in the area. The supply of fresh water is very limited; however, unlimited amounts of slightly brackish water are available.

There is an artificial pond, which was built by the Armed Forces during the war, located on the southwest shore of the lagoon at a point about 1-1/2 miles from the docksite. The pond is about 75 yards in diameter and has a small raceway built up from the bottom of the entrance, so that at low tide, water is retained within

6/STANLEY PETERSON, FISHERY ENGINEER, POFI, ACCOMPANIED THE AUTHOR, AND OBSERVATIONS WERE MADE JOINTLY.

the enclosure. This relatively shallow body of water might serve as a holding pond for live bait. Bait from the pond could easily be carried to the pier by means of a shallow draft (1 to 1-1/2 feet) bait receiver and power skiff.

The prevailing winds in this region blow from the east with an average velocity of 12 to 18 knots. Little rain falls on the Island itself, but off the Island frequent rain squalls occur.

SEA CONDITIONS: The sea bottom surrounding Canton Island drops off rapidly to great depths, just outside the fringing reef. The 1,000-fathom curve lies within about two miles of the reef, while the 2,000-fathom contour extends outward no less than 7 miles from shore. A deep-water trough (over 3,000 fathoms) lies to the northwest of the island. Depths in excess of 1,000 fathoms separate Canton from Enderberry Island which lies to the southeast. Comparison of summer and winter surface water isotherms shows little seasonal variation in sea temperature, the surface water remaining close to 80.6° F. through the year (figures 6 and 7). The prevailing current in this area sets almost due west.

BAIT RESOURCES: Within the lagoon, several species of mullet (Mugil vaigiensis and M. crenilabis), from 1 inch to over 12 inches long, were evident in considerable quantities. They appear to be the most common fish here and provide the chief food fish for the natives. Numerous schools of small round herring (Spratelloides delicatulus) were in evidence along the beaches during the afternoons, but disappeared from these areas shortly after sundown. None of this species were present in the light collections at night. "Aholehole" (Kuhlia sandvicensis) were also present in the lagoon and a few were taken by seining. The natives reported that this species is most abundant here during the spring months. Various species of small goatfish were also seen in varying abundance in the lagoon, but were not evident in sufficient quantities to permit any statement as to their availability for use as bait. There were apparently no members of either the silverside or anchovy families here; at least, these fish were not seen and they were not present in the collections.

The observations made at Canton during this survey indicate that the bait stock within the lagoon might prove to be adequate for a limited number of live-bait tuna vessels, but how well this stock would stand up under continued fishing is not known. The best baiting grounds for the various species listed above appeared to be located over the uninterrupted sand beaches along the northeast and northwest shores inside the lagoon. A surround-type net (see p. 18) could be used to best advantage, as many of the beaches here are devoid of coralline growth, and at high tide, the waters off the shoal areas are of sufficient depth to permit its operation.

TUNA RESOURCES: During our stay at the Island, several large schools of yellowfin tuna were seen within several hundred yards of the fringing reef along the west side of the Island, and in each case the fish were under flocks of "working birds." A local fishing party fished for skipjack on the afternoon of our last day's visit. Two fishermen landed 15 fish on a pole and jig in a period of about 20 minutes. They estimated the size of the school fished to be "about five acres." CAA personnel, stationed on the island, reported that schools of both yellowfin and oceanic skipjack are in evidence through the year, but appear in greater numbers during the winter months. So far as is known, the tuna resources of this area have never been exploited commercially.

It may be expected that skipjack and yellowfin tuna exist in this region in commercial quantities, but the limited nature of this survey precludes any conclusions as to the relative abundance of these species in different areas and at different seasons.

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S. S. PACIFIC EXPLORER

Part III-Below Deck Arrangements and Refrigeration Equipment

Brine freezing has been reported to have an adverse effect on the quality of certain fish which are to be ultimately distributed in fresh fish markets, but fortunately the freezing of tuna in brine does not have an apparent adverse effect when it is to be canned. On the modern tuna clippers, the fish are dropped into the brine wells, chilled in sea-water brine, and partially frozen in a strong sodium-chloride brine to a temperature ranging from 15° to 20° F. The brine is then removed and the fish are held in subsequent dry storage in the same well. Depending on the length of time they are in storage, the tuna may eventually be lowered in temperature to the range of 0° to 10° F. This system of preservation is the most satisfactory of those which have been developed to date on the clippers. The advantages are that it requires less labor and reasonably maintains the general quality of the cargo, although the storage temperatures are not ideal. Persons interested in the operation of receiving ships should devote extensive thought and research to applications and refinements of the direct-brine-freezing technique before adopting it on larger ships.

—Fishery Leaflet 316