A SUMMARY OF ENVIRONMENTAL AND FISHING INFORMATION OF THE NORTHWESTERN HAWAIIAN ISLANDS

Richard N. Uchida
Southwest Fisheries Center
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96812

January 1977

INTRODUCTION

The Northwestern Hawaiian Islands (NWHI), often called the "Leeward chain" and which has been, with the exception of Midway, a wildlife sanctuary since 1909, stretches for over 1,800 km (1,000 mi.)[1] westward beyond the island of Niihau, one of the islands in the major

Fig. 1 Hawaiian group (Figure 1a). The tiny islands and atolls composing this "Leeward" chain have been worn down to vestiges of their former estate and support only a limited assortment of animals and plants (Carlquist 1970). The flora, for example, is similar to that of a tropical beach with virtually all the plants near the shore with a few exceptions. Crowding these islands is a rich assortment of marine and shore birds.

There is a great urgency to know a great deal more about the marine resources of these NWHI. The State of Hawaii, pressed with growing demands for an assessment and rational utilization of its marine resources, recognizes the vital importance of the sea to its economic growth and has fostered a program of harvesting the marine resources of the waters surrounding the entire Hawaiian chain (State of Hawaii 1969, 1974). Furthermore, the Fishery Conservation and Management Act of 1976 will extend U.S. jurisdiction over the fishery resources to within 200 nautical miles from our nation's coastline. Some foreign nations already restrict U.S. fishermen from the

---

[1]Throughout this report, distances are given in kilometers followed by their equivalent in statute miles over land and nautical miles over the ocean.

traditional fishing grounds off their coasts, but as others follow their example, there will be increased pressure from the fishing industry to find new fishing grounds.

There are also conflicting demands for utilization of the NWHI's resources. The U.S. Department of the Interior's Fish and Wildlife Service (FWS) has maintained the wildlife refuge for the protection and benefit of its inhabitants--sea birds, seals, and turtles.

The National Marine Fisheries Service (NMFS) in Honolulu has proposed a cooperative study to survey and assess the marine resources of the NWHI. An intensive 5-year investigation, with the Hawaii Division of Fish and Game, FWS, and the University of Hawaii Institute of Marine Biology and Sea Grant participating, will include assessment of the terrestrial, nearshore, slope, and pelagic resources of the NWHI and their interrelationships.

The purpose of this report is to review and summarize all available information, published or unpublished, on the environment and marine resources of the NWHI.

DESCRIPTION OF THE ISLANDS

The NWHI is part of the Hawaiian chain which rises above an elongated submarine ridge that stretches roughly 3,200 km (1,700 mi.) in a southeast-northwest direction (Freeman 1951). Constructed of volcanic material that was erupted from a zone of fissures on the ocean floor, the Hawaiian chain consists not only of visible islands but also of several submarine peaks and numerous banks.

Beginning at Kure atoll, it is possible to trace the history of the formation of the Hawaiian Islands through a sequence of eruptions which has continued over the years from west to east (Carlquist 1970). Even within each island, the oldest part is to the west and the newest to the east. Because of this clear sequence of formation, it is hypothesized that the atolls of the NWHI are vestiges of once high volcanoes that have been worn down through the ages into low, sandy atolls. Many of the atolls and islands are surrounded by banks, some of them shallow (Figure 1).

Based on the nature of the islands and the stage of erosion, the Hawaiian chain may be divided into the southeastern portion, which is composed of the eight high volcanic islands or the present major islands, the middle portion including Kaula Island near Niihau, Nihoa, Necker, French Frigate Shoals, La Perouse Pinnacle, and Gardner Pinnacles, and the northwestern part consisting of low atolls, sandy islets, reefs and shoals including Laysan, Lisianski, Pearl and Hermes Reef, Midway and Kure (Carlquist 1970; McDonald and Abbott 1970). The area and altitude of the islands and atolls in the Hawaiian chain are given in Table 1.

Table 1

KAULA ISLAND

Kaula Island, a crescent-shaped tuff cone, lies 43 km (23 mi.) southwest of Niihau and actually belongs with Kauai and Niihau rather than with the rest of the Leeward chain (McDonald and Abbott 1970). Resting on a broad base that is a big submerged volcano, the island lies near the southeastern edge of a shoal which is 13 km (8 mi.) long in a west-northwesterly direction, 7 km (4.5 mi) wide, and roughly 61 m (200 ft) below sea level (Figure 2). McDonald and Abbott concluded that this flat platform must have been cut across the top of the shield volcano by wave action. A projection rises to about 9 m (30 ft) below sea level near Kaula and is probably an erosional residual rather than another cone rising from the platform. Kaula rises about 168 m (550 ft) above sea level. Its position is given by Bryan (1942) as lat. 20°39'N and long. 160°31'W.

Fig. 2

NIHOA ISLAND

The first of the uninhabited islands to the northwest of the major Hawaiian group is Nihoa, which is located at lat. 23°06'N and long. 161°58'W, roughly 315 km (170 mi.) west northwest of Kauai (McDonald and Abbott 1970). This small volcanic island, plainly visible from a great distance, is 1.4 km (0.85 mi.) long, averages about 457 m (1,500 ft) wide, and is the largest of the lava islands west of Niihau (Figure 3). The island has two peaks--Miller's Peak on the west and rising 273 m (895 ft) above sea level and Tanager Peak on the west rising 260 m (852 ft). A broad swale separates the peaks.

Fig. 3

The island covers about 0.7 sq km (175 acres) (Carlquist 1970). The northern edge of Nihoa is an abrupt sea cliff, which plunges directly from the crest of the island into the water (McDonald and Abbott 1970). On the southern side, the land slopes fairly gently to low bluffs near the coast where it is truncated by a sea cliff towering 15-30 m (50-100 ft) high with a wave-cut platform at the base and about 1.2-2.4 m (4-8 ft) above sea level. The east and west ends of the island are also inaccessible cliffs (Emory 1928).

All the lava flows on Nihoa dip southwestward. Emory (1928) reported that less than half of the area of Nihoa is comprised of gently sloping ground covered with several varieties of grass.

Extending northwestward from the island for about 29 km (18 mi.) is a platform about 37 to 76 m (120 to 250 ft) below sea level (McDonald and Abbott 1970). Apparently, the whole northwestern part of a volcanic island, perhaps 32 km (20 mi.) across at sea level, has been eroded by wave action. Another bank at the 30-46 m (100-150 ft) depth range lies 33 km (18 mi.) west southwest of Nihoa; it is about 27 km (17 mi) long and 19 km (12 mi.) wide.

Nihoa has a large population of nesting seabirds giving the island its former name of Moku Manu (Bird island) (Emory 1928; McDonald and Abbott 1970). Sheets of guano coat some of the cliffs. Also, on the southern side, some of the valleys are partly filled with a conglomerate in which a mixture of clay and guano predominate in the cement.

Remains of home sites and terraces used for cultivation are abundant evidence that the island was formerly occupied by people in the past (McDonald and Abbott 1970). How the inhabitants obtained their water is still speculative. Archeological explorations have found several seeps on the islands, the principal one 82 m (270 ft) high; the water, however, is somewhat brackish and heavily tainted with guano.

NECKER ISLAND

Necker is a narrow bit of land less than 1,200 m (4,000 ft) long and about 150 m (500 ft) wide (McDonald and Abbott 1970). Lying 556 km (300 mi) northwest of Niihau at lat. 23°34'N and long. 164°42'W, the island covers 0.2 sq km (41 acres) with its highest point 84 m (276 ft) above sea level (Figure 4). Emory (1928) described the island as shaped like a fishhook with the shank lying in an east-west direction and the barb, the northwest cape, measuring about 183 m (600 ft) long and 61 m (200 ft) wide. At the east end is an islet about 61 m (200 ft) long and 23 m (75 ft) wide; it is generally awash (McDonald and Abbott 1970).

Fig. 4

Necker lies on a shallow, roughly oval platform which measures 61 km (38 mi.) long in the northwest-southeast direction and about 32 km (20 mi.) wide (McDonald and Abbott 1970). The positions of the island and the former volcano center within this platform, which undoubtedly has been eroded over the years by wave action, indicate that the core was not a single shield volcano, but a group of shields similar to the present island of Hawaii. (Shield volcano is built up by successive outpourings of lava with little or no fragmental material.) Necker itself is composed of vertical dikes and is an eroded remnant of one of the shield volcanoes.

Although presently uninhabited except by innumerable seabirds, Necker once had a sizable human population (McDonald and Abbott 1970). Remains of fishponds, ditches, agricultural terraces, and house and temple platforms attest to the occupation of the island by humans. Furthermore, it has been conjectured that many of the ruins and artifacts appear to have been left by an early group of people, who preceded the more recent Hawaiians.

As on Nihoa, the source of fresh water is a mystery (McDonald and Abbott 1970). The present supply appears to be about 38 liters (10 gal) per day of undrinkable, guano-tainted water.

FRENCH FRIGATE SHOALS

Located almost at the midpoint of the 3,200-km (1,700-mi.) long Hawaiian Archipelago (Figure 5), French Frigate Shoals is about 1,360 km (735 mi.) northwest of the eastern tip of the island of Hawaii and 1,445 km (780 mi.) southeast of Kure Atoll (Amerson 1971). There are 13 small named islands in the lagoon; 12 are low and sandy with sparse or no vegetation whereas the remaining island is a volcanic rock.

Fig. 5

Officially located at lat. 23°45'N and long. 166°10'W, the atoll consists of a crescent-shaped reef on a 36-m (20-fathom deep oval platform (Amerson 1971). Palmer (1927) reported that this platform, at a depth of 55 m (30 fathoms), covers about 648 sq km (250 sq mi.).

The atoll, with the long axis stretching 35 km (22 mi.) in a northwest-southeast direction, is actually a double crescentic reef (Amerson 1971). The 363-sq km (140-sq mi.) lagoon is 13 km (8 mi.) wide at its midpoint, whereas the broken inner arc of the reef is 33 km (21 mi.) long and the almost continuous outer arc is 57 km (36 mi) long. The crescent tips, pointing westward, are about 28 km (17 mi.) apart with La Perouse Pinnacle lying on an imaginary line between these two tips about 11 m (6 mi.) southeast of the northern tip and 17 km (9 mi.) northwest of the southern tip.

The 12 sand islands of French Frigate Shoals cover 0.4 sq km (111.3 acres) of which 0.1 sq km (33.3 acres) are covered with vegetation (Amerson 1971). Two exposed volcanic rocks exist near the center of the oval platform. Islands with well-established vegetation include East, Tern, Trig, and Whale Islands. Skate and Little Gin Islands, although quite large, are only sparsely vegetated. Two other large islands--Gin and Disappearing--are without vegetation and La Perouse Pinnacle, in spite of its size and height, supports no vegetation. The rest--Bare, Mullet, Near, Round, and Shark Islands--are sandbars that shift continuously. Three other nameless sandy islets are submerged during periods of high tide.

Tern Island, the largest island in the atoll and located near the northwest tip of the crescent, is a man-made island about 945 m (3,100 ft) long (Amerson 1971). A runway 76-m (250-ft) wide extends the length of the island. Tern island is presently used as a U.S. Coast Guard loran station.

La Perouse Pinnacle (Figure 5), located at lat. 23°45'N and long. 166°15'W, is 11 km (6 mi.) south-southeast of Tern and 6 km (3 mi.) west-southwest of East Island (Amerson 1971). Shaped in the form of a saddle, the main pinnacle at the northwestern end rises 37 m (122 ft) above sea level whereas at the southeastern end it is nearly as high at 36 m (120 ft). The main rock is roughly 222 m (730 ft) from northwest to southeast and 50 m (165 ft) at its widest point. A second rock, lying 119 m (390 ft) northwest of the main pinnacle, rises about 3 m (9 ft) above sea level and about 61 m (200 ft) long, northwest to southeast, and 20 m (65 ft) wide.

GARDNER PINNACLES

Gardner Pinnacles, which consist of two small volcanic rocks in the middle of the NWHI, are located at lat. 25°00'N and long.
Fig. 6 167°55'W (Figure 6) (Clapp 1972). Being the westernmost volcanic island in Hawaiian waters, Gardner Pinnacles stand on the northeastern part of a bank which is 32 km (20 mi.) wide and 80 km (50 mi.) long with depths ranging between 16 and 73 m (9 and 40 fathoms).

The northwestern peak of Gardner Pinnacles, the smaller of the two islands, rises about 30 m (100 ft) above sea level and is about 76 m (250 ft) long and 30 m (100 ft) wide (Clapp 1972). About 46 m (150 ft) to the southeast is the larger peak, which is about 213 m (700 ft) long and 152 m (500 ft) wide (Palmer 1927; Bryan 1939). Clapp (1972) reported that the larger peak formerly rose to 52 m

(170 ft), but its height was reduced by blasting in 1961 to provide sites for astronomic stations. The two islets have an overall area of about 0.01 sq km (3 acres) (Freeman 1951). From a distance, Gardner Pinnacles have a snow-capped appearance because of the liberal coating of guano (Clapp 1972).

LAYSAN ISLAND

Laysan Island, roughly rectangular in shape with the long axis slightly east of north, is the largest of the NWHI and is located at lat. 25°42'N and long. 177°44'W (Figure 7) (Ely and Clapp 1973). Situated 213 km (115 mi.) east of Lisianski, 374 km (202 mi.) northwest of Gardner Pinnacles, and 1,314 km (709 mi.) northwest of Honolulu, Laysan is 2,858 m (9,375 ft) long and just over 1,700 m (1 mi.) wide. Warner[2] estimated a total area of slightly under 4 sq km (913 acres).

The island, probably the flattened top of a once massive volcanic peak, is capped by large sand accumulations and has a large saltwater lagoon occupying about one-fifth of the island's central interior (Ely and Clapp 1973). Relatively shallow water surrounds the island for some distance offshore; the bottom drops off precipitously to an average depth of 3,293 m (1,800 fathoms). Warner (1963) estimated that the 180-m (100-fathom) contour around Laysan encloses an area of

---

[2]Warner, R. E. Completion report--Midway and Laysan Islands bird studies. Manuscript in preparation. Hawaii Division of Fish and Game, State of Hawaii, 11 p.

about 544 sq km (210 sq mi.). The maximum crest elevation is just over 12 m (40 ft) and occurs in the sand dune area at the north end of the island.

Presently, Laysan is well vegetated except for coastal dunes that appear to be well stabilized (Ely and Clapp 1973). The original flora, the most varied in the NWHI, was destroyed by man and introduced rabbits. By 1923, the island was in near desert condition and several species became extinct. The abandonment of the island by man permitted the vegetation to recover, nearly restoring the original conditions that existed in the past.

LISIANSKI ISLAND

Lisianski is a low sand and coral island which covers approximately 1.8 sq km (450 acres) and is situated at lat. 26°02'N
Fig. 8 and long. 174°00'W (Figure 8) (Freeman 1951; [U.S.] Office of Geography 1956). At a location about 1,677 km (905 mi.) northwest of Honolulu (Bryan 1942), Lisianski is at the northern end of a large reef bank which is about 168 sq km (65 sq mi.) in total area (Clapp and Wirtz 1975). The island, which has a circumference roughly 5 km (3.2 mi.), resembles a parallelogram with the north-south axis about 1,829 m (2,000 yd) long and the east-west axis 1,006 m (1,100 yd) wide.

The island is ringed by mostly sandy and sand-coral beaches with the exception of the eastern side which is dominated by an exposed ledge of reef rock and small tidal pools (Clapp and Wirtz 1975). Near the middle of the western beach is a small cove which is designated a small-boat landing on the hydrographic charts. At the north end of the cove is a group of Casuarina trees. A rim of Scaevola growth covers the island's entire perimeter with the densest growth along the north point and southward along the east beach and across the south end. Lush growth of bunchgrass, Eragrostis, attaining heights of up to 1 m (3 ft) or more, covers the island's interior.

PEARL AND HERMES REEF

One hundred sixty kilometers (87 mi.) east southeast of Midway Atoll and about 1,931 km (1,042 mi.) northwest of Honolulu is Pearl and Hermes Reef, a low coral atoll near the northwestern end of
Fig. 9 the Hawaiian Archipelago (Figure 9) (Amerson, Clapp, and Wirtz 1974). Given an official location of lat. 27°55'N and long. 175°45'W, this atoll has been known as Pearl and Hermes Reef since two ships bearing these names were wrecked there in 1822.

The fringing reef of this atoll has a circumference of 69 km (43 mi.) and is open to the west (Thorp 1936). The long axis of the elliptical enclosed area, oriented in a northeasterly direction, is 32 km (20 mi.) and the broadest point 18 km (12 mi.). Gross et al. (1969) estimated that the area within this reef covers 370 sq km (143 sq mi.). Nine islands within the reef cover 0.3 sq km (85 acres) (Amerson et al. 1974). Grass, North, Seal, and Southeast Islands have established vegetation; Little North Island, which has continued to emerge since it was first reported as a sandbar awash at high tide, has limited vegetation. Kittery Island is low and subject to occasional inundation despite its size and relative permanency. The remaining three islands--Bird, Planetree, and Sand--are shifting sandbars. Historical and recent data examined by Amerson et al. (1974) suggest that considerable changes in the topography of Pearl and Hermes Reef have occurred in the past 100 years as a result of continuous shifting, splitting, and reforming of sandspits.

MIDWAY ISLANDS

Lying about 2,101 km (1,134 mi.) west northwest of Honolulu at lat. 28°12'N and long. 177°23'W, Midway atoll is near the extreme western end of the Hawaiian Archipelago and consists of two islands
Fig. 10 (Figure 10). These islands are situated on the southeastern part of a lagoon, which is within a protective coral reef with a circumference of 24 km (15 mi.) and which is submerged in some places but about 1.2-1.5 m (4-5 ft) above water level in others. Of the two islands, Sand Island, on which the active runway is built, is larger. It measures 2.4 km (1.5 mi.) long and 1.6 km (1 mi.) wide (Bryan 1942). About 1.6 km (1 mi.) east of Sand Island is the smaller Eastern Island, which is triangular and measures about 2.0 km (1.3 mi.) long and 1.2 km (0.8 mi.) wide.

The entrance to the lagoon is on the south side between Sand and Eastern Islands (Tudor 1972). In 1905, Sand Island was converted into a submarine cable station and in 1936, it was designated a transpacific station for the China Clipper. According to Bryan (1942), the single most outstanding feature with respect to the natural history of Midway is the change which Sand Island has undergone through the efforts of man. Because this island had no trees and scarcely any herbaceous plants to hold the shifting sand in place when the cable station was first established, a coarse grass, Ammophila arenaria, was imported from the wind-swept beaches near San Francisco. To provide windbreaks, ironwood trees, Casuarina equisetifolia, were plated in 1907 as well as numerous other ornamental trees, shrubs, and herbs. Soil was also brought in from Honolulu to encourage growth of useful plants. Midway was converted into a U.S. naval base in 1939 and is presently under administrative control of the Department of the Navy.

KURE ISLAND

Claiming the distinction of being the northernmost coral atoll in the world and the westernmost land of the NWHI, Kure atoll, located at lat. 28°25'N and long. 178°10'W, is about 2,177 km (1,175 mi.) northwest of Honolulu and 4,012 km (2, 165 mi.) southeast of

Fig. 11 Tokyo (Figure 11) (Woodward 1972). The closest neighboring island to Kure is Midway, 91 km (49 mi) to the southeast. Kure, situated atop a submerged volcano, is nearly circular; the outer reef almost completely encircles the lagoon except for passages to the southwest. The maximum diameter is about 9 km (6 mi.). Gross et al. (1969) estimated that the reef comprises an area of about 5 sq km (1,235 acres). The lagoon depth is about 14 m (46 ft).

The only permanent land in the atoll is crescent-shaped Green Island located near the fringing reef in the southeast part of the lagoon (Woodward 1972). Its long axis curves north to west 2 km (1.4 mi.) and the maximum width is 0.6 km (0.4 mi.). The ocean side of Green Island is devoid of sand dunes and the elevation here does not exceed 5 m (15 ft). Sandy beaches encircle the entire island. The lagoon side is dominated by a series of sand dunes which vary up to 8 m (25 ft) in height. The dunes decrease in elevation southwest along the beach, whereas eastward behind them is a low, relatively flat depression in the surface with elevations varying from 2 to 3 m (6 to 10 ft).

The dominant features of Kure atoll are the man-made 190-m (625 ft) loran tower and transmitter building, the 21-m (70-ft) high radar reflector, the 1,219-m (4,000-ft) runway, and the building complex near the center of the island (Woodward 1972). Covering much of the island except for man-made open areas and the natural central plain where only low herbaceous plants grow is a dense growth of *Scaevola taccada*.

CLIMATE

The climatological data from the NWHI are primarily from French Frigate Shoals, Midway Islands, and Kure Island where man-made installations and operational personnel are located. Climatic data collected from Midway Naval Station can be used to describe weather conditions not only at the atoll but also the nearby atolls of Lisianski and Pearl and Hermes Reef (Amerson et al. 1974; Clapp and Wirtz 1975).

Along the Hawaiian chain, the marine influence upon the climate is very significant because of the extreme insularity (U.S. Weather Bureau 1961). The mountains, however, especially the massive ones on Hawaii and Maui, strongly modify this marine effect with the result that conditions are somewhat continental in some localities. In the NWHI, however, the low profile of the islands and atolls results in conditions that are almost wholly marine and tropical.

A prominent feature of the air circulation across the tropical Pacific is the general east to west flow of the trade winds (U.S. Weather Bureau 1961). In the central North Pacific, the trades blow from the northeast quadrant and represent an outflow of air from the Pacific anticyclone, a region of high pressure. This Pacific high and trade wind zone move north-south seasonally reaching their northernmost positions in May-September, at which time the trades prevail 80%-95% of the time. In October-April, the Hawaiian Archipelago is positioned to the north of the heart of the trades; as a result, the frequency of trades decreases to 50%-80%. In general, then, the Hawaiian climate is characterized by a two-season year.

AIR TEMPERATURE

Temperatures recorded at French Frigate Shoals show variations that are typical of a tropical marine environment (Amerson 1971).

Fig. 12 Figure 12 shows the mode of the mean monthly temperatures and the range of the maximum and minimum modes of temperature for French Frigate Shoals in December 1950-December 1962. The mean annual temperature was 24.2°C (75.5°F) and the mean annual range was 5.6°C (10°F). In December-April, the means varied between 21.7° and 23.3°C (71° and 74°F) whereas in May-November, they varied from 23.9° to 26.7°C (75° to 80°F). August-September were the warmest months; February-March the coolest. The extreme high and low in the 12-year period studied were 32.8° and 12.2°C (91° and 54°F), respectively, a difference of 20.6°C (37°F).

Temperatures at Midway showed a mean monthly range of 7.2°C (13°F), which is indicative of a marine environment (Mauck 1975).
Fig. 13 Figure 13 shows that the means varied from 18.9° to 20.6°C (66° to 69°F) in December-April and from 21.1° to 27.2°C (70° to 81°F) in May-November. The warmest months were July-September and the coolest January-February and April. The extreme high of 31.7°C (89°F) and low of 11.1°C (52°F) differed by 20.6°C (37°F). The monthly maximum, minimum, and mean temperatures at Midway in 1949-72 are given in
Table 2 Table 2.

Kure's climate is described as subtropical marine and is influenced primarily by two air masses and by the surrounding ocean where changes in sea-surface temperatures and salinities are relatively small (Woodward 1972). For example, Seckel (1962) has shown that in this area, sea-surface temperatures vary from 20.5°C (69°F) in February to 26.7°C (80°F) in August-September and salinities from 35.0°/oo in November-February to 35.2°/oo in April-August.

At Kure, Woodward (1972) observed yearly variation occurring in the average semimonthly temperatures but concluded that the pattern of temperature change throughout the year was the same. For example, the data showed that the average maximum varied 11.2°C (20°F) from 18.2° to 29.4°C (65° to 85°F) and the average minimum about 9.5°C (17°F) from 14.4° to 23.9°C (58° to 75°F). The extremes were 3.8°C and 37.2°C (39° and 99°F), a difference of 33.4°C (60°F) (Table 3). In December-April, the semimonthly maximum averaged 21.1°C (70°F), but in May-June and November, the averages varied between 21.1° and 26.7°C (70° and 80°F). Averages of 26.7° to 32.2°C (80° to 90°F) occurred in June-October. The average semimonthly minimums varied between 15.6° and 18.3°C (60° and 65°F) in December-May and between 21.1° and 23.9°C (70° and 75°F) in November (Table 4).

Table 3

Table 4

The coldest months at Kure were January and February and the warmest July-September (Woodward 1972). The average temperature usually increased in May although the rise sometimes occurred in June. A decrease in average temperature was usually observed in September or October.

WIND DIRECTION AND VELOCITIES

French Frigate Shoals is influenced most of the year by the Pacific high with easterly trades predominating (Amerson 1971). In winter, the Aleutian low moves southward to the Kure-Midway-Pearl and Hermes area affecting the Pacific high slightly and bringing increased winds and higher precipitation.

At French Frigate Shoals, data show that the record for maximum sustained wind was 52 knots from east-northeast in December (Amerson 1971). Monthly wind speed averaged higher than the annual mean of 12.6 knots in November-April and lower in March-October. Seasonal data on prevailing wind direction and speed, shown in

Fig. 14 Figure 14, indicated an easterly component. The mean wind speed in winter reached 14.3 knots with winds high from all directions but highest from northwest to east-southeast and the mean maximum from east-northeast. In spring, the mean wind speed reached 13.1 knots and winds were highest from west to south although the mean maximum was from the northeast. The summer wind speeds, which averaged 11.5 knots, were highest from northeast to east-southeast and the mean maximum was from the east. The change in mean wind speed from summer to autumn was insignificant as autumn winds averaged only 11.6 knots. The highest winds blew from west-northwest and northwest, north through south-southeast, and from the northeast.

In general, climatological data show that Midway's climate was influenced by marine tropical or marine Pacific air masses depending on seasonal changes (Amerson et al. 1974; Clapp and Wirtz 1975). In the summer, the Pacific high predominated, placing the area around Midway under the influence of northeasterly trade winds (Mauck 1975). In the winter, however, especially in November-January, the Aleutian low moved southward over the North Pacific and displaced the Pacific high; the result was that the Kure-Midway area was affected by prevailing winds from the west and frontal weather. A definitive study of Midway's climate may be found in Mauck (1975).

Winter storms in the Midway area were relatively common and brought significant increases in wind and rain especially in September-December (Amerson et al. 1974; Mauck 1975). The prevailing wind was easterly in February-November but westerly in December-January (Figure

ig.15 15). The wind speed averaged 10 knots annually and the range 5 knots. In July-October, maximum winds blew generally from the east whereas in November-June, they blew from the west. Peak wind speed reached 35-41 knots in May-August and 42-55 knots in September-April. Peak gusts usually occurred in December and January, reaching 77 and 67 knots, respectively.

At Kure, which lies in the path of the northeast trades from the Pacific subtropical anticyclone most of the year, westerly winds predominate in winter as a result of the position of the island along the southern edge of the Aleutian low (Woodward 1972). Data collected at Kure in 1961-68 showed that in November-February, winds were variable but usually had a strong westerly component. In March-June and September, winds were again variable but the major component during these periods were easterly. The trades usually predominated in July-August when almost all the winds came from the east. Wind speed ranged from 0 to 46 knots and the annual means varied between 4 and 7 knots. The data also showed that the strongest winds usually occurred in

able 5 winter and early spring and the weakest winds in summer (Table 5).

RAINFALL

Annual precipitation at French Frigate Shoals in June 1954-December 1962 (February 1960 not included) reached an average of 1,150 mm (45.29 in.) (Amerson 1971). Figure 16 shows the mean number of days with measurable precipitation (at least 16 days) each month. It reached 20 or more days in July-August, October, and January and was least frequent in February-June and September. Thunderstorms usually occurred only in April and December. Figure 17 shows the mean monthly precipitation in 1954-62 at French Frigate Shoals. Heaviest rain usually occurred in December-March.

Fig. 16

Fig. 17

At Midway, data on mean number of days with measurable precipitation (Figure 18) and mean annual precipitation (Figure 19) show that May and June are the driest months of the year (Amerson et al. 1974). Rain or drizzle occurred most frequently in July-February and least frequently in May-June. The annual precipitation in 1953-63 averaged 1,082 mm (42.59 in.) with the monthly maximum of 129 mm (5.07 in.) occurring in January and August, a secondary high of 125 mm (4.92 in.) occurring in October, and a minimum of 52 mm (2.03 in.) occurring in November. Mauck (1975) noted that during the summer, rainfall was usually associated with scattered cumulus buildups of the trade wind region whereas during winter, the heaviest rainfall was associated with frontal passages.

Figs. 18, 19

No rainfall data were collected from Kure; therefore, the reader is referred to data from Midway atoll (Table 6).

Table 6

OCEANOGRAPHIC CLIMATE

In the Hawaiian Islands region, not only the meteorological but also the oceanographic properties show little apparent seasonal variation. Ranging between 22.8° and 25.6°C (73° and 78°F), sea-surface temperatures show relatively small seasonal and year to year changes ([U.S.] Bureau of Commercial Fisheries (BCF) 1963). Surface salinity also varies little seasonally with averages ranging from 34.8°/oo to 35.1°/oo, but in contrast to temperatures, the year to year variations in surface salinity are rather large. The result is that in some years, the change in salinity between seasons is not clearly detectable whereas in others, it may be more than 0.5°/oo.

The water types and currents of the Pacific are illustrated
Fig. 20 in Figure 20. A boundary near the Hawaiian region separates North Pacific Central water from the California Current Extention water (BCF 1963). The former has a salinity greater than 35°/oo; the latter less than 34.8°/oo. The boundary, therefore, is identified by a relatively small and narrow salinity gradient.

Shifting with the season, this boundary, from a position just south of the Hawaiian Islands during late fall and early winter, moves to one just north of the islands in late summer (BCF 1963). Shifts of longer duration also occur possibly because there is either movement or dilations and contractions of the North Pacific Central system.

SURFACE TEMPERATURE

In oceanography, as in meteorology, temperature has long been recognized as an important climatic character. Seckel (1962) observed that north of the Hawaiian chain, there is a parallel isothermal structure between November and April with latitudinal temperature gradient of about 0.6° to 0.8°C (1.0° to 1.5°F) per

Fig. 21 degree of latitude (Figures 21a to 21ℓ). A change in this temperature structure first becomes apparent in May followed by a breakdown of the parallel isothermal structure in June. An irregular temperature regime persists in the northern section of the Hawaiian chain in July-September, but in October, the isotherms again become parallel.

Minimum and maximum temperatures generally occur in March and September, respectively (Seckel 1962). Although the minimum sometimes occurs in February and the maximum in August or October, they show no significant differences from those in March and September.

Fig. 22 Figure 22, which shows the March and September mean profile in long. 153°-161°W and in long. 168°-176°W, demonstrates that the annual temperature range between lat. 10° and 15°N is about 1.4° (2.5°F) both in the eastern and western sections. The range increases to about 5.8° and 6.4°C (10.5 and 11.5°F) at lat. 29°N in the eastern and western sections, respectively.

The mean zonal temperature profiles for March and September show that for these months, the temperature is about 1.7°C (3°F) higher in the western than in the eastern part of the region, except in September in lat. 15°-20°N and in lat. 20°-25°N where the increases

Fig. 23 are 2.2° and 2.8°C (4° and 5°F), respectively (Figure 23) (Seckel 1962). Seckel also showed that the seasonal temperature range between long. 153° and 161°W at lat. 12°, 17°, 20°, and 26°N increased only slightly northward from 1.7°C (3°F) at lat. 12°N to 2.8°C (5°F) at lat. 22°N, but the range almost doubled to 5.3°C

Fig. 24 (9.5°F) at lat. 26°N (Figure 24).

THERMOCLINE DEPTH

Another important feature of the oceanographic climate in the NWHI region is the vertical temperature distribution. The permanent or main thermocline, in which the maximum temperature change occurs and which lies between the surface layer of constant temperature and the deeper layer in which the rate of change of temperature vertically is rather small, is always present in the Hawaiian region (Seckel 1962). Below the mixed layer the average temperature gradient is about 15°, 6°, and 5°C per 100 m (59°, 43°, and 41°F per 330 ft) at lat. 10°, 20°, and 30°N, respectively. Superimposed on the permanent thermocline may be a seasonal thermocline and, in addition, there may also be a diurnal thermocline, which is defined as a small rise in surface temperature of the order of 1°C (1.8°F) extending to a depth of about 10 m (33 ft).

Concerning the depth of the mixed layer in the Hawaiian region, Seckel (1962) observed that in January-February there is a prominent trough in which the depth of the mixed layer is greater than in the surrounding areas extending east to west between lat.

15° and 2°N (Figures 25a to 25ℓ). The depth is generally greater than 76 m (250 ft) and west of long. 165°W it exceeds 122 m (400 ft). But in March-May, the depth of the mixed layer decreases except along the southern boundary east of long. 162°W where it tends to increase.

A new distributional pattern of the depth of the mixed layer is evident in June-August (Seckel 1962). A trough is established at lat. 10°-13°N to the west of long. 156°W where the depth reaches about 91 m (300 ft), whereas to the east of long. 156°W, the trough reaches 61-76 m (200-250 ft). Over much of the area north of lat. 20°N, the mixed layer increases only slightly from less than 30 m (100 ft) deep in June to less than 46 m (150 ft) in July-August. In September, there appears to be a northward movement of a trough which is centered at about lat. 15°N west of long. 160°W with depths 76-91 m (250-300 ft). By October, the trough resumes its winter position. The depth of the mixed layer north of lat. 20°N increases and the beginnings of the typical January-February structure are again visible.

The primary feature, then, of the distribution of the mixed layer in the Hawaiian Islands region is the presence of a trough and

Fig. 26 seasonal differences in its location (Figure 26). In January, there is maximum development in the depth of the trough which may exceed 122 m (400 ft) in an east-west direction between lat. 15° and 20°N. The June distribution typifies the other extreme when the trough is found in its southernmost position and its depth is also at a minimum in the northern region. Seckel noted that in the March-May transition period, the irregular depth distribution suggests disintegration of a pattern rather than a southward movement.

SURFACE SALINITY

Equivalent in importance as a climatic indicator in oceanography is salinity. In the vicinity of the Hawaiian Archipelago, the maximum salinity occurs in November-February and the minimum in July (Seckel 1962). For example, Seckel found that the 35°/oo salinity isopleth started a northward movement in April and reached an extreme
ig. 27 position in July (Figure 27). The southward movement eventually positioned the 35°/oo isopleth at lat. 17°-19°N, the extreme winter location, in November-February. In April-August, the salinity increases northward from 34.65°/oo at lat. 10°N to 34.75°/oo at lat. 20°N but
Fig. 28 only by an average of 0.01°/oo per degree of latitude. Figure 28 shows that the salinity then rises at an average rate of 0.13°/oo at lat. 23°N. The maximum of 35.35°/oo is reached at lat. 28°N, the increase occurring at a rate of 0.04°/oo per degree of latitude. Of significance here is the high salinity gradient which can be found within and slightly north of the Hawaiian chain, indicating the presence of a transition zone or boundary between different types of water. In winter, the salinity decreases from 34.3°/oo at lat. 10°N to a minimum of 34.2°/oo at lat. 12°N, then increases rapidly to 35.05°/oo at lat. 19°N at a rate averaging 0.12°/oo per degree of latitude (Figure 28).

Seckel (1962) also noted that in April-August, the high salinity gradient between lat. 20° and 25°N is well defined in the eastern region of the Hawaiian Islands (Figure 29a). Of particular interest are two cells in which the salinity is higher than 35.4°/₀₀. In November-February (Figure 29b), the salinity gradient near the southeastern region of the Hawaiian Islands has moved northwestward and the gradient formerly in the area has shifted southward.

Fig. 29

Seckel (1962) concluded that to the north and south of the Hawaiian Islands, low and high salinities occur about the same time as low and high temperatures. In the vicinity of the Hawaiian Islands, however, low and high salinities occur about 3 months after the time that the mixed layer reaches its minimum and maximum depths, respectively. Finally, Midway Island is located near the salinity maximum; the sharp decline of about 0.35°/₀₀ in July in this region may be due to either a southward or a northward displacement of the high salinity cell. Seckel further postulated that in spring, the high salinity boundary moves northward east of long. 165°W and northwestward west of long. 165°W reaching Midway in July.

SURFACE CURRENTS

The NWHI lie in an area of the Pacific where no major current system passes through them. Sverdrup, Johnson, and Fleming (1946) reported that part of the water in the North Pacific Current, which has a general eastward flow, appears to turn southward before reaching long. 150°W and only a small portion continues to flow southward between the Hawaiian Islands and the west coast of North America. The main part of the North Pacific Current, therefore, turns back toward the west near the Hawaiian Islands.

A major feature of this North Pacific gyre is the Subtropical Convergence which marks the region of weak horizontal flow and where water tends to pile up and thicken the surface layer as a result of water accumulation. Sverdrup et al. (1946) observed that the position of the convergence changes from north to south with the season and may even shift from year to year so that under certain conditions the Hawiian Islands may lie inside or outside the gyre.

Generally, the main surface currents in the NWHI region
Fig. 30 flow westward or northwestward in summer (Figures 30a and 30b) (June 1951). Between Lisianski and Pearl and Hermes Reef, however, the flow appears to be northward at this time. In winter, the current flow tends to be southeastward from Midway to Gardner Pinnacles. There is a tendency for the current to flow southward most of the year in the
Fig. 31 vicinity between Midway and Kure atolls. Shown in Figures 31a to 31ℓ are charts of monthly surface currents and temperatures around the Hawaiian Archipelago (see Appendix 1 for explanation).

BOTTOM TOPOGRAPHY

From an oceanographer's point of view, the chief interest in the topography of the sea floor is that it forms the lower and lateral

boundaries of water. The fishery biologist's chief interest in bottom topography, however, is that it shows the locations of fishable
Fig. 32 grounds. Figures 32a to 32ℓ are graphic representations of the bottom topography in the area around the Hawaiian chain (enclosed in heavy
Fig. 33 lines in Figure 33). They show the trenches, troughs, fracture zones, ridges, banks, and seamounts. The banks and seamounts are of particular interest because the Japanese and Russians have established a trawl fishery for pelagic armorhead, Pentaceros richardsoni, and alfonsin, Beryx splendens, which adopt a lifestyle associated with tops of seamounts.

Within the NWHI region, there exists a series of shallow-water banks, which vary from about 1.5 km (1 mi.) to over 80 km (50 mi.) in length and which lie amongst various islands in this group (June 1951). Whereas the water depth over these banks are between 16 and 73 m (9 and 40 fathoms) the troughs between the banks and islands may be as deep as 1,830 m (1,000 fathoms). June observed that along the northern and southern boundaries of the NWHI chain, the 3,660-m (2,000-fathom) contour is usually within 37 km (20 mi.) of the shoals.

PLANKTON

In the Pacific Ocean, zooplankton volume is distributed in a similar fashion as PO_4-P (Reid 1962). The volumes are usually high in the eastern boundary currents, low in central water, and relatively

high along the equator and in two zones north and south of the
ig. 34 equator associated with the equatorial divergence (Figure 34).

From studies conducted by King and Demond (1953) in the central Pacific, it was shown that the greatest abundance, both by number and volume, of zooplankton occurred near the equator. Figure
Fig. 35 35 shows the variation in temperature, salinity, oxygen, inorganic phosphate, thermocline depth, and zooplankton volume along long. 158° and 172°W in June-August 1950. In examining differences among the mean zooplankton volume among latitudes, King and Demond demonstrated that there were significant differences ($P < 0.02$) among the means for latitudes. For example, along long. 172°W, not only zooplankton volume but also the estimated numbers per cubic meter of water strained tended to be low in the higher latitudes around the NWHI and high near the equatorial region.

MARINE RESOURCES

Very litle is known about the marine resources of the NWHI. Most of what is known about them comes from observations made during research cruises by several agencies and from data collected by foreign fishing vessels. The sections that follow present some of the published and until now unpublished results obtained by research and commercial vessels that were engaged in assaying the fish stocks in waters of the NWHI.

BIRD FLOCK AND FISH SCHOOL SIGHTINGS

The chief interest in sightings of bird flocks and fish schools is in obtaining some indication of the density of fish schools in a given area. For example, because pole-and-line and purse seine fisheries for tuna are wholly dependent on the presence of surface schools, it is highly desirable to have some index of relative abundance of tuna schools on the fishing grounds.

Although there is no established commercial fishery for surface schooling tunas in the NWHI region at the present time, there are sufficient reliable reports of tuna schools sightings--based on several exploratory fishing cruises--and reports of Japanese fishing vessels operating within the waters of the NWHI to indicate the presence of commercial concentrations of yellowfin tuna, Thunnus albacares, skipjack tuna, Katsuwonus pelamis, and kawakawa, Euthynnus affinis.

Most of the bird flock and fish school sightings in the NWHI region occurred near land. Murphy and Ikehara (1955), who summarized sightings of bird flocks and fish schools in the NWHI, noted that the sightings were predominantly within 110 km (60 mi.) of the islands and very few schools in the semioceanic area (110 and 330 km or 60 and

Table 7 180 mi. from land) (Tables 7a and 7b). Waldron (1964) observed that the rate of sightings in the NWHI area was highest in March-May and in June-August, periods which overlap the May-September skipjack tuna fishing season in Hawaiian waters. The rate of sightings in waters of the NWHI was similar to that for Hawaiian waters and was at times considerably higher.

'ig. 36 Footnote 3 Charts summarizing sightings of bird flocks, skipjack tuna schools, and total fish schools by time-area units bounded by lat. 30°S and 30°N, and long. 110°W and 120°E are shown in Figure 36a through 36ℓ.[3]

COMMERCIAL FISHING OPERATIONS

As early as June 1946, commercial fishing vessels operating out of Honolulu began fishing in waters of the NWHI (Amerson 1971). Establishing a fishing base at French Frigate Shoals, Hawaiian commercial fishermen enjoyed good fishing and the catches, air shipped to Honolulu by chartered plane, were large enough to make the operation profitable.

By early November 1946, two companies--the Hawaiian American Fisheries, headed by Louis K. Agard, Jr., and the Seaside Fishing Company, run by Frank Opperman and Warren Haines--established fishing bases on Tern Island at French Frigate Shoals and used a chartered DC-3 from Trans-Air Hawaii to transport the catch to markets in Honolulu (Amerson 1971). Most of the catches consisted of fish taken by traps; however, a large proportion of the landings consisted of green sea turtle, which was also a profitable commodity.

[3]Naughton, J. J. Bird flock and surface tuna school sightings in the central Pacific Ocean, 1950-72. Manuscript in preparation. Western Pacific Programs Office, Southwest Region, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

The joint venturers involved in this newly developed fishery, however, eventually encountered difficulties in keeping the operation viable (Amerson 1971). In an attempt to reduce costs and increase profits, Hawaiian American Fisheries acquired new partners and formed a new corporation--Aero Fisheries--with a plane of its own. One flight was completed in July 1949. Mechanical problems with the plane and lack of financing to continue the plane operation forced Aero Fisheries to abandon its NWHI fishing operation.

Several other attempts to revive the fishing in the NWHI during the 1950's met with varying success. In 1959, Agard formed another joint venture and even purchased a refrigerated vessel and a plane to transship the catches. This venture was also short-lived.

HANDLINE FISHING

Some commercial fishing operators still believe that an efficiently run operation in the NWHI could be profitable, but others maintain a cautious attitude about the possibility of developing the fishing potential in these waters. Commercial deep-sea fishing vessels, using handline, lobster traps, and trolling gear, make periodic trips to waters around Nihoa and Necker Islands and enjoy relatively good fishing. Maintaining the catch in marketable condition, once a serious obstacle to further expansion of the fishery appears to be somewhat less of a problem today as modern methods of fish handling have reduced spoilage. The catches made by these vessels around Nihoa and Necker, by type of gear used in 1966-75 and the

ble 8

value of the catch, are given in Table 8.

Among the species that contribute a large proportion to the catches of the commercial vessels fishing NWHI waters are sea bass,

gure 37

jack crevally, amberjack, and pink, gray, and red snappers. Figure 37, which shows the annual handline catches and value of the species from Necker Island, indicates landings were 22,000 kg or less in 1966-69. In 1970, however, the total landings increased significantly, nearly doubling from about 18,000 to 34,000 kg. Catches since then have fluctuated widely and show a slight downward trend from 33,000 kg in 1971 to 27,000 kg in 1975. The values, which rose precipitously in 1970, have also fluctuated widely between $40,000 and $65,000.

Exploratory handline fishing was also attempted during a research cruise of the *Townsend Cromwell* (cruise report, *Townsend Cromwell* cruise 67, October 20, November 26, 1975). Fourteen handline stations in depths of 26-100 m (14-55 fathoms), occupied at various locations in waters of the NWHI, yielded catches dominated by *Carangoides ajax*, *Caranx cheilio*, *Pristipomoides microlepis*, *Seriola dumerilii*, and *Epinephelus quernus*. The largest handline catches were made near Gardner Pinnacles where 11 *C. ajax* totaling 181 kg (400 lb) were taken and at Laysan Island where 33 *C. ajax* weighing a total of 293 kg (645 lb) were captured during 3 h of fishing with five handlines.

POLE-AND-LINE FISHING

At present, there is no established fishery for the surface schools of tuna occurring in waters of the NWHI. The frequency of bird flock and fish school sightings made during several exploratory cruises to the area, however, gives an indication of the relative abundance of surface fish schools. Furthermore, the fact that Japanese pole-and-line fishing vessels have been observed actively fishing in NWHI waters attests to the potential of the area as a tuna fishing ground. For example, on July 11, 1976, four Japanese pole-and-line fishing vessels were sighted within 22 km (12 mi.) of Laysan Island; two were actively fishing with pole and line for skipjack tuna (William Streeter, Western Pacific Programs Office, Southwest Region, National Marine Fisheries Service, NOAA, Honolulu, HI 96812, pers. commun.). At the time of sighting, one vessel had already taken 907 kg (2,000 lb) of skipjack tuna. Subsequent sightings included not only pole-and-line fishing vessels but also longline vessels as well as Soviet trawlers.

The paucity of data on pole-and-line catches by research vessels of NMFS (including its predecessor agencies, Pacific Oceanic Fishery Investigations and Bureau of Commercial Fisheries) during cruises in waters in the vicinity of the NWHI makes it difficult to evaluate the effectiveness of this type of fishing. Data for 26 schools, however, have been examined; the catch rates for these schools which included both skipjack and yellowfin tunas, averaged 1.33 fish per hook-minute. Not all the data collected give an indication of biting rate. Several schools were fished primarily to obtain fish for tagging experiments. Therefore, the catch rates are not indicative of actual biting rates.

Past reports on the availability of live bait in the NWHI pointed to the existence of some productive baiting grounds (Eckles 1949; Smith and Schaefer 1949; June 1951). For example, Smith and Schaefer reported catching 437 scoops (4.5 kg per scoop) of silverside, *Pranesus pinguis*, locally called iao at French Frigate Shoals. The silverside is a hardy baitfish and suitable for long-distance transport in the baitwells of tuna fishing boats; however, although this species is the best baitfish found in the NWHI, June and Reintjes (1953) observed that its abundance fluctuates markedly. On one particular cruise of the RV *Charles H. Gilbert*, which operated in waters of the NWHI during a skipjack tuna tagging experiment, only 27 buckets (5.4 kg per bucket) of iao were taken in 2 days of baiting (Narrative Report, *Charles H. Gilbert*, cruise 114, April 19–May 29, 1969).

TROLLING

Trolling offers an alternative to the ways pelagic surface schooling fish such as tunas and tunalike fishes can be captured in waters of the NWHI. Not requiring live bait, trolling is used extensively in the fishery off the U.S. west coast for albacore, *Thunnus alalunga*. For capturing other species of tunas, however, it has never attained a position of major importance.

In the normal course of steaming through waters of the NWHI during exploratory cruises, research vessels of the NMFS used trolling gear as an incidental procedure. The troll catches made over the years from 1954 to 1964 are summarized in Table 9. Troll catches made by commercial vessels operating in the NWHI are shown in Table 8.

Table 9

The data available are meager and do not provide a definitive pattern of the availability and relative abundance of the various species taken in the NWHI. In terms of temporal distribution of the catches, however, it appears from the data that skipjack tuna, yellowfin tuna, kawakawa, and, in particular, mahimahi, Coryphaena hippurus, tend to be more available and vulnerable to the gear in April-August than in other months of the year.

LONGLINE FISHING

The Japanese high-seas longline fishery for deep-swimming tunas began in 1950 as part of a postwar recovery plan. Subsequent expansion of the longline fishing grounds was phenomenal and by 1954, Japanese longliners were operating in a large part of the Pacific as fishing operations extended from the Japanese coast eastward as far as long. 135°W (Figure 38).[4] The continued search for new fishing ground eventually extended to long. 105°W. By 1962, Japanese longliners were operating throughout the tropical and subtropical waters of the Pacific Ocean (Figure 39).

Fig. 38

Fig. 39

---

[4] Shomura, R. S., and R. N. Uchida. Pelagic fishes and fisheries of the Indian Ocean. Paper presented at the Biological Seminar of the Cooperative Investigations in the North and Central Western Indian Ocean, Nairobi, Kenya, 25 March-1 April 1976.

To get an estimate of the amount of fishing effort being exerted by Japanese longliners near the Hawaiian Islands, data from "Annual report of effort and catch statistics by area on Japanese tuna longline fishery" were extracted and summarized for the area bounded by lat. 20°-30°N and long. 160°W-180°. The percentage of the North Pacific longline fishing effort expended within the NWHI region (able 10) by Japanese longliners in 1963-73 is given in Table 10, together with catches and percentages for tunas and billfishes.

In 1964-73, only about 2% of the entire Japanese longline fishing effort in the North Pacific were expended within the NWHI (Fig. 40) region (Figure 40). The data show that nearly 3% of the North Pacific effort were expended in this area in 1964, but the proportion declined to 0.6% in 1966. Since then, however, the proportion increased irregularly and peaked at 3.3% in 1970. In 1971-73, it fluctuated around 2.5%.

Albacore, which was the first species of tuna to be intensively exploited by the Japanese longline fishery in the North Pacific, is by far, the most important tuna species taken within the (ig. 41) NWHI region by Japanese longliners. Figure 41 shows the percentage of the North Pacific catches of tunas and billfishes, by species, taken within the NWHI region by the Japanese. Albacore and bigeye tuna, *Thunnus obesus*, from near Hawaii accounted for about 2% of the entire North Pacific catch of these species. The proportion, however, has increased in recent years, fluctuating between 2% and 4%. Whereas albacore is not an important component of the Hawaiian longline catch, bigeye tuna is one of the major species of the Hawaiian longliners. Hida (1966) has shown that the Japanese longline fishery has been a causative agent in reducing the catch of bigeye tuna by the Hawaiian longline fleet.

Among billfishes, striped marlin is the most important species of the Japanese longliners within the NWHI region; however, it does not appear that the proportion taken near the NWHI has increased relative to the North Pacific catch of this species by Japanese longliners.

TRAWLING

Of all the methods that are used to exploit the fish resources of the NWHI, trawling is potentially one of the most important, particularly over the numerous banks and seamounts or guyots (banks are usually sizable and appear somehow to have become detached from the flanks of continents and now stand like great underwater mesas; seamounts or guyots are submerged volcanoes that are several hundred meters below the water level and which have flat tops, probably as a result of the erosive action of the surf).

The discovery of pelagic armorhead and alfonsin on seamounts northwest of Midway was made by a commercial trawler of the Soviet Union in November 1967 (Sakiura 1972). Almost immediately after the discovery, Soviet trawlers worked the banks and seamounts of the Emperor Seamount range. Subsequent surveys by Soviet research vessels were made closer to the Hawaiian Islands, including Kinmei Bank and Milwaukee Bank both outside the U.S. zone of extended jurisdiction, and Hancock Seamount inside the zone.

Fishing over seamount tops that were from 100 to 400 m below the sea surface, the Soviet trawlers found schools of armorhead averaging 30 m in thickness and produced catches varying from 3 to 50 metric tons (MT) on 10- to 20-min hauls. Often, the catches were as much as 30 MT in a 10-min haul. Sakiura (1972) reported that the Soviet trawlers produced 133,400 MT of armorheads from these seamounts between December 1969 and July 1970.

In 1969, the Japanese started deepwater trawling over seamounts and banks in the central North Pacific, north of Midway atoll. Working the grounds for pelagic armorhead, alfonsin, and a species of rockfish, _Sebastes matsubari_, the Japanese trawlers made fairly good catches. On one particular trip made from mid-June to early August 1975, one trawler reported catching 280 MT of fish valued at US$220,000 over the seamounts (U.S. NMFS 1975). Although armorhead first encountered consumer resistance when first marketed in Japan about 6 years ago, the species gradually gained consumer acceptance. By early 1975, an upsurge in demand brought about a renewed intensity in fishing for this species.

There appears to be some indication that the seamount resource of armorhead has started to decline. Three Japanese trawlers, fishing for this species off Midway atoll reported an average catch of 30 MT per day, considerably less than the break-even level of 40 MT per day

(U.S. NMFS 1976). These Japanese trawlers reported that armorhead landings in this area have declined sharply since early April when a Soviet trawling fleet worked the same grounds for armorhead.

More recent data on trawling operations in waters of the NWHI are also available from research cruises (Cruise Report, Townsend Cromwell, cruise 67, October 20-November 26, 1975). The Cromwell, which operates out of Honolulu, Hawaii, has conducted demersal resource surveys in the vicinity of Middle Bank, Nihoa, Necker, St. Rogatien Bank, Gardner Pinnacles, Pearl and Hermes Reef, Kure, Lisianski, and Laysan Islands. Using a high opening "Norwegian" fish trawl, which has a 19.2-m (63-ft) headrope, 25.3-m (83-ft) footrope, 10.2-cm (4-in.) diameter roller line, 10.2-cm (4-in.) mesh body and cod end, 3.8-cm (1.5-in.) mesh cod end cover, and 340.2-kg (750-lb) steel, V-doors, the Cromwell made several "blind" tows, which varied from 10 to 60 min and which caught a large variety of fish.

At Middle Bank, which has a depth of 62 m (34 fathoms), catches were dominated by three species of Acanthuridae--*Naso brevirostris*, *N. hexacanthus*, and *N. lopezi*, a small serranid, *Caesioperca thompsoni*, and the introduced lutjanid, *Lutjanus kasmira*. Catch rates ranged up to 110 kg/h (243 lb/h) for *Naso* spp., 129 kg/h (285 lb/h) for *C. thompsoni* in the small mesh cod end cover, and 41 kg/h (90 lb/h) for *L. kasmira*. The zooplanktivorous and herbivorous fishes constituted from 40% to 91% of the trawl catches at this locale. From the four daylight hauls at Middle Bank, total catches varied from 33 to 230 kg (48 to 507 lb), which when extrapolated indicate catch rates of 44-414 kg/h (96-913 lb/h) and an average catch rate of 242 kg/h (534 lb/h). Assuming that the trawl sampling width was 11.5 m (about 38 ft), the Cromwell's scientists calculated that the standing biomass at Middle Bank is 855-8,137 kg/km^2 and the mean, 4,680 kg/km^2. These values compare favorably with estimated densities of demersal stocks in the region of the South China Sea, which is considered one of the most productive fisheries region of the world with densities ranging from 1,250 to 5,000 kg/km^2.

Five trawl stations occupied by the Cromwell north of Nihoa Island also yielded good catches. The catches, which varied from 83 to 158 kg/h (184 to 349 lb/h) and averaged 117 kg/h (258 lb/h), indicated a standing biomass of 1,011-2,074 kg/km^2. Catches at Nihoa Bank, which is relatively shallow at 48-55 m (26-30 fathoms), were dominated by N. brevirostris, N. hexacanthus, and Acanthurus olivaceus. Zooplanktivorous and herbivorous species constituted from 38% to 84% of the catch.

At a depth of 29-48 m (16-26 fathoms) near Necker Island, two daylight hauls by the Cromwell yielded relatively poor catches. A single night tow, however, produced a catch equivalent to a rate of 512 kg/h (1,129 lb/h) and to a standing biomass of about 8,028 kg/km^2. Although a variety of species was caught at this location, N. hexacanthus was again the dominant species. Trawl catches from deeper areas around Necker Island were very poor as were those made on St. Rogatien Bank.

Scientists aboard the Cromwell also surveyed waters of the NWHI with a 12.5-m (41-ft) headrope, semiballoon shrimp trawl at depths of 29-37 m (16-20 fathoms) and in deeper waters ranging from 400 to 785 m (218 to 430 fathoms). Catches were small; the deeper hauls produced the caridean shrimps, Heterocarpus ensifer and H. laevigatus, at the rate of 0.7-0.9 kg/h (1.5-2.0 lb/h).

TRAP FISHING

Both fish and shrimp traps have been fished experimentally in waters of the NWHI. On cruise 67 of the Townsend Cromwell, exploratory fishing was conducted with two sizes of fish traps and shrimp traps. The fish traps were of two general types--large traps which measured 1.5-m (5-ft) square, 1.2-m (4-ft) high, and with two bottom and one upper opening, and small traps which measured 0.6 x 0. 0.6 x 0.6 x 1.2 m (2 x 2 x 4 ft) and had either one or two entrances. The traps, baited with 0.4-2.3 kg (1-5 lb) of chopped fish in 13-mm (0.5 in.) wire mesh containers secured to the bottom of the traps, were fished overnight for 13-16 h at depths ranging from 29 to 119 m (16-65 fathoms).

The trap catches were quite variable and generally small. Snappers, locally called "opakapaka," Pristipomoides microlepis, were caught in fair numbers on four occasions in the large traps that were fished at the shelf edge north of Necker Island in 44-57 m (24-31 fathoms) of water. Catches ranged from 4.5 to 7.7 kg (10 to 17 lb) per set and averaged 514 kg (11.9 lb). Near Kure atoll, one trap, fished at 48 m (26 fathoms) produced 18.4 kg (40.5 lb) of carangids, *Caranx cheilio*. Two traps out of 12 that were fished at Lisianski Island produced 16 and 48 kg (35 and 105 lb) of another species of carangid, *Carangoides ajax*.

Catches of lobsters were also variable. At a locale north of Necker Island, 17 traps fished at 29-57 m (16-31 fathoms) produced 160 lobsters, *Panulirus marginatus*, which averaged 0.6 kg (1.4 lb). Traps fished near the edge of the bank in 44-57 m (24-31 fathoms) of water produced the best catches. At a station north-northwest of Nihoa Island, the traps, fished in 44-48 m (24-26 fathoms) of water produced fair numbers of lobsters. Here, the 11 traps yielded 41 lobsters which averaged 0.9 kg (2.0 lb). Catches were relatively poor at stations occupied near Pearl and Hermes Reef, Kure Island, Lisianski Island, Laysan Island, and Gardner Pinnacles. The commercially valuable kona crab, *Ranina serrata*, occurred in traps set in 46-55 m (25-30 fathoms) of water off Pearl and Hermes Reef and Kure Island. Three traps at Kure produced 4.5-27.2 kg (10-60 lb) per trap or an average of 13.9 kg (30.7 lb) per trap.

Six shrimp traps set overnight in depths of 475 and 549 m (260 and 300 fathoms) on two occasions off Necker Island, produced 16.6 kg (36.5 lb) of *Heterocarpus laevigatus* (18-20 shrimps per kilogram or 8-9 shrimps per pound, head on). Four traps fished off Nihoa Island yielded 11.0 kg (24.2 lb) of *H. laevigatus* and 2.0 kg (4.3 lb) of *H. ensifer*.

SURVEY OF NEARSHORE FISHERY RESOURCES

During cruise 76-04-71 of the Townsend Cromwell (Narrative Report, Townsend Cromwell, cruise 76-04-71, May 3-June 9, 1976) the nearshore and shoreline fishery resources were surveyed by personnel of the Hawaii Division of Fish and Game at Nihoa Island, French Frigate Shoals, Laysan Island, and Necker Island. Data on species composition, distribution, and densities of fishes at each of these locales, collected through shoreline, surface, and underwater

Tables 11,12 observations, are given in Tables 11 and 12.

The preliminary results indicated that the carangids, locally called "ulua," and sharks, Carcharhinidae, were large and relatively abundant in certain areas. Other families such as Holocentridae, Apogonidae, Pomacentridae, Chaetodontidae, Acanthuridae, and Muraenidae, commonly associated with similar habitats in waters surrounding the major Hawaiian Islands, appeared to be noticeably absent in the communities observed. The low diversity of fish species present within the nearshore area surveyed may be the result of the presence and abundance of large predators. Estimated fish density,

Table 13 given in Table 13, was highest at Whale-Skate Island at French Frigate Shoals. Here, *Mulloidichthys samoensis*, *Carangoides ajax*, and *Scarus perspicillatus*, occurred in greatest densities.

SIZE OF FISH AND LOBSTERS

No definitive study has been made on the size composition of the various species of fish caught in waters of the NWHI. The segment of the population that the deep-sea handline fleet samples is not documented. The reader is, therefore, referred to Gosline and Brock (1960) for information on size of the various handline-caught species. For nearshore fishes, surveys by the Hawaii Division of Fish and Game indicate that species observed were predominantly in the maximum or near-maximum size classes at Nihoa, French Frigate Shoals, Laysan, and Necker. Furthermore, they noted that the relative absence of juveniles was particularly striking (Narrative Report, Townsend Cromwell, cruise 76-04-71, May 3-June 9, 1976).

Concerning the species taken in the Japanese trawl fishery, data from the 1972 North Pacific seamount surveys of the RV Kaiyo

Table 14 Maru were used (Japan Fisheries Agency 1974b). Table 14 shows that at Hancock Seamount, the alfonsin taken on one of the tows varied from 23.2 to 33.6 cm and averaged 27.1 cm. The average weight was 428 g. Armorhead taken in several tows at the same seamount varied widely in size from 21.0 to 38.3 cm; the average size calculated for each tow ranged between 26.8 and 27.7 cm in length and between 291 and 356 g in weight.

Size distribution of skipjack tuna and kawakawa taken by pole-and-line fishing during NMFS cruises in NWHI waters are shown

Fig. 42 in Figure 42. Sizes varied widely from 29 to 82 cm in skipjack tuna and from 38 to 64 cm in kawakawa. The data for skipjack tuna were collected in February, April-July, and September-November and, therefore, represent a fairly good sampling of the size of skipjack tuna that occur in that area. Large, "season" skipjack tuna were encountered in April, May, July, and September which coincides with the time of occurrence of the large fish in waters around the major Hawaiian Islands.

Other species of tuna also were taken, but the samples were too small to be of any value. Briefly, the yellowfin tuna caught by pole and line varied from 44 to 82 cm and frigate mackerel, _Auxis thazard_, varied from 29 to 41 cm. Among troll-caught fish, the size range were as follows: skipjack tuna--16 to 80 cm; kawakawa--32 to 77 cm; yellowfin tuna--48 to 87 cm; and albacore--52-98 cm.

Among lobsters taken in traps near Nihoa, Necker, Gardner Laysan, and Kure, the females were considerably smaller than the males.

Fig. 43 Figure 43 shows the percentage weight-frequency distribution of male and female lobsters taken at these locales and for 71 females sampled, the weights varied between 202 and 1,151 g and averaged 256 g. Among 128 male lobsters, however, the range in weights was larger, varying from 205 to 1,374 g and averaging 692 g.

OBSERVATIONS ON TURTLES, SEAL, AND DOLPHINS

At the intensity with which harvesting was being carried on a few years ago, the green sea turtle, _Chelonia mydas_, faced the possibility of complete extirpation. Presently, however, there is confidence among scientists that the species is in no such danger. Instead, there is even the prospect that the green sea turtle will become a resource of major importance. In this respect, the NWHI, a wildlife sanctuary, provide undisturbed breeding grounds not only for turtles but also the Hawaiian monk seal, Monachus schauinslandi. In the sections that follow, some observations made on turtles, seal, and dolphins in the various islands and atolls of the NWHI are discussed.

FRENCH FRIGATE SHOALS

Only the green sea turtle is known from French Frigate Shoals (Amerson 1971). The species is a common resident breeder with nests on the six major sand islands. The object of a commercial fishery in 1946-48, the green sea turtles were abundant at French Frigate Shoals and two Honolulu-based fishing companies established a base at Tern Island. The abundance gradually declined, more as a result of human disturbance than actual killing and harvesting was eventually abandoned. The USFWS reported that commercial fishermen again caught turtles from the atoll in the spring of 1957 (Narrative Report, Hugh M. Smith, cruise 39, April 19-May 30, 1957).

Among the Hawaiian Islands, French Frigate Shoals support the largest population of green sea turtles (Amerson 1971). They occur the year round although the adult population is lowest in the fall, winter, and early spring. The population density increased in late spring and summer coinciding with breeding. Copulation occurs in early May, nesting commences later the same month, and egg laying has been reported to occur in August-September. Hatchlings probably appear in late July and are common in August and early fall.

GARDNER PINNACLES

The green sea turtle has been reported from waters around Gardner Pinnacles (Clapp 1972). The species does not breed there because the island does not afford a suitable reproductive habitat.

The Hawaiian monk seal, first recorded from Gardner Pinnacles in 1826, appears quite regularly in waters and along the shore of this island (Clapp 1972). There is, however, no evidence that breeding occurs there.

LAYSAN ISLAND

Laysan's mammalian fauna is limited to one species, the Hawaiian monk seal, which uses the sandy beaches for hauling grounds. Considered numerous at one time, the Hawaiian monk seal was hunted almost to extinction during the last half of the 19th century (Ely and Clapp 1973). Legislation to protect the population has increased their numbers until the species has once again become a regular part of the Laysan fauna.

The green sea turtle, using Laysan as a hauling ground, occur in relatively small numbers and probably only a few breed there (Ely and Clapp 1973). Although abundant at one time during the 19th century, they were heavily harvested; the result is that there has been little increase in the population since then.

LISIANSKI ISLAND

The Hawaiian monk seal and the green sea turtle have been recorded from Lisianski, but their abundance has been reduced considerably in the late 1800's and early 1900's as a result of predation by sealers (Clapp and Wirtz 1975). The Hawaiian monk seal is a common breeder at this island and occur throughout the year. Kenyon (1972) has suggested that the decline of populations of monk seals on Midway and Kure Islands was probably due to excessive disturbance by man. Recent population studies suggested that there has not been any decrease in the productivity of the Lisianski population. Clapp and Wirtz observed that about 30-40 pups are produced annually. Peak pupping season appears to be from about March through May-June.

The green sea turtles were once a conspicuous and numerous component in the Lisianski fauna but recent observations indicate a large decrease in numbers since about 1923 (Clapp and Wirtz 1975). This decrease has been attributed to poaching by fishermen in the decade after the Tanager expedition. Clapp and Wirtz also reported that the number of green sea turtles currently at Lisianski is undoubtedly higher than the maximal count but it is doubtful that the breeding population, if one exists, consists of more than a few individuals. There has been no recent reports of nests or sightings of hatchlings. The presence of rather small turtles at Lisianski also suggests that many are visitors, probably from French Frigate Shoals, the primary breeding ground and from Pearl and Hermes Reef.

PEARL AND HERMES REEF

From Pearl and Hermes Reef, three marine mammalian species have been reported--the Hawaiian monk seal, the Hawaiian spinner dolphin, Stenella roseiventris, and the bottle-nosed dolphin Tursiops truncatus (Amerson et al. 1974). The Hawaiian monk seal, found on most of the NWHI is a resident breeding species present at Pearl and Hermes Reef the year round. A visitor to the NWHI, the bottle-nosed dolphin appear to be regularly associated with shallow waters from French Frigate Shoals to Kure Island. One of the early sightings of this species was made on March 1956 when personnel aboard the RV John R. Manning recorded three large bottle-nosed dolphin on the western side of Pearl and Hermes Reef. The Hawaiian spinner dolphin, on the other hand, although common in Hawaiian waters, appear to be only an occasional visitor to Pearl and Hermes Reef. Eight of them were sighted offshore from Southeast Island on March 1968.

Only one reptile, the black turtle, _Chelonia agassizi_, has been recorded from Pearl and Hermes Reef (Amerson et al. 1974). There is no substantiated record of sightings of the Pacific hawksbill turtle, _Eretmochelys imbricata_, from Pearl and Hermes Reef. The black turtle, although uncommon, is a resident breeder at Pearl and Hermes Reef and a few are probably present the year round. The species have been reported to frequent Little North, North, and Southeast Islands.

KURE ISLAND

Two species of turtles--the hawksbill and green sea turtles--have been recorded from Kure Island, although the validity of the sightings of hawksbill turtle is uncertain (Woodward 1972). Most of the sightings, although infrequent, occurred in the lagoon or outside the reef.

LITERATURE CITED

Amerson, A. B., Jr.

1971. The natural history of French Frigate Shoals, Northwestern Hawaiian Islands. Atoll Res. Bull. 150, 383 p.

Amerson, A. B., Jr., R. B. Clapp, and W. O. Wirtz, II.

1974. The natural history of Pearl and Harmes Reef, Northwestern Hawaiian Islands. Atoll Res. Bull. 174, 306 p.

Bryan, E. H., Jr.

1939. We see only the peaks of Hawaii. Paradise of the Pacific. 51:13-16.

1942. American polynesia and the Hawaiian chain. Tongg Publ. Co., Honolulu, Hawaii, 253 p.

Carlquist, S.

1970. Hawaii, a natural history. Nat. Hist. Press, Garden City, N.Y., 463 p.

Clapp, R. B.

1972. The natural history of Gardner Pinnacles, Northwestern Hawaiian Islands. Atoll Res. Bull. 163, 25 p.

Clapp, R. B., and W. O. Wirtz, II.

1975. The natural history of Lisianski Island, Northwestern Hawaiian Islands. Atoll Res. Bull. 186, 196 p.

ECKLES, H. H.

1949. Fishery exploration in the Hawaiian Islands (August to October 1948, by the vessel Oregon of the Pacific Exploration Company). Commer. Fish. Rev. 11(6):1-9.

Ely, C. A., and R. B. Clapp.

1973. The natural history of Laysan Island, Northwestern Hawaiian Islands. Atoll Res. Bull. 171, 361 p.

Emory K. P.

1928. Archaeology of Nihoa and Necker Islands. B. P. Bishop Museum Bull. 53, 124 p.

Freeman, O. W.

1951. Hawaii and American island outposts. In O. W. Freeman (editor), Geography of the Pacific. John Wiley and Sons, Inc., N.Y., p. 328-363.

Gosline, W. A., and V. E. Brock.

1960. Handbook of Hawaiian fishes. Univ. Hawaii Press, Honolulu, Hawaii, 372 p.

Gross, M. G., J. D. Milliman, J. I. Tracey, and H. S. Ladd.

1969. Marine geology of Kure and Midway Atolls, Hawaii: A preliminary report. Pac. Sci. 23:17-25.

Hida, T. S.

1966. Catches of bigeye and yellowfin tunas in the Hawaiian longline fishery. In T. A. Manar (editor), Proceedings of the Governor's Conference on Central Pacific Fishery Resources, State of Hawaii, p. 161-167.

Japan Fisheries Agency.

1967a. Annual report of effort and catch statistics by area on Japanese tuna longline fishery - 1964. Research Division, Fisheries Agency of Japan, 379 p.

Japan Fisheries Agency.

1967b. Annual report of effort and catch statistics by area on Japanese tuna longline fishery - 1965. Research Division, Fisheries Agency of Japan, 375 p.

1968. Annual report of effort and catch statistics by area on Japanese tuna longline fishery - 1966. Research Division, Fisheries Agency of Japan, 299 p.

1969. Annual report of effort and catch statistics by area on Japanese tuna longline fishery - 1967. Research Division, Fisheries Agency of Japan, 293 p.

1970. Annual report of effort and catch statistics by area on Japanese tuna longline fishery - 1968. Research Division, Fisheries Agency of Japan, 283 p.

1971. Annual report of effort and catch statistics by area on Japanese tuna longline fishery - 1969. Research Division, Fisheries Agency of Japan, 299 p.

1972. Annual report of effort and catch statistics by area on Japanese tuna longline fishery - 1970. Research Division, Fisheries Agency of Japan, 326 p.

1973. Annual report of effort and catch statistics by area on Japanese tuna longline fishery - 1971. Research Division, Fisheries Agency of Japan, 319 p.

1974a. Annual report of effort and catch statistics by area on Japanese tuna longline fishery - 1972. Research and Development Department, Fisheries Agency of Japan, 279 p.

Japan Fisheries Agency.

1974b. Report of Kaiyo Maru cruises, North Pacific seamount surveys - 1972, 136 p.

1975. Annual report of effort and catch statistics by area on Japanese tuna longline fishery - 1973. Research and Development Department, Fisheries Agency of Japan, 265 p.

June, F. C.

1951. Preliminary fisheries survey of the Hawaiian-Line Islands area. Part II-Notes on the tuna and bait resources of the Hawaiian, Leeward, and Line Islands. Commer. Fish. Rev. 13(1): 1-22.

June, F. C., and J. W. Reintjes.

1953. Common tuna-bait fishes of the central Pacific. U.S. Fish Wildl. Serv., Res. Rep. 34, 54 p.

Kenyon, K. W.

1972. Man versus the monk seal. J. Mammal. 53:687-696.

King, J. E., and J. Demond.

1953. Zooplankton abundance in the central Pacific. U.S. Fish Wildl. Serv., Fish. Bull. 54:111-144.

Mauck, C. J., III.

1975. Forecaster's handbook. Local area forecaster's handbook for U.S. Naval Station, Midway Island. Compiled by U.S. Naval Weather Service Environmental Detachment (NWSED), 61 p. [Mimeogr.]

McDonald, G. A., and A. T. Abbott.

1970. Volcanoes in the sea. Univ. Hawaii Press, Honolulu, Hawaii, 441 p.

Murphy, G. I., and I. I. Ikehara.

1955. A summary of sightings of fish schools and bird flocks and of trolling in the central Pacific. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 154, 19 p.

Palmer, H. S.

1927. Geology of Kaula, Nihoa, Necker, and Gardner Islands, and French Frigate Shoals. B. P. Bishop Museum, Bull. 35, 35 p.

Reid, J. L., Jr.

1962. On circulation, phosphate-phosphorus content, and zooplankton volumes in the upper part of the Pacific Ocean. Limnol. Oceanogr. 7:287-306.

Sakiura, H.

1972. The pelagic armorhead, <u>Pentaceros richardsoni</u>, fishing grounds off the Hawaiian Islands, as viewed by the Soviets (So-Ren kara mita Hawaii oki kusakari tsubodai gyojyo). Suisan Shuho 658:28-31. (Engl. transl. by T. Otsu, 1977, 7 p., Translation No. 17; available Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.)

Scripps Institution of Oceanography.

1971. Bathymetric atlas of the north central Pacific Ocean. Compiled by Scripps Institution of Oceanography, under contract to the U.S. Naval Oceanographic Office. U.S. Naval Oceanographic Office, Washington, D.C., 75 p.

Seckel, G. R.

1962. Atlas of the oceanographic climate of the Hawaiian Islands region. U.S. Fish Wildl. Serv., Fish. Bull. 193: 371-427.

Smith, O. R., and M. B. Schaefer.

1949. Fishery exploration in the western Pacific (January to June 1948, by vessels of the Pacific Exploration Company). Commer. Fish. Rev. 11(3):1-18.

State of Hawaii.

1969. Hawaii and the sea. Report to the Governor's Task Force on Oceanography. Published by the State of Hawaii Department of Planning and Economic Development, 112 p.

1974. Hawaii and the sea - 1974. Prepared for the Governor's Advisory Committee on Science and Technology. Published by the State of Hawaii, Department of Planning and Economic Development, 99 p.

Sverdrup, J. U., M. W. Johnson, and R. H. Fleming.

1946. The oceans. 2d ed. Prentice-Hall, Inc., N.Y., 1,087 p.

Thorp, E. M.

1936. The sediments of Pearl and Hermes Reef. J. Sediment. Petrol. 6:109-118.

Tudor, J. (editor).

1972. Pacific islands year book. 11th ed. Pac. Publ. Pty, Ltd., Sydney, Australia, 542 p.

[U.S.] Bureau of Commercial Fisheries.

1963. Skipjack - A world resource. U.S. Fish Wildl. Serv., Circ. 165, 28 p.

U.S. National Marine Fisheries Service.

1975. Japanese trawl operations off Midway Islands. Foreign Fishery Information Release 75-15:4. Compiled by J. H. Shohara, National Marine Fisheries Service, NOAA, Southwest Region, Terminal Island, CA.

1976. Japanese landings of tsubodai off Midway decline sharply. Foreign Fishery Information Release 76-9:4. Compiled by S. C. Sonu, National Marine Fisheries Service, NOAA, Southwest Region, Terminal Island, CA.

U.S. Navy Hydrographic Office.

1950. Atlas of surface currents. Northwestern Pacific Ocean. First ed., H. O. 569.

[U.S.] Office of Geography.

1956. National Intelligence Survey (U.S. Dep. Interior). NIS Gazetteer, Hawaiian Islands. Central Intelligence Agency, Washington, D.C., 89 p.

U.S. Weather Bureau.

1961. Climates of the states - Hawaii. Climatology of the United States. U.S. Weather Bureau, 60-51, 20 p.

Waldron, K. D.

1964. Fish schools and bird flocks in the central Pacific Ocean, 1950-61. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 464, 20 p.

Warner, R. E.

1963. Recent history and ecology of the Laysan duck. Condor 65:3-23.

Woodward, P. W.

1972. The natural history of Kure Atoll, Northwestern Hawaiian Islands. Atoll Res. Bull. 164, 318 p.

U.S. Navy Hydrographic [illegible]
1950

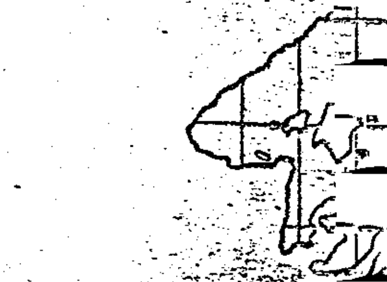
NORTHWESTERN PACIFIC OCEAN

SURFACE CURRENTS AND TEMPERATURES

Appendix 1

SOURCE OF INFORMATION

The information relating to monthly surface currents shown on this chart was compiled from observations made during the month for all years prior to 1935 by the co-operating observers of the Hydrographic Office. Observations were not considered reliable where tidal currents prevailed; where winds, sea, or swell of force 6 or above were recorded; where the vessel's draft or trim would cause excessive leeway; or when doubt existed as to the meaning of the entry "Nil" on the current report. All current calculations are based on the MEDIAN POSITION method; namely, each observation is applied at only one point, that point being midway between the beginning and end of the ship's run for which the current observation was made.

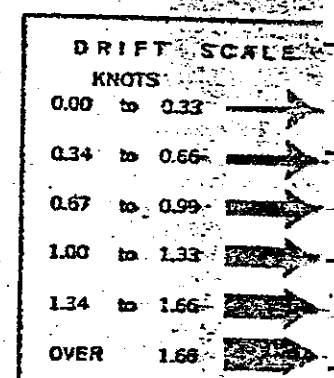


RESULTANT CURRENTS

The black arrows and numerals show the mean direction and force of the surface current in each 1-degree quadrangle for the month under average normal conditions. The accuracy of the resultant current in any quadrangle is necessarily determined by the number of observations used in the computation. The Hydrographic Office considers a resultant to be fairly accurate if computed from five or more observations in an area of 3,600 square miles. But on this chart all reliable information is shown, for the benefit of the navigator, even where less than the desired five observations were obtained.

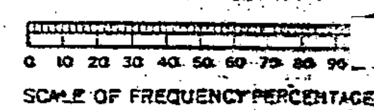
The resultant currents in each 1-degree quadrangle are shown as follows:

The number in the upper right hand corner of the quadrangle represents the total current observations used in the computation. The numerals in the lower left hand corner of the quadrangle give the resultant drift in miles per day to the nearest tenth of a mile. The direction of the arrow in the center of the quadrangle shows the resultant set.

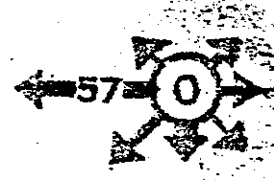


PREVAILING CURRENTS

The current roses shown in green on this chart were computed from the same information as the 1-degree resultants shown in black. The eight-point rose presents a graphical picture of the frequency of direction and the average drifts within the directions for each area outlined by the heavy brown lines.

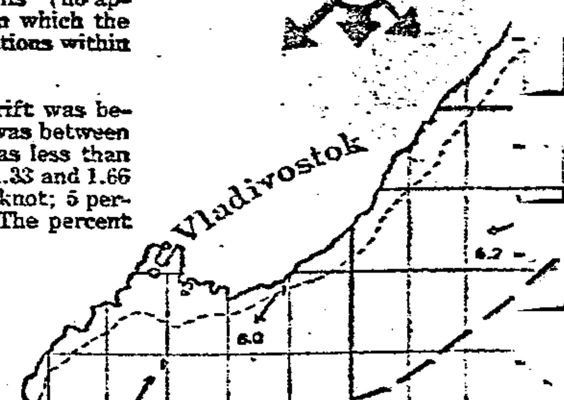


The arrows point in the direction towards which the current sets. When the frequency of direction is less than 5 percent, no arrow is shown. The length of the arrow, from the base of the arrow head to the inner edge of the circle, when placed on the attached frequency scale gives the number of times in each 100 observations that the current has been setting in or near the indicated direction. In instances where the full length of the arrow cannot be shown, the shaft is broken and the true percentage inserted in numerals within the break. The width of the shaft when placed on the attached drift scale gives the average drift in knots. The numeral in the center circle gives the percent of "nils" (no appreciable current observed). The approximate number of observations from which the current rose was computed can be obtained by adding the number of observations within the 1-degree quadrangles covered by the rose.



For example the attached rose should be read as follows:

Of the currents observed; 5 percent were setting northeast, the average drift was between 0.33 and 0.66 of a knot; 5 percent were setting east, the average drift was between 0.33 and 0.66 of a knot; 9 percent were setting southeast, the average drift was less than 0.33 of a knot; 5 percent were setting south, the average drift was between 1.33 and 1.66 knots; 57 percent were setting west, the average drift was between 0.67 and 1 knot; 5 percent were setting northwest, the average drift was less than 0.33 of a knot. The percent of "nils" was zero.



SEA TEMPERATURES

The monthly mean sea surface 5-degree isotherms shown in MAGENTA were compiled from the same source and for the same period as the resultant currents shown on this chart.

Islands	Area	Altitude
	Sq km	m
Hawaii	10,437.70	4,201.36 (Mauna Kea)
		4,169.66 (Mauna Loa)
Maui	1,885.52	3,055.62 (Haleakala)
Molokai	673.40	1,514.86
Kahoolawe	116.55	454.46
Lanai	365.19	1,027.18
Oahu	1,564.36	1,226.82
Kauai	1,437.45	1,575.82
Niihau	186.48	390.45
Kaula	0.42	167.64
Nihoa	0.71	272.80
Necker	0.16	84.12
French Frigate Shoals (including La Perouse Pinnacle)	0.45	37.18
Gardner Pinnacles	0.01	51.82
Laysan	4.05	12.19
Lisianski	1.82	12.19
Pearl and Hermes Reef	1.21	3.05
Midway	8.09	13.11
Kure	1.21	7.62
Area (8 main islands)	16,666.65	
Outlying islands	18.11	
Entire chain	16,684.76	

Table 1.--The area (sq km) and altitude (m) of the islands and atolls in the Hawaiian archipelago (Freeman 1951; Carlquist 1970; Amerson 1971; Woodward 1972).

MONTH	MAXIMUM	MINIMUM	MEAN
JAN	74.2	56.4	66.0
FEB	74.1	56.6	65.9
MAR	74.8	57.0	66.5
APR	76.4	59.2	67.9
MAY	80.3	62.7	71.3
JUN	83.2	66.8	76.0
JUL	84.0	69.3	78.0
AUG	85.1	70.3	79.0
SEP	86.0	70.2	78.9
OCT	83.3	66.0	75.7
NOV	80.3	62.1	72.1
DEC	76.8	58.0	68.4

Table 2.--Maximum, minimum and mean air temperatures, by month, at Midway Atoll, (1949-72 (Mauck 1975).

Woodward 1972

	January		February		March		April		May		June	
1961	-	-	-	-	-	71.9 (68-78)	69.1 (57-75)	74.5 (67-83)	73.5 (65-86)	81.6 (74-88)	84.2 (79-87)	82.8 (77-88)
1962	69.3 (59-73)	68.0 (63-72)	70.1 (62-76)	70.8 (66-74)	70.9 (66-74)	71.4 (62-76)	71.9 (65-76)	69.9 (64-75)	75.4 (74-79)	78.1 (69-84)	77.5 (75-83)	83.1 (74-87)
1963	69.9 (66-74)	69.6 (67-72)	68.5 (62-73)	67.1 (63-71)	72.1 (66-78)	69.6 (63-79)	69.7 (65-79)	74.4 (66-79)	79.3 (74-82)	80.4 (78-88)	81.7 (75-87)	83.5 (77-88)
1964	70.7 (64-74)	71.0 (65-74)	71.0 (64-75)	71.1 (65-74)	71.3 (65-78)	72.3 (67-76)	69.5 (64-78)	70.9 (66-76)	71.7 (65-78)	77.9 (70-80)	78.5 (70-84)	82.7 (79-85)
1965	66.5 (60-71)	65.8 (60-70)	68.7 (64-74)	70.9 (64-79)	69.4 (63-75)	71.6 (64-77)	72.2 (65-79)	70.9 (66-76)	72.2 (68-76)	72.9 (68-79)	80.5 (71-85)	79.9 (72-87)
1966	70.6 (67-74)	69.7 (60-74)	69.1 (63-72)	70.2 (63-74)	70.8 (65-74)	72.1 (67-75)	71.1 (65-75)	73.5 (67-78)	74.9 (72-78)	76.0 (72-78)	71.6 (76-87)	84.7 (81-87)
1967	72.0 (67-76)	70.9 (63-76)	67.9 (64-74)	70.5 (65-77)	68.1 (59-75)	71.4 (64-78)	74.5 (70-79)	75.0 (72-80)	75.5 (69-88)	79.1 (75-83)	77.7 (70-82)	81.8 (77-88)
1968	69.5 (64-75)	68.9 (65-70)	68.1 (61-70)	65.4 (61-70)	68.9 (60-77)	73.9 (67-78)	72.9 (68-79)	72.9 (65-79)	75.2 (67-80)	78.6 (72-85)	80.4 (70-88)	85.4 (76-91)

Table 3.--Average semi-monthly maximum air temperatures and their range (in parentheses) at Kure Atoll, 1961-68 (Woodward 1972).

Woodward 1972

Table Ø43. (continued)

	July		August		September		October		November		December	
1961	86.5 (80-89)	88.9 (87-91)	86.8 (82-93)	89.0 (84-92)	87.0 (82-91)	86.5 (76-90)	82.4 (75-89)	79.2 (70-85)	78.4 (75-84)	78.6 (76-82)	74.9 (67-81)	73.8 (69-77)
1962	83.6 (76-86)	84.9 (78-89)	87.6 (83-92)	86.7 (80-93)	86.9 (84-90)	88.7 (84-92)	85.9 (77-89)	80.1 (72-86)	79.3 (74-85)	79.3 (75-87)	73.5 (67-79)	69.8 (64-73)
1963	82.7 (76-86)	83.3 (76-86)	83.9 (76-87)	87.1 (80-90)	85.9 (84-89)	86.2 (78-90)	82.3 (74-86)	81.8 (77-85)	79.2 (74-84)	75.3 (69-78)	70.4 (62-76)	70.9 (65-78)
1964	83.5 (79-85)	82.5 (79-84)	82.6 (79-86)	85.2 (78-88)	85.1 (82-87)	83.1 (80-87)	84.8 (83-88)	80.2 (76-83)	76.9 (72-80)	73.5 (69-80)	72.4 (67-78)	65.6 (59-70)
1965	85.7 (85-87)	84.1 (75-89)	86.6 (84-88)	86.1 (84-89)	85.3 (78-99)	81.5 (77-86)	80.5 (73-85)	79.8 (72-83)	76.5 (70-81)	76.5 (70-81)	72.2 (66-78)	66.7 (62-75)
1966	86.1 (80-89)	86.1 (79-90)	86.3 (80-89)	87.1 (80-91)	84.1 (76-89)	84.3 (80-89)	81.0 (73-84)	80.3 (75-86)	75.0 (68-80)	74.1 (70-80)	71.2 (68-74)	72.6 (69-75)
1967	82.9 (77-89)	83.7 (79-88)	84.3 (80-87)	85.8 (81-89)	86.7 (83-90)	85.0 (80-89)	83.6 (80-86)	84.1 (76-88)	81.2 (75-86)	78.2 (75-86)	73.6 (65-80)	70.1 (63-74)
1968	91.3 (87-93)	90.9 (89-93)	91.1 (87-96)	86.1 (80-93)	90.6 (87-94)	84.7 (75-93)	81.6 (76-91)	84.6 (82-95)	78.6 (68-87)	73.7 (67-81)	73.0 (68-76)	69.1 (64-73)

	January		February		March		April		May		June	
1961	-	-	-	-	-	62.0 (52-66)	56.9 (52-67)	61.7 (52-64)	61.7 (58-65)	66.9 (63-70)	72.3 (67-76)	72.8 (70-75)
1962	62.4 (56-68)	60.2 (52-64)	60.3 (57-65)	61.9 (57-67)	63.5 (59-67)	62.0 (55-65)	63.3 (57-69)	62.6 (55-69)	63.9 (61-66)	66.2 (60-74)	67.2 (64-71)	71.0 (68-74)
1963	64.7 (60-69)	63.4 (60-67)	61.9 (59-65)	60.8 (57-65)	63.3 (59-67)	62.3 (56-68)	51.5 (59-64)	63.7 (59-70)	68.3 (64-73)	69.1 (67-72)	72.9 (70-75)	73.5 (72-77)
1964	62.4 (57-68)	65.1 (61-69)	63.1 (50-69)	62.2 (55-70)	62.5 (55-70)	64.1 (60-68)	59.6 (56-63)	61.5 (57-65)	61.1 (59-66)	65.6 (60-70)	63.8 (52-72)	72.1 (70-73)
1965	60.7 (56-66)	58.3 (39-64)	60.5 (55-66)	62.2 (50-69)	61.7 (56-67)	63.1 (60-67)	60.4 (45-66)	58.5 (47-66)	62.3 (58-64)	61.1 (58-63)	68.3 (63-73)	71.6 (67-74)
1966	62.1 (57-68)	61.9 (50-69)	60.7 (59-65)	60.8 (57-65)	60.8 (50-67)	62.3 (55-68)	59.9 (56-68)	62.6 (57-66)	64.7 (62-68)	66.7 (64-69)	68.6 (62-73)	73.5 (69-77)
1967	64.7 (59-69)	62.3 (53-68)	58.7 (54-64)	59.8 (53-66)	58.9 (53-63)	59.9 (55-64)	64.9 (60-69)	64.3 (61-66)	64.1 (59-69)	67.2 (64-73)	70.7 (65-75)	70.6 (65-73)
1968	59.7 (48-66)	58.8 (50-63)	60.5 (49-64)	59.5 (55-64)	57.5 (51-64)	61.1 (57-65)	61.7 (59-65)	62.6 (60-65)	64.3 (58-70)	70.3 (66-74)	69.1 (63-74)	73.1 (65-78)

Table 4.--Average semi-monthly minimum air temperatures and their range (in parentheses) at Kure Atoll, 1961-68 (Woodward 1972).

Woodward 1972

Woodward 1972

Table A#4. (continued)

	July		August		September		October		November		December	
1961	73.9 (68-76)	75.2 (73-76)	75.1 (74-77)	75.3 (72-78)	71.1 (72-79)	74.7 (72-77)	73.3 (64-76)	70.7 (62-74)	68.3 (64-73)	71.1 (67-74)	67.1 (57-70)	65.6 (58-71)
1962	74.7 (70-77)	73.9 (69-76)	75.5 (74-77)	74.5 (70-77)	75.5 (70-78)	75.0 (72-78)	75.3 (72-78)	70.8 (66-74)	69.7 (65-73)	69.8 (66-73)	66.3 (59-72)	63.0 (57-68)
1963	74.5 (68-77)	73.8 (71-76)	73.9 (70-77)	74.8 (69-78)	75.9 (72-78)	76.3 (72-79)	75.0 (70-79)	73.8 (70-78)	72.7 (65-77)	65.9 (56-73)	64.5 (57-72)	64.4 (54-72)
1964	72.5 (71-74)	71.1 (60-74)	71.5 (61-82)	73.0 (70-75)	73.1 (70-76)	71.9 (68-76)	70.6 (60-74)	69.8 (64-73)	68.2 (65-71)	64.1 (60-70)	62.0 (56-69)	57.6 (53-63)
1965	73.5 (71-75)	73.8 (71-75)	75.2 (74-77)	74.1 (71-77)	74.3 (70-77)	70.3 (67-74)	70.9 (67-94)	68.8 (62-72)	67.7 (65-71)	67.1 (60-70)	61.3 (54-68)	56.5 (52-62)
1966	75.6 (73-79)	76.3 (74-78)	75.2 (73-77)	75.4 (74-78)	74.1 (68-79)	72.7 (69-76)	72.5 (66-75)	69.9 (64-77)	65.9 (63-69)	66.7 (61-71)	63.1 (59-69)	65.3 (60-70)
1967	71.9 (67-75)	73.2 (69-75)	74.7 (72-78)	75.0 (73-76)	76.3 (75-78)	72.9 (68-77)	71.7 (68-75)	71.4 (68-75)	71.4 (66-75)	69.5 (62-74)	63.3 (52-72)	62.9 (55-68)
1968	74.8 (69-78)	74.6 (70-77)	77.3 (76-78)	76.4 (71-80)	76.4 (75-80)	74.4 (70-78)	72.3 (67-75)	72.1 (67-75)	66.3 (55-73)	65.5 (51-70)	67.9 (65-70)	61.3 (54-66)

Woodward 197x

Table 5.--Average semi-monthly wind speed and their range (in parentheses) in Beaufort Scale[1/] at Kure Atoll, 1961-68 (Woodward 1972).

	January		February		March		April		May		June	
1961	-	-	-	-	-	2.8 (0-6)	2.9 (0-6)	2.2 (1-4)	2.6 (0-5)	2.6 (0-5)	2.1 (0-3)	2.8 (1-4)
1962	3.5 (0-7)	3.1 (0-7)	2.5 (0-6)	2.7 (1-5)	3.3 (0-6)	3.3 (0-8)	3.3 (1-6)	3.4 (0-6)	2.9 (1-4)	2.4 (0-6)	3.4 (0-5)	1.6 (0-4)
1963	3.6 (1-6)	3.6 (0-7)	4.0 (1-6)	3.2 (0-5)	2.3 (0-4)	3.5 (1-6)	2.7 (0-6)	3.3 (0-5)	2.7 (1-4)	3.2 (1-5)	2.2 (0-4)	2.6 (0-4)
1964	2.5 (0-5)	2.4 (0-5)	2.6 (0-5)	2.8 (0-7)	2.8 (0-6)	3.7 (0-6)	3.3 (1-5)	2.9 (0-5)	1.9 (0-4)	1.5 (0-5)	1.8 (0-5)	2.0 (1-4)
1965	3.2 (0-6)	2.7 (0-5)	2.3 (0-4)	3.6 (1-5)	3.2 (0-6)	3.1 (0-7)	2.8 (0-5)	2.7 (0-6)	2.6 (1-5)	2.6 (0-4)	1.9 (0-5)	2.1 (0-5)
1966	1.6 (0-5)	2.6 (0-7)	2.1 (0-5)	3.4 (0-7)	2.2 (0-5)	2.2 (0-4)	2.3 (0-5)	1.9 (0-5)	2.5 (1-5)	2.2 (1-4)	1.4 (0-5)	1.6 (0-6)
1967	1.9 (1-3)	1.9 (1-3)	2.3 (0-4)	1.6 (0-3)	2.3 (0-4)	1.9 (1-4)	2.6 (1-4)	1.9 (0-4)	2.0 (0-3)	2.2 (1-3)	1.8 (0-3)	2.5 (0-3)
1968	2.4 (0-4)	3.1 (1-5)	3.5 (1-6)	4.0 (2-7)	2.8 (1-5)	2.7 (1-5)	2.9 (1-5)	2.9 (1-5)	2.9 (1-5)	2.2 (1-3)	2.1 (1-4)	1.6 (1-4)

1/ *Beaufort Scale: 0 = 1 knot, 1 = 1-3 knots, 2 = 4-7 knots, 3 = 8-12 knots, 4 = 13-18 knots, 5 = 19-24 knots, 6 = 25-31 knots, 7 = 32-38 knots, 8 = 39-46 knots

Table ~~C-2~~ 5. (continued)

	July		August		September		October		November		December	
1961	1.8 (0-3)	2.6 (0-6)	2.6 (0-5)	2.0 (0-5)	2.3 (0-5)	2.4 (0-5)	2.6 (1-5)	3.6 (1-6)	2.4 (0-5)	2.9 (1-5)	2.9 (0-6)	3.7 (0-5)
1962	3.0 (1-7)	2.6 (0-6)	2.8 (1-5)	1.6 (0-5)	2.1 (0-4)	2.3 (0-8)	2.9 (1-5)	3.0 (0-5)	2.2 (0-5)	3.0 (1-5)	3.6 (0-7)	2.6 (0-5)
1963	2.7 (1-4)	3.4 (1-5)	3.3 (1-8)	1.9 (0-6)	2.0 (0-6)	3.0 (1-7)	2.7 (1-6)	3.5 (1-6)	2.8 (0-6)	3.0 (0-7)	3.1 (0-6)	3.2 (0-6)
1964	2.9 (1-6)	2.8 (1-6)	3.0 (1-5)	2.1 (0-4)	2.5 (1-6)	2.3 (0-5)	2.0 (0-4)	3.2 (2-7)	3.1 (1-5)	2.9 (1-6)	2.7 (0-4)	4.0 (0-9)
1965	2.2 (0-4)	3.1 (1-6)	2.7 (1-4)	2.1 (0-4)	2.2 (0-4)	2.9 (0-6)	1.8 (0-5)	2.2 (0-5)	2.6 (0-4)	3.0 (0-5)	2.0 (0-8)	2.2 (0-5)
1966	1.9 (0-6)	2.4 (1-5)	2.8 (0-5)	2.3 (1-5)	2.3 (0-5)	2.0 (0-8)	3.0 (1-6)	2.1 (0-4)	2.3 (0-5)	2.2 (0-4)	2.2 (0-8)	2.0 (1-4)
1967	1.8 (0-3)	2.0 (0-3)	2.1 (0-3)	2.2 (1-3)	2.2 (0-3)	1.7 (0-4)	1.5 (0-3)	1.6 (0-3)	2.1 (1-5)	2.3 (1-4)	2.5 (0-5)	2.5 (0-5)
1968	2.5 (1-3)	2.7 (1-4)	2.4 (0-3)	2.3 (0-5)	2.2 (0-4)	2.3 (0-5)	3.1 (1-5)	2.2 (0-4)	2.6 (1-5)	2.9 (1-5)	3.6 (1-6)	3.0 (1-7)

Woodward 1972
Table 6

Table 6.—Semi-monthly rainfall (in) at Midway Atoll, 1963-68 (Woodward 1972).

	January		February		March		April		May		June	
1963	3.2	3.5	1.5	1.7	3.9	9.3	2.8	0.5	1.4	0.1	0.1	1.4
1964	1.2	3.5	1.8	0.5	6.8	2.4	1.9	0.2	3.0	0.1	1.3	0.9
1965	1.3	1.2	2.0	1.5	2.0	1.1	0.1	2.1	0.2	0.1	1.8	3.7
1966	0.8	1.6	0.5	0.4	1.1	0.6	0.8	0.1	1.3	1.2	0.1	0.7
1967	0.7	2.2	3.1	5.0	1.7	0.5	0.5	1.8	0.7	0.4	3.0	0.1
1968	2.7	3.6	3.9	0.6	0.1	0.1	1.0	0.1	0.7	1.8	1.7	0.8

	July		August		September		October		November		December	
1963	1.3	5.3	2.7	0.3	0.4	2.7	3.8	2.4	9.2	1.7	1.6	0.4
1964	0.7	1.9	0.8	0.4	0.3	0.8	1.4	4.7	7.0	2.1	1.7	3.9
1965	0.3	1.0	0.2	1.3	1.3	2.2	0.2	0.6	0.8	3.2	0.5	3.4
1966	0.3	1.9	0.8	0.9	4.4	0.1	7.4	1.3	1.4	1.3	0.9	0.5
1967	5.9	7.4	6.5	0.3	0.9	1.0	1.3	0.3	7.0	3.3	2.8	2.0
1968	0.3	1.6	0.5	6.7	3.1	2.3	0.9	0.5	1.1	2.8	6.0	11.9

Locality	Period	Number of days		Yellowfin		Skipjack		Mixed 1/		Unidentified		Total fish schools		Bird flocks	
		Fishing and scouting	Running	Number	Number per day	Number	Number per day	Number	Number per day	Number	Number per day	Number	Number per day	Number	Number per day
Hawaiian Is.	Mar.-May	0	9	0	0.0	7	0.8	0	0.0	7	0.8	14	1.6	18	2.0
	June-Aug.	33	15	4	0.1	81	1.7	0	0.0	20	0.4	105	2.2	100	2.1
	Sept.-Nov.	4	31	0	0.0	17	0.5	0	0.0	21	0.6	38	1.1	47	1.3
	Dec.-Feb.	0	4	1	0.2	1	0.2	0	0.0	1	0.2	3	0.8	3	0.8
Leeward Is.	Mar.-May	1	4	1	0.2	3	0.6	0	0.0	25	5.0	29	5.8	47	9.4

Table 7a.--Summary of island observations on fish schools and bird flocks (Murphy and Ikehara 1955).

1/ Yellowfin and skipjack.

Locality	Period	Number of days		Yellowfin		Skipjack		Unidentified		Total fish schools		Bird flocks		Number of birds 2/	
		Fishing and scouting	Running	Number	Number per day	Number	Number per day	Number	Number per day	Number	Number per day	Number	Number per day	Number	Number per day
Hawaiian Is.	Mar.-May	0	10	0	0.0	3	0.3	5	0.5	8	0.8	12	1.2	558	55.8
	June-Aug.	1	8	0	0.0	4	0.4	10	1.1	14	1.6	19	2.1	1212	134.7
	Sept.-Nov.	0	16	0	0.0	10	0.6	7	0.4	17	1.1	16	1.0	1283	80.2
	Dec.-Feb.	0	7	0	0.0	1	0.1	1	0.1	2	0.3	3	0.4	144	20.6
Leeward Is.	Mar.-May	0	2	0	0.0	2	1.0	1	0.5	3	1.5	3	1.5	85	42.5

Table 7b.--Summary of semioceanic 1/ observations associated with particular island groups (Murphy and Ikehara 1955).

1/ Semi-oceanic observations were considered to be from 60 to 180 miles from the islands.
2/ Includes scattered birds.

Local name	Common name	Scientific name	NIHOA 1971	1972	1973	1974	1975	HANDLIN[E] 1966	1967	1968
Aku	Skipjack tuna	Katsuwonus pelamis								
Ahi	Yellowfin tuna	Thunnus albacares	–	–	–	–	–	–	–	
Kawakawa	Little tuna	Euthynnus affinis	6	230	–	82	36	28	93	7[illegible]
A'u	Pacific blue marlin	Makaira nigricans	–	–	–	–	–	15	117	
Mahimahi	Dolphin fish	Coryphaena hippurus	–	–	–	–	–	–	–	
Ono	Wahoo	Acanthocybium solandri	6	6	–	–	4	51	269	
Hapuupuu	Sea bass	Epinephelus quernus	675	604	–	–	–	–	944	3[illegible]
Kahala	Amberjack	Seriola dumerilii	1,950	388	219	1,966	393	8,239	6,461	4,4[illegible]
Kalikali	Pink snapper	Pristipomoides sieboldii	340	93	86	103	–	3,834	992	1,3[illegible]
Omilu	Blue crevally	Caranx melampygus	13	30	8	169	109	8	18	1[illegible]
Opakapaka	Pink snapper	Pristipomoides microlepis	22	–	–	–	–	–	–	
Uku	Gray snapper	Aprion virescens	37	11	24	83	54	2,126	1,449	4[illegible]
Ulaula (Ehu)	Red snapper	Etelis marshi	28	136	62	771	–	122	40	8[illegible]
Ulaula koae (Onaga)	Red snapper	Etelis carbunculus	77	390	67	484	269	111	200	4[illegible]
Ulua	Jack crevally	Carangidae	12	–	29	97	58	1,763	1	1[illegible]
Weke ula	Red goatfish	Mulloidichthys auriflamma	57	6	45	210	99	5,680	5,609	8,31[illegible]
Aawa	Spot wrasse	Bodianus bilunulatus	–	–	–	–	–	3	–	
Alaihi	Squirrel fish	Holocentridae	–	–	–	–	–	6	–	
Aweoweo	Red bigeye	Priacanthus cruentatus	–	–	–	–	–	2	–	
Kaku	Barracuda	Sphyraena barracuda	–	–	–	–	–	16	–	
Kamanu	Hawaiian salmon	Elegatus bipinnulatus	–	–	–	–	–	–	–	
Kawalea	Japanese barracuda	Sphyraena helleri	–	–	–	–	–	–	29	
Kumu	Red goatfish	Parupeneus porphyreus	–	–	–	–	–	–	54	
Moano	Common scorpion	Scorpaenopsis gibbosa	–	–	–	–	–	1	–	
Oio	Bonefish	Albula vulpes	–	–	–	3	–	6	10	
Opelu	Mackerel scad	Decapterus pinnulatus	–	–	–	–	–	–	–	
Ukikiki	Snapper	Rooseveltia brighami	–	–	–	–	–	–	–	
Upapalu	Cardinal fish	Apogon snyderi	12	12	29	–	–	3	22	5[illegible]
Uu	Squirrel fish	Myripristis berndti	–	–	–	–	–	4	–	
Uluaki	Thread crevally	Alectis ciliaris & A. indica	–	–	–	–	–	–	–	
Miscellaneous			–	–	–	–	–	–	–	
			–	–	–	–	–	–	–	
TOTAL CATCH			3,235	1,906	569	3,968	1,022	22,018	16,303	16,32[illegible]
VALUE			$4,628	$3,276	$1,356	$8,359	$1,918	$18,342	$14,809	$14,98[illegible]

Table 8.—Catches of Hawaiian deep-sea fishing vessels made in waters around Nihoa and Necker Islands, by species and type of gear, and the value of the catch, 1966–75 (data are from catch reports of the Hawaii Division of Fish and Game).

				HANDLINE CATCH (KG)										TROLL CATCH (KG)			
…HOA				NECKER										NIHOA			NECKER
…2	1973	1974	1975	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1967	1974	1975	1975
–	–	–	–	–	–	–	–	–	–	38	–	–	–	–	–	562	68
…30	–	82	36	28	93	742	–	80	1,035	836	373	723	944	–	342	5,525	338
–	–	–	–	15	117	79	–	3	40	80	146	208		–	164	703	544
–	–	–	–	–	–	–	–	–	–	–	–	–		142	–	–	–
…6	–	–	4	51	269	–	11	93	234	155	334	235	109	–	–	24	14
…04	–	–	–	–	944	357	180	300	298	2,107	1,905	347	20	–	561	363	363
…28	219	1,966	393	8,239	6,461	4,467	1,319	12,166	13,846	7,742	16,526	7,362	9,435	–	–	–	–
…73	86	103	–	3,834	992	1,375	613	5,809	2,011	2,102	3,548	968	1,726	–	–	–	–
…0	8	169	109	8	18	12	9	347	171	371	623	262	55	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–
…11	24	83	54	2,126	1,449	412	394	1,441	2,702	337	560	1,601	6,208	–	–	–	–
…66	62	771	–	122	40	84	18	831	106	1,747	995	1,363	103	–	–	–	–
…20	67	484	269	111	200	409	54	1,508	1,846	4,095	2,524	2,141	557	–	–	–	–
–	29	97	58	1,763	1	11	–	135	308	491	1,268	649	21	–	–	–	–
…6	45	210	99	5,680	5,609	8,317	15,649	10,993	10,087	1,094	947	3,958	7,805	40	–	–	–
–	–	–	–	3	–	–	–	7	4	10	5	21	19	–	–	–	–
–	–	–	–	6	–	–	–	10	–	6	–	–	–	–	–	–	–
–	–	–	–	2	–	–	–		–	–	–	–	–	–	–	–	–
–	–	–	–	16	–	6	–		–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–		–	10	–	5	–	–	–	–	–
–	–	–	–	–	24	–	91	18	36	–	–	–	–	–	–	–	–
–	–	–	–	–	54	–	–		–	–	–	–	–	–	–	–	–
–	–	–	–	1	–	–	–		1	–	–	–	–	–	–	–	–
–	–	3	–	6	10	–	–	14	42	9	7	–	–	–	–	–	–
–	–	–	–	–	–	–	–		–	–	–	106	–	–	–	–	–
–	–	–	–	–	–	–	–		14	9	–	–	–	–	–	–	–
…2	29	–	–	3	22	53	20	375	502	261	426	106	3	–	–	–	–
–	–	–	–	4	–	–	–		–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–		–	1	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–		–	–	11	–	–	–	–	–	–
–	–	–	–	–	–	2	–	14	7	7	–	4	210	–	–	–	23
…06	569	3,968	1,022	22,018	16,303	16,326	18,358	34,148	33,290	21,508	30,198	20,059	27,212	182	1,067	7,177	1,350
…76	$1,356	$8,359	$1,918	$18,342	$14,809	$14,983	$15,007	$39,542	$48,220	$43,009	$64,627	$43,948	$62,974	$120	$970	$4,589	$955

Month	Total hours trolled	Average number of lines fished	SJ	YF	KK	AL	SD	BE	Total tuna	MA	WA	Others	Catch/line-hour Tuna	Catch/line-hour MA
January	30.3	3.25	2	0	0	2	0	0	4	1	0	0	0.041	0.010
February	47.5	4.50	6	3	0	2	1	0	12	0	0	0	0.056	0.000
March	4.1	6.00	0	0	0	4	0	0	4	1	0	0	0.163	0.007
April	190.1	3.06	2	1	10	3	0	0	16	23	1	1	0.028	0.040
May	182.3	4.19	6	14	14	3	0	0	37	24	2	1	0.048	0.031
June	104.9	4.18	1	3	9	0	0	0	13	24	0	0	0.030	0.055
July	239.9	2.77	7	9	19	0	0	1	36	32	4	0	0.054	0.048
August	65.0	4.83	10	11	0	0	0	0	21	14	0	0	0.067	0.044
September	24.0	8.00	0	0	0	0	0	0	0	3	0	0	0.000	0.016
October	39.2	2.00	0	1	5	0	0	0	6	2	0	0	0.076	0.026
November	74.3	2.71	5	1	0	0	0	0	6	7	2	2	0.030	0.035
December	21.3	5.50	0	0	6	0	0	0	6	3	1	0	0.051	0.026

Table 9.--Catches and catch rates of tunas and tuna-like fishes by trolling gear during exploratory surveys of research vessels operating in and around NWHI waters, 1954-64. SJ - Skipjack; YF - Yellowfin; KK - Kawakawa; AL - Albacore; SD - *Sarda* sp.; BE - Bigeye; MA - Mahimahi; and WA - Wahoo.

Table 10.—Percentages of the North Pacific longline fishing effort and catches, by species, of Japanese vessels made in the NWHI region, 1964-73.

Year	North Pacific Ocean (NPO) Hooks 10^3 [1]	NWHI Region Hooks 10^3	%	Bluefin NPO No. 10^3	Bluefin NWHI No.	Bluefin %	Albacore NPO No. 10^3	Albacore NWHI No.	Albacore %	Bigeye NPO No. 10^3	Bigeye NWHI No.	Bigeye %	Yellowfin NPO No. 10^3	Yellowfin NWHI No.	Yellowfin %	Broadbill NPO No. 10^3	Broadbill NWHI No.
1964	139,893	3,759	2.7	20 [3]	37	0.2	927	3,105	0.3	857	15,282	1.8	517	8,730	1.7	111	1,58[illegible]
65	152,942	3,079	2.0	16 [3]	19	0.1	801	1,846	0.2	713	7,443	1.0	646	6,815	1.0	147	74[illegible]
66	149,691	937	0.6	8	0	0.0	1,491	1,780	0.1	979	4,927	0.5	586	1,955	0.2	172	28[illegible]
67	192,960	1,696	0.8	6	0	0.0	1,741	3,826	0.2	797	6,313	0.8	539	2,975	0.6	194	61[illegible]
68	165,372	3,639	2.2	4	1	0.0	1,360	14,370	1.0	736	13,399	1.8	428	5,398	1.2	158	2,47[illegible]
69	168,750	2,259	1.3	3	6	0.2	1,017	12,386	1.2	915	22,026	2.4	598	3,418	0.6	148	1,08[illegible]
70	162,674	5,449	3.3	2	5	0.2	786	13,252	1.7	806	28,709	3.6	837	19,609	2.3	108	1,91[illegible]
71	139,680	3,176	2.3	2	5	0.2	528	12,187	2.3	701	18,887	2.7	402	11,259	2.8	107	70[illegible]
72	124,571	3,378	2.7	1	2	0.2	559	18,667	3.3	827	29,822	3.6	411	5,999	1.4	92	1,51[illegible]
73	134,997	3,211	2.4	1	8	0.8	667	23,806	3.6	745	21,991	3.0	454	4,246	0.9	99	83[illegible]
Σ	1,531,530	30,583	x̄ 2.0						1.8								

[1] Data for hooks fished in the North Pacific are from Japan Fisheries Agency (1973).
[2] Data for 1964-73 are from Japan Fisheries Agency 1967a, 1967b, 1968, 1969, 1970, 1971, 1972, 1973, 1974a, and 1975
[3] Include southern bluefin.

Yellowfin NPO			Broadbill NPO			Striped Marlin NPO			Blue NPO	Marlin		Black NPO	Marlin		Sailfish & NPO	Shortbill		Skipjack NPO		
NPO No. 10^3	NWHI No.	%	NPO No. 10^3	NWHI No.	%	NPO No. 10^3	NWHI No.	%	NPO No. 10^3	NWHI No.	%	NPO No. 10^3	NWHI No.	%	NPO No. 10^3	NWHI No.	%	NPO No. 10^3	NWHI No.	%
517	8,730	1.7	111	1,581	1.4	210	27,159	12.9	105	3,368	3.2	6	320	5.3	35	2902	8.3	13	276	2.1
646	6,815	1.0	147	744	0.5	156	37309	23.9	83	3,760	4.5	12	102	0.8	41	2,260	5.5	30	1,920	6.9
586	1,255	0.2	172	287	0.2	98	5,426	5.5	74	506	0.7	7	42	0.6	35	256	0.7	23	979	4.2
539	2,975	0.6	194	618	0.3	159	17,819	11.2	79	1,255	1.6	6	23	0.4	41	710	1.7	23	377	1.6
428	5,348	1.2	158	2,471	1.6	154	27,551	17.9	62	1,898	3.1	3	42	1.4	33	2568	7.8	20	675	3.3
598	3,418	0.6	148	1,083	2.2	101	5,716	5.6	72	302	0.4	5	12	0.2	23	238	1.0	22	278	1.3
837	19,609	2.3	108	1,418	1.3	242	37,942	15.7	122	5,536	4.5	4	66	1.6	41	4,816	11.7	47	865	1.8
402	11,259	2.8	107	705	0.6	130	9,693	7.4	59	935	1.6	4	70	1.8	20	499	2.5	15	347	2.3
411	5,994	1.4	92	1,514	1.6	70	5,381	7.7	57	768	1.3	4	36	0.9	18	479	2.7	13	284	2.2
454	4,246	0.9	99	839	0.8	100	4,797	4.8	69	351	0.5	3	30	1.0	31	777	2.5	13	217	1.7

1973, 1974a, and 1975

le 11.--Fishes, macro-invertebrates, algae and bottom substrates sampled (S) and observed (O) during surveys at Nihoa, Necker, French Frigate Shoals and Laysan Island (Narrative Report, Townsend Cromwell, cruise 76-04-71, May3-June 9, 1976).

SHES:

Common Name	FAMILY NAME Scientific Name	Nihoa Island	French Frigate Shoals	Laysan Island	Necker Island
ARKS	CARCARHINIDAE				
ark	(Unidentified species)	S	O	S,O	O
ger shark	Galeocerdo cuvieri	-	O	S	-
YS	MYLIOBATIDAE				
himanu	Aetobatus narinari	-	O	O	-
YS	MOBULIDAE				
lalua	(Unidentified species)	O	-	-	-
ZARDFISHES	SYNODONTIDAE				
lae	Synodus variegatus	-	-	O	-
ITFISHES	DUSSUMIERIIDAE				
ha	Spratelloides delicatulus	-	O	O	-
UIRRELFISHES	HOLOCENTRIDAE				
la'ihi	Adioryx spinifer (=Holocentrus spinifer)	-	O	-	-
la'ihi	A. xantherythrus (=H. xantherythrus)	S	-	O	-
la'ihi	Flammeo sammara (=H. sammara)	-	O	-	-
'u	Myripristis amaenus (=M. argyromus)	-	-	O	-
RRACUDAS	SPHYRAENIDAE				
walea	Sphyraena helleri	S	-	-	-
EDLEFISHES	BELONIDAE				
ha'aha	Strongylura gigantea	S, O	S, O	-	O
LFBEAKS	HEMIRAMPHIDAE				
eihe	(Unidentified species)	-	O	-	-
READFINS	POLYNEMIDAE				

Table 12.--Ten species of fish observed during underwater fishcounting transects, ranked by estimated densities and number of individuals counted (Narrative Report, Townsend Cromwell, cruise 76-04-71, May 3-June 9, 1976).

timated Densities:

nk	Common Name	Scientific Name	Density Pounds/ Acre	Occurrenc (No. Static
	Weke-'a'a	Mulloidichthys samoensis	1,969	3
	Uhu uliuli	Scarus perspicillatus	1,948	3
	White ulua	Carangoides ajax	1,022	1
	Nenue	Kyphosus cinerascens	559	4
	Kala	Naso unicornis	384	4
	Manini	Acanthurus triostegus (=A. sandvicensis)	375	4
	Hinalea	Thalassoma purpureum (=T. fuscum and T. umbrostigma)	152	3
	'Omilu	Caranx melampygus	128	3
	Hinalea luahine	Thalassoma ballieui	85	4
	White banded maiko	Acanthurus leucopareius	81	4

mber of Individuals:

nk	Common Name	Scientific Name	Density Pounds/ Acre	Occurre (No Station
	Piha	Spratelloides delicatulus	50,000	2
	Weke-'a'a	Mulloidichthys samoensis	1,006	3
	Manini	Acanthurus triostegus (=A. sandvicensis)	239	4
	Nenue	Kyphosus cinerascens	222	4
	Uhu uliuli	Scarus perspicillatus	180	3
	Kole	Ctenochaetus strigosus	108	4
	Hinalea lau-wili	Thalassoma duperreyi	105	3
	Blue damselfish	Chromis ovalis	100	1
	Kala	Naso unicornis	98	4
	'Omaka	Stethojulis balteata (=S. axillaris and S. albovittata)	75	2

ACRO-INVERTEBRATES:

Common Name	FAMILY NAME Scientific Name	Nihoa Island	French Frigate Shoals	Laysan Island	Necker Island
PINY LOBSTER la	PANULIURIDAE Panalirus marginatus (=P. Japonicus)	-	O	-	-
OCK CRAB A'ama	GRAPSIDAE Grapsus grapsus	O	-	O	S, O
HOST CRAB O-hi-ki	OCYPODIDAE Ocypode ceratophthalma	-	O	O	-
QUILLA Alo'alo	SQUILIIDAE Squilla oratoria	O	O	-	-
RINE SHRIMP rine shrimp	--- Artemia sp.	-	-	O	-
ARNACLES arnicle	BALANIDAE Balanus sp.	-	-	O	-
OOSE NECK BARNACLES oose neck barnicle	LEPADIDAE Lepas sp.	-	O	O	-
OWRY owry	CYPRAEIDAE Cypraea spp.	-	-	-	S
EA SNAILS ipihi	NERITIDAE Nerita spp.	S, O	-	O	S, O
IMPETS pihi	PATELLIDAE Patella spp.	S, O	-	-	S, O
OCK SHELLS ock shell	MURICIDAE Purpura spp.	S, O	-	-	S, O
ERIWINKLES eriwinkle	LITTORINIDAE Littorina spp.	O	-	O	O
URBINE SHELL at-eye shell	TURBINIDAE Turbo intercostalis	-	-	O	O

Common Name	FAMILY NAME Scientific Name	Nihoa Island	French Frigate Shoals	Laysan Island	Necker Island
OORISH IDOLS	ZANCLIDAE				
ihikihi	Zanclus canescens	O	O	O	O
URGEONFISHES	ACANTHURIDAE				
anini	Acanthurus triostegus (=A. sandvicensis)	O	O	S, O	O
urf maiko	A. guttatus	O	-	-	-
aikoiko	A. leucopareius	O	O	O	-
aiko	A. nigroris	O	O	S, O	-
alani	A. dussumieri	O	-	-	-
ualu	A. xanthopterus	O	-	-	-
ualu	A. mata	O	O	-	-
ole	Ctenochaetus strigosus	O	O	O	-
au'i-pala	Zebrasoma flavescens	O	-	O	-
ala	Naso lituratus	O	-	O	-
ala	N. unicornis	O	O	O	-
RIGGERFISHES	BALISTIDAE				
umuhumu-'ele'ele	Melichthys niger (=M. buniva)	S, O	O	-	-
umuhumu-uli	M. vidua (=M. nycteris)	S, O	-	-	-
umuhumu-umauma-lei	Sufflamen bursa (=Balistes bursa)	O	-	-	-
umuhumu-mimi	S. frenatus (=Balistes capistratus)	S	-	-	-
HARPBACKED PUFFERS	CANTHIGASTERIDAE				
potted puffer	Canthigaster jactator	-	O	O	-
LENNIES	BLENNIDAE				
ao'o	Istibelnnis zebra	O	-	O	O
LEOTRIDS	ELEOTRIDAE				
lcotrid	(Unidentified species)	-	-	-	O
UNA	SCOMBRIDAE				
awakawa	Euthynnus yaito	S	-	S	-

Common Name	FAMILY NAME Scientific Name	Nihoa Island	French Frigate Shoals	Laysan Island	Necker Island
ANGEL FISHES	POMACANTHIDAE				
Black banded angelfish	Holacanthus arcuatus	O	-	-	-
DAMSELFISHES	POMACENTRIDAE				
Kupipi	Abudefduf sordidus	O	-	O	O
Maomao	A. abdomilais	-	O	S, O	-
Damselfish	A. imparipennis	O	-	-	-
Damselfish	Pomacentrus jenkinsi	O	O	O	-
Blue damselfish	Chromis ovalis	O	-	-	-
HAWKFISHES	CIRRHITIDAE				
Po'o-pa'a	Cirrhitus pinnulatus (=C. alternatus)	-	O	-	-
WRASSES	LABRIDAE				
'A'awa	Bodianus bilunulatus	S, O	S, O	S	-
Cleaner wrasse	Labroides phthirophagus	-	O	O	-
Po'ou	Cheilinus rhodochrous	S	S	-	-
Wrasse	Hemipteronotus taeniourus (=Novaculichthys taeniourus)	-	-	O	-
Lae-nihi	H. umbrilatus	-	-	O	-
Hinalea lau-wili	Thalassoma duperreyi	-	O	O	-
Hinalea luahine	T. ballieui	S, O	S, O	S, O	S, O
Wrasse	T. purpureum (=T. umbrostigma and T. fuscum)	S	O	S, O	O
Hinalea i'iwi	Gomphosus varius	-	O	O	-
Hilu	Coris flavovittata	O	O	O	-
'Omaka	Stethojulis balteata (=S. axillaris and S. albovittata)	-	O	O	-
Hinalea 'aki-lolo	Macropharyngodon goeffroyi	-	O	-	-
'Opule	Anampses cuvieri (=A. godefforyi)	-	-	O	-
PARROT FISHES	SCARIDAE				
Uhu	Calotomus spinidens (=C. sandvicensis)	-	O	-	-
Uhu	Scarus dubius	O	O	-	-
Uhu uliuli	S. perspicillatus	-	O	S, O	-
Uhu	S. sordidus	-	-	O	-

Common Name	FAMILY NAME Scientific Name	Nihoa Island	French Frigate Shoals	Laysan Island	Necker Island
RED BIG EYE	PRIACANTHIDAE				
'Aweoweo	Priacenthus cruentatus	-	S, O	-	-
KUHLIIDS	KUHLIIDAE				
Aholehole	Kuhlia sandvicensis	O	S	S, O	O
MULLETS	MUGILIDAE				
Uouoa	Neomyxus chaptalii	-	S	S	-
'Ama'ama	Mugil cephalus	-	S	-	-
JACKS	CARANGIDAE				
'Opelu	Decapterus pinnulatus	-	S	-	-
Akule	Trachurops crumenophthalmus	-	S	-	-
White ulua	Carangoides ajax	-	S, O	S	-
Papa ulua	C. ferdau	S, O	S, O	O	-
'Omilu	Caranx melampygus	-	S, O	S, O	S
SNAPPERS	LUTJANIDAE				
Gurutsu	Aphareus furcatus	S	-	-	-
GOATFISHES	MULLIDAE				
Weke'a'a	Mulloidichthys samoensis	-	S, O	O	-
Malu	Parupeneus pleurostigma	-	O	O	-
Moano koa	P. chrysorydros	-	-	O	-
Kumu	P. porphyreus	-	O	-	-
Moano	P. multifasciatus	O	S, O	O	-
RUDDERFISHES	KYPHOSIDAE				
Nenue	Kyphosus cinerascens	S, O	S, O	S, O	S,
BUTTERFLYFISHES	CHAETODONTIDAE				
Blue striped butterflyfish	Chaetodon fremblii	-	O	O	-
Cross striped butterflyfish	C. auriga	-	O	-	-
Tear drop butterflyfish	C. unimaculatus	-	-	O	-
Orange striped butterflyfish	C. ornatissimus	O	-	-	-
Butterflyfish	C. miliaris	-	O	O	-

Table 13.--Number of fish species observed, estimated densities, and major fish species ranked by density at Nihoa Island, French Frigate Shoals, and Laysan Island (Cruise Report, *Townsend Cromwell*, cruise 76-04-71, May 3-June 9, 1976).

Location	No. of fish species	Estimated densities (lb/acre)	Major fish species ranked in terms of greatest densities
Nihoa Island	26	147.61	1. *Chromas ovalis* 2. *Ctenochaetus strigosus* 3. *Naso lituratus*
French Frigate Shoals			
East Island	29	1,979.89	1. *Scarus perspicillatus* 2. *Kyphosus cinerascens* 3. *Mulloidichthys samoensis*
Whale-Skate Island	32	4,232.31	1. *Mulloidichthys samoensis* 2. *Carangoides ajax* 3. *Scarus perspicillatus*
Laysan Island	34	756.95	1. *Scarus perspicillatus* 2. *Acanthurus triostegus* (= *A. sandvicensis*) 3. *Thalassoma purpureum* (= *T. umbrostigma* and *T. fuscum*)

Table 14.--Fishing and size information of alphonsins and armorheads taken at Kammu and Hancock Seamounts R/V *Kaiyo Maru* during the North Pacific seamount surveys in 1972 (Japan Fisheries Agency 1974b).

種名 Species	調査海山 Location	水深 (m) Depth (m)	網次番号 Trawl No.	測定尾数 No. measured	標本体長範囲 (FL・mm) Size range (mm)	平均体長 (mm) Average length (mm)	平均体重 (g) Average weight (gm)
キンメダイ	カンム	355	T 2	40	124 — 281	199	189
〃	〃	350	T 3	12	179 — 228	191	151
〃	〃	335	T 10	40	156 — 305	230	310
〃	〃	380	T 11	2	249 — 298	274	547
〃	〃	383	T 12	170	161 — 220	186	150
〃	〃	370	T 13	40	176 — 234	203	193
〃	ハンコック南東	265	T 6	9	232 — 336	271	428
クサカリツボダイ	カンム	355	T 2	88	246 — 300	273	339
〃	〃	350	T 3	32	246 — 311	274	338
〃	〃	355	T 8	3	262 — 297	275	453
〃	〃	365	T 9	91	244 — 320	273	347
〃	〃	335	T 10	40	252 — 302	273	348
〃	〃	380	T 11	7	249 — 276	267	318
〃	〃	383	T 12	87	262 — 325	289	382
〃	〃	370	T 13	91	249 — 307	273	348
〃	ハンコック南東	270	T 5	107	246 — 313	275	356
〃	〃	265	T 6	110	233 — 320	271	322
〃	〃	265	T 7	104	238 — 311	270	320
~~クサカリツボダイ~~	~~ハンコック南東~~	265	T 3	271	229 — 325	272	304
〃	〃	265	T 4	124	240 — 325	272	309
〃	〃	265	T 8	240	240 — 310	272	323
〃	〃	265	T 9	154	229 — 316	268	291
〃	〃	265	T 10	191	242 — 305	271	333
〃	〃	270	T 11	133	244 — 310	272	332
〃	〃	265	T 25	94	225 — 308	271	324
〃	〃	265	T 26	119	240 — 383	277	346
〃	~~ハンコック北西~~	267	T 5	210	238 — 310	274	348
〃	〃	290	T 7	163	210 — 313	273	336
〃	〃	263	T 27	51	240 — 304	271	326
〃	〃	270	T 28	2	273 — 273	273	350

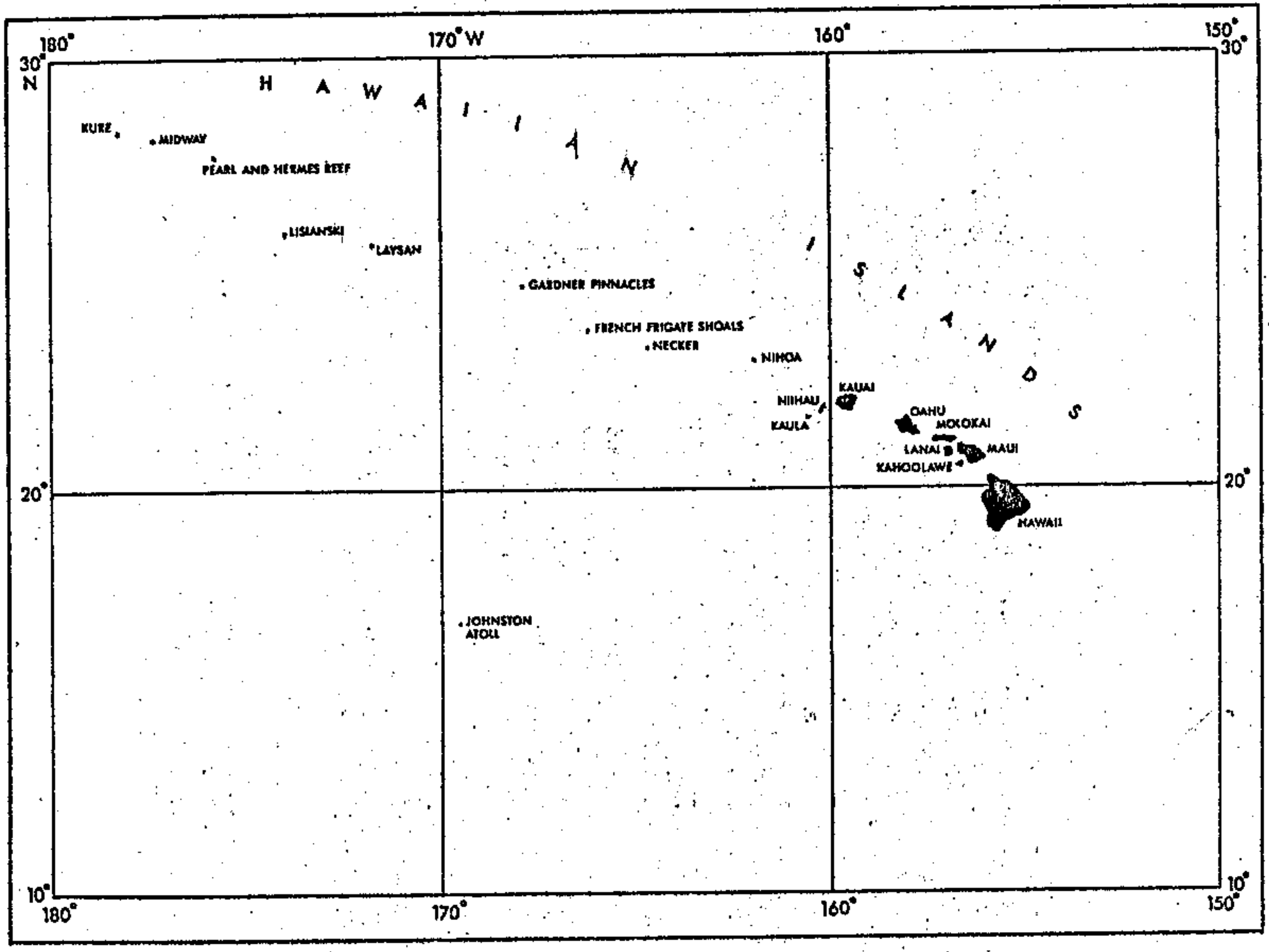


Figure 1d. The Hawaiian Islands.

Carlquist 1970
Fig. 1b

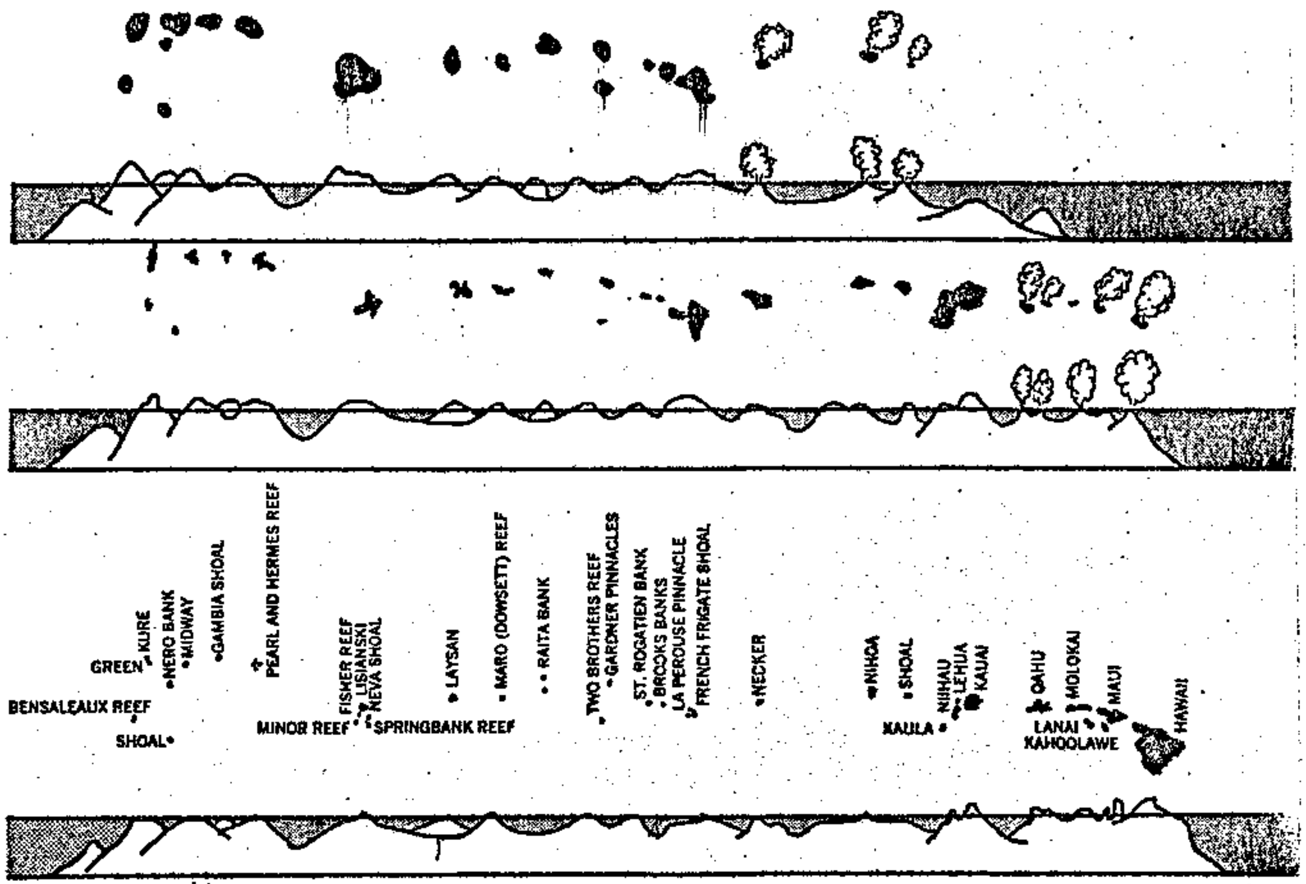


Figure 1b--Three stages of island building in the Hawaiian chain. The first stage represents how the chain might have looked about ten million years ago, the second perhaps five million years ago or less, and the third is the present-day Hawaiian chain (Carlquist 1970).

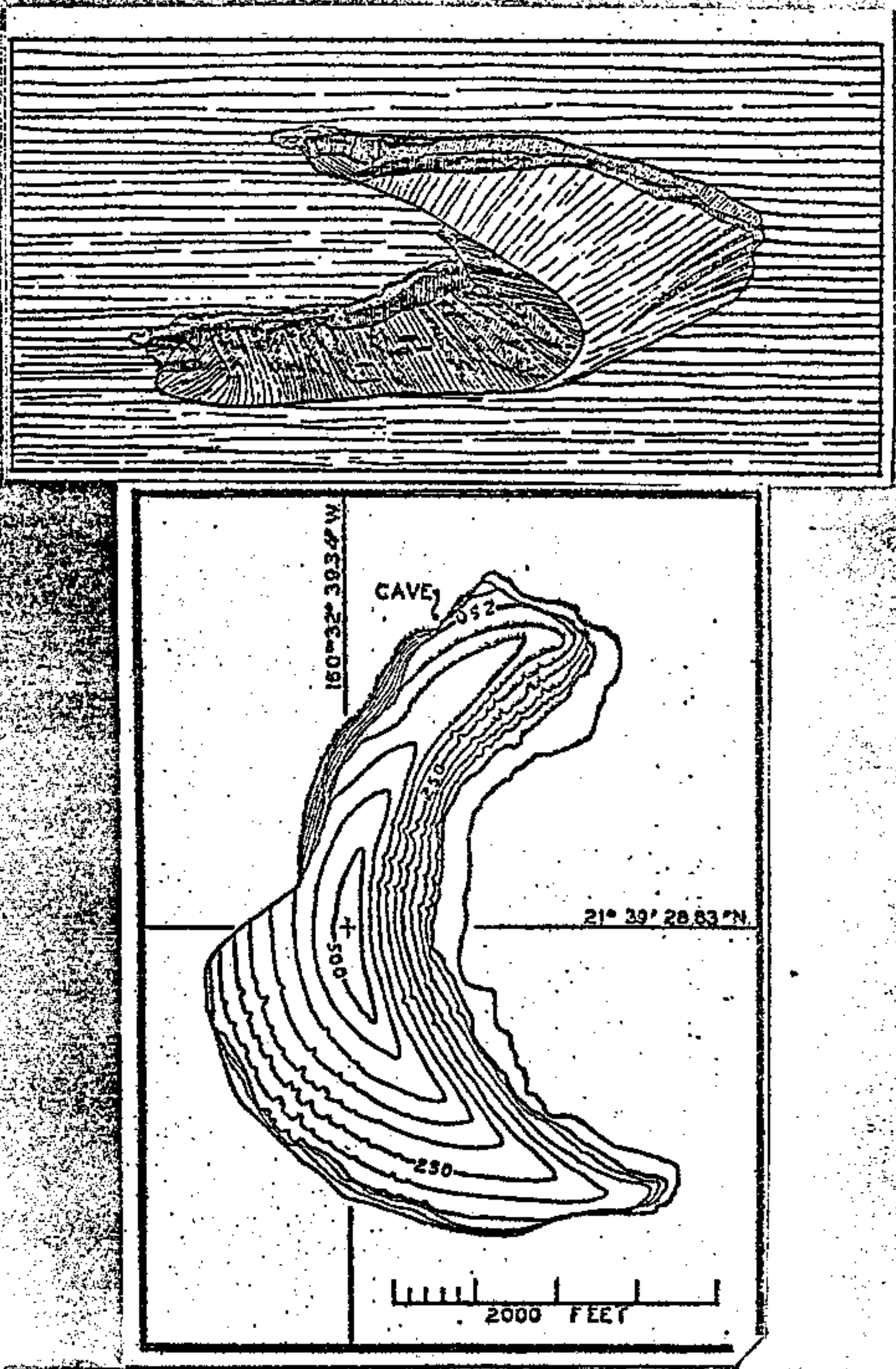


Figure 2.—Kaula Island (Bryan 1942).

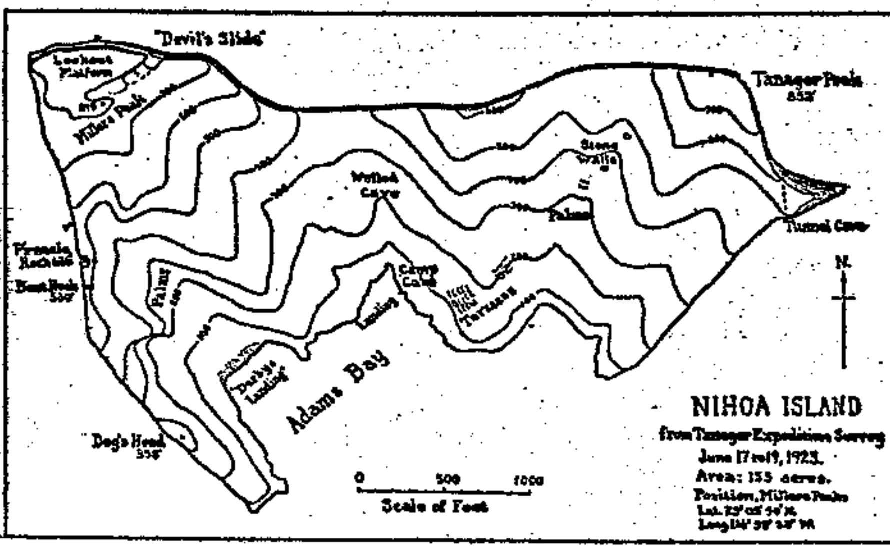


Figure 3.--Nihoa Island (Bryan 1942).

Bryan 1942

Fig. 4

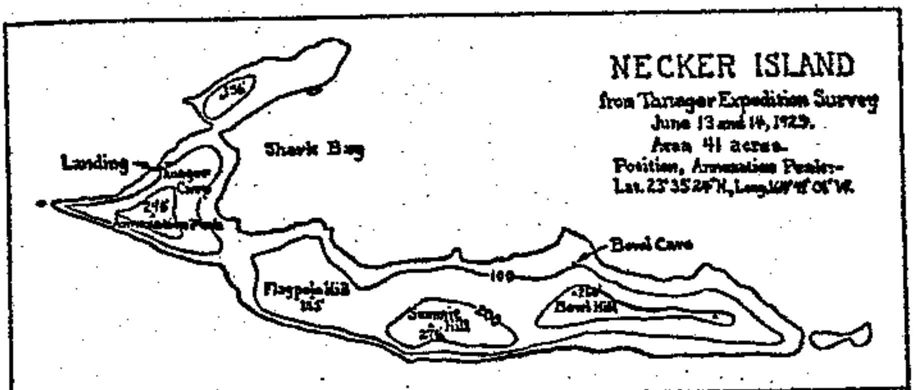


Figure 4.6—Necker Island (Bryan 1942).

Amerson 197
Fig. 5

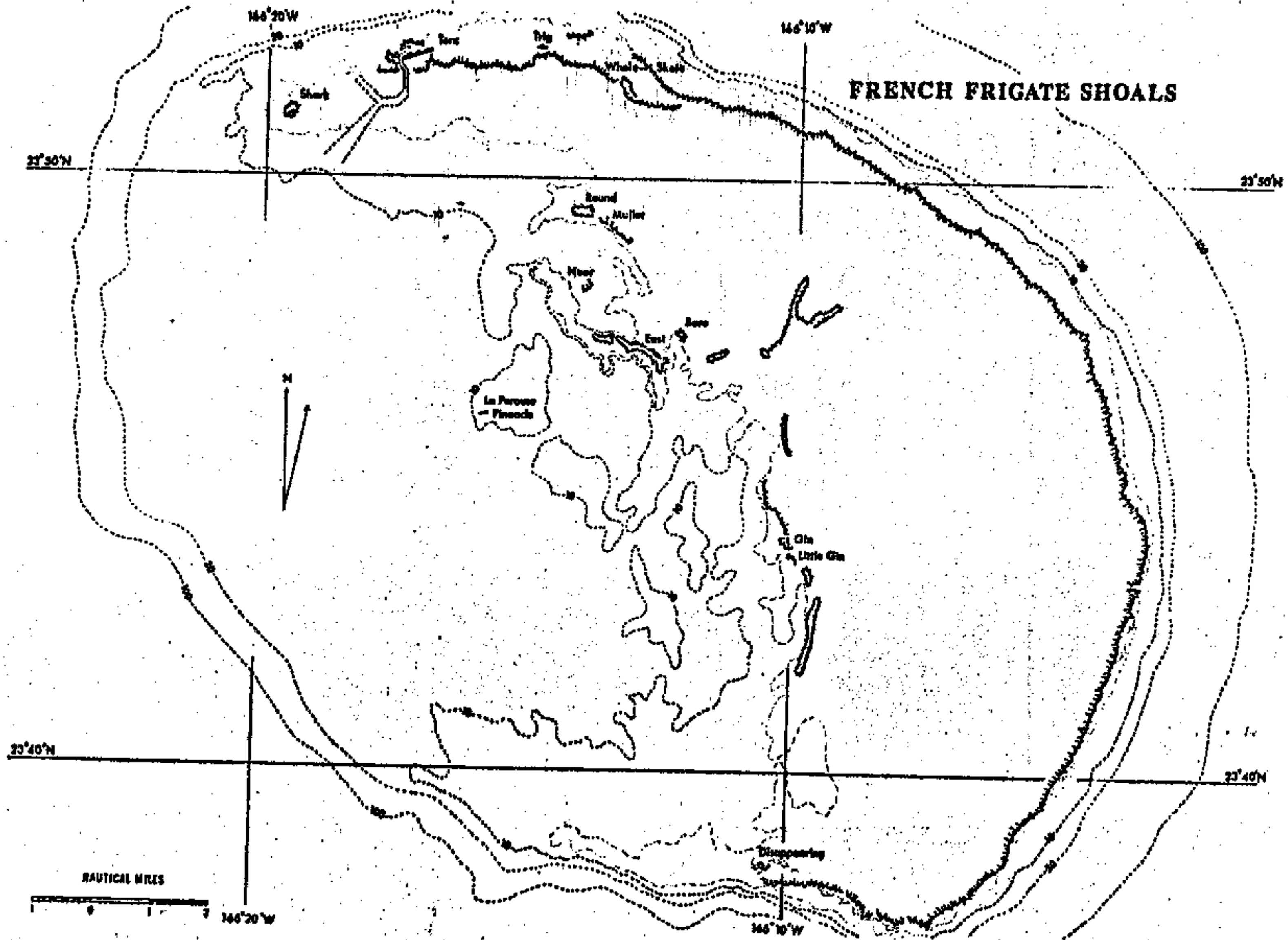
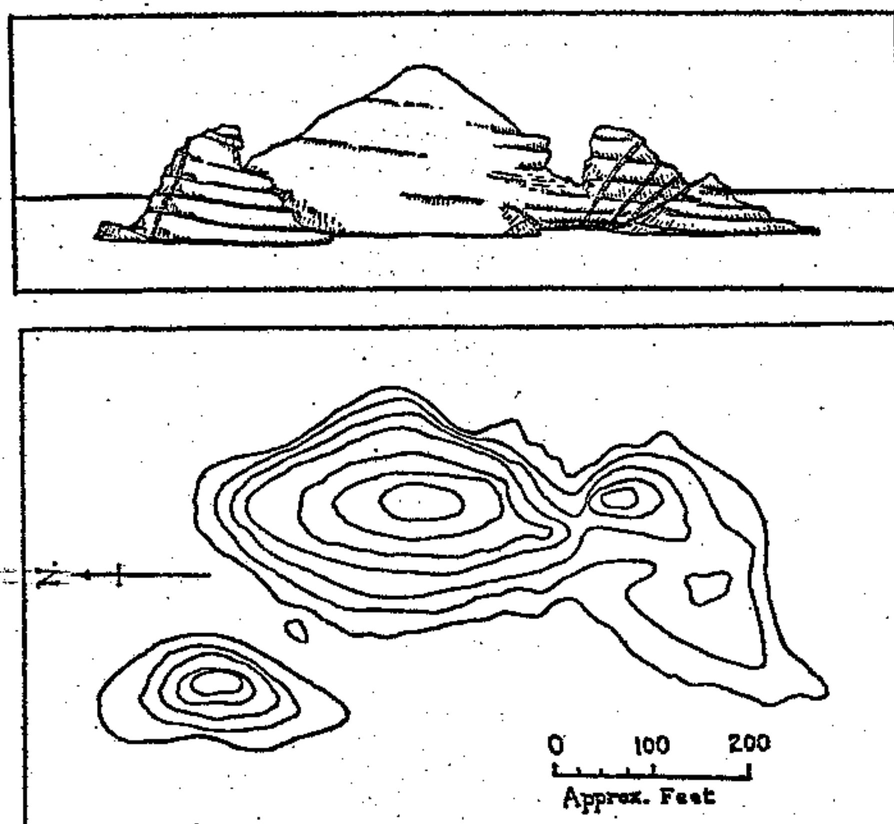


Figure 5.—French Frigate Shoals (Amerson 1971).

Bryan 1942
Fig. 6



(After H. S. Palmer)

Figure 6.—Gardner Pinnacles (Bryan 1942).

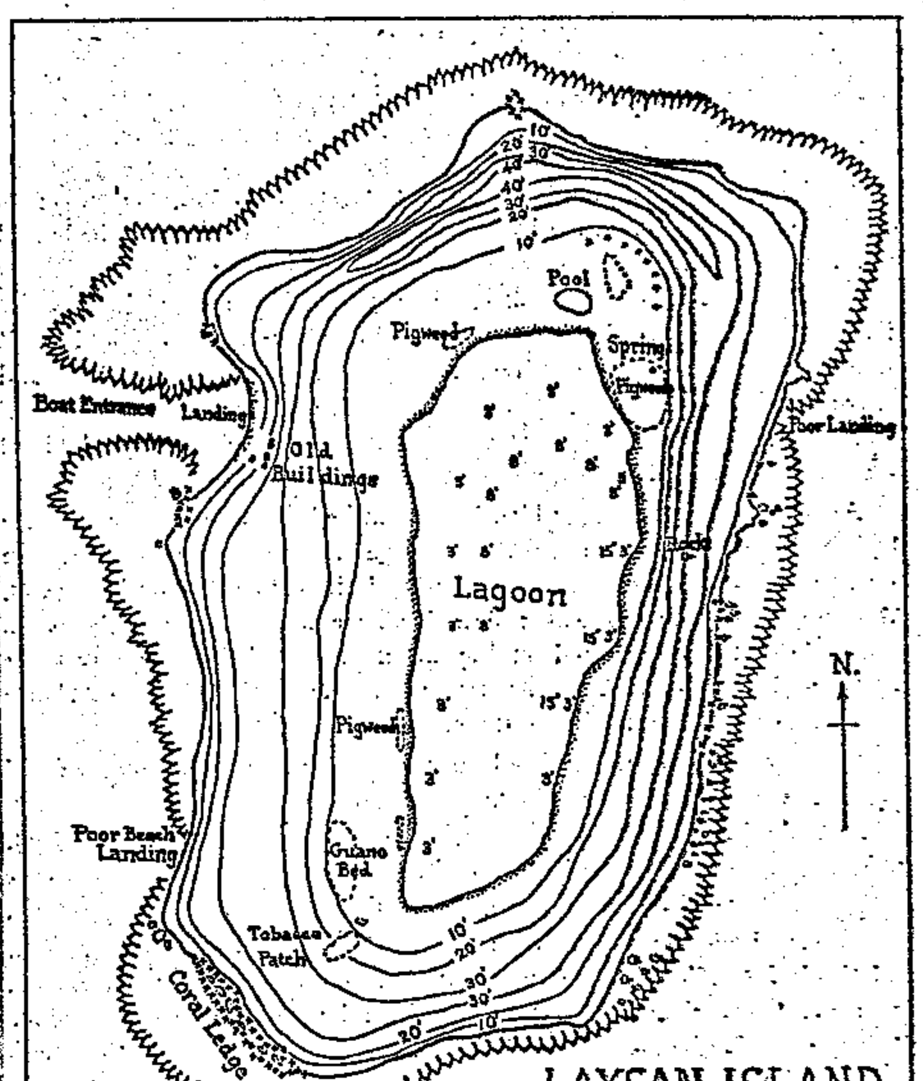


Figure 7.—Laysan Island (Bryan 1942).

Clapp + Wirtz 1975

Figure 8.--Lisianski Island (Clapp and Wirtz 1975).

Amerson, Clapp + Wirtz 197
Fig. 9

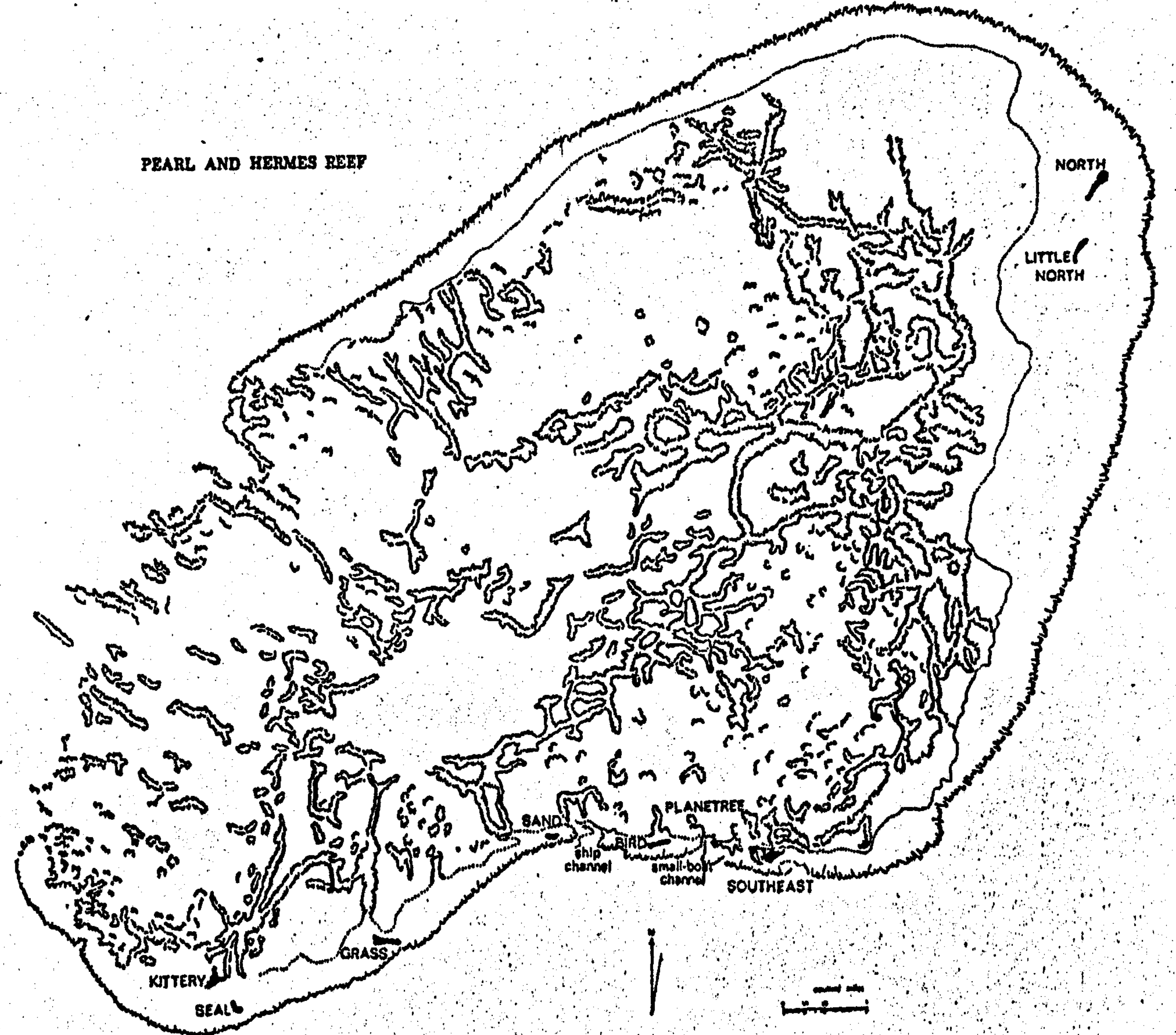


Figure 9.—Pearl and Hermes Reef (Amerson, Clapp and Wirtz 1974).

Bryan 1942

Fig. 10

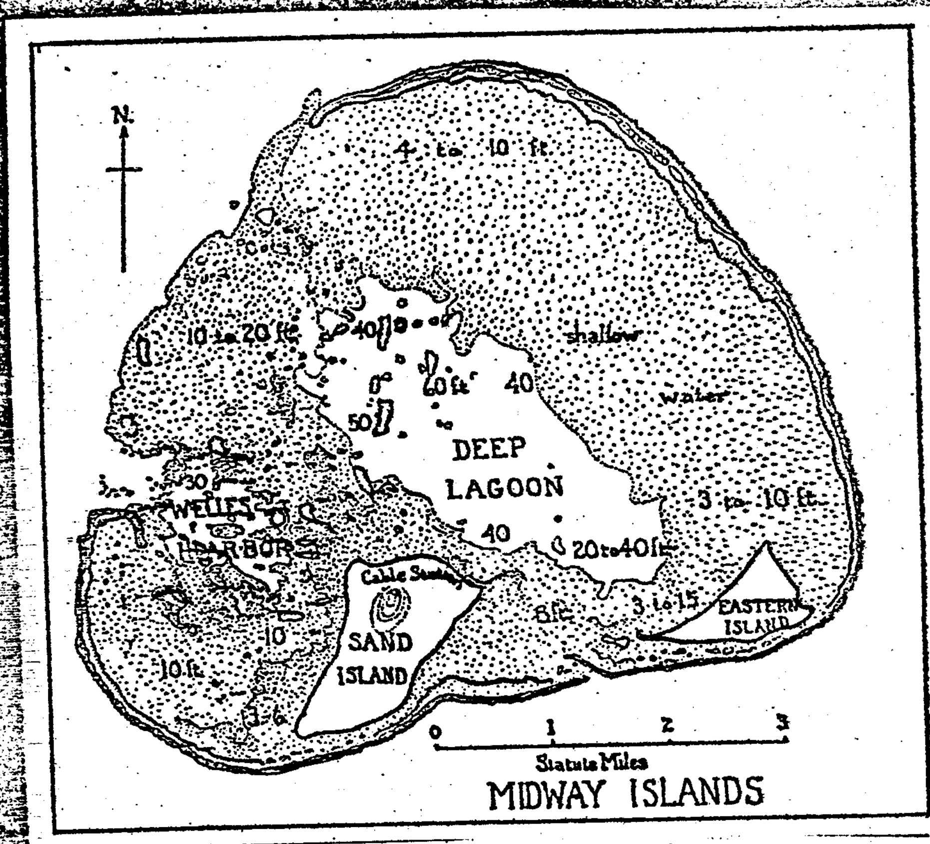


Figure 10.—~~Midway Atoll~~ (Bryan 1942).

Island

Bryan 1942
Fig. 11

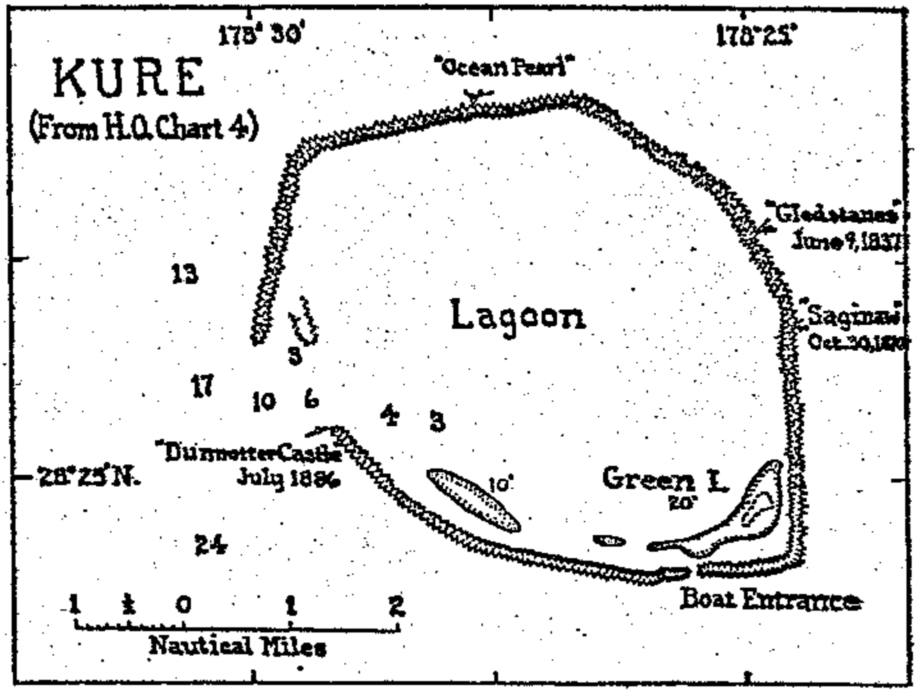


Figure 11.—Kure ~~Atoll~~ (Bryan 1942).

Island

Amerson 1971

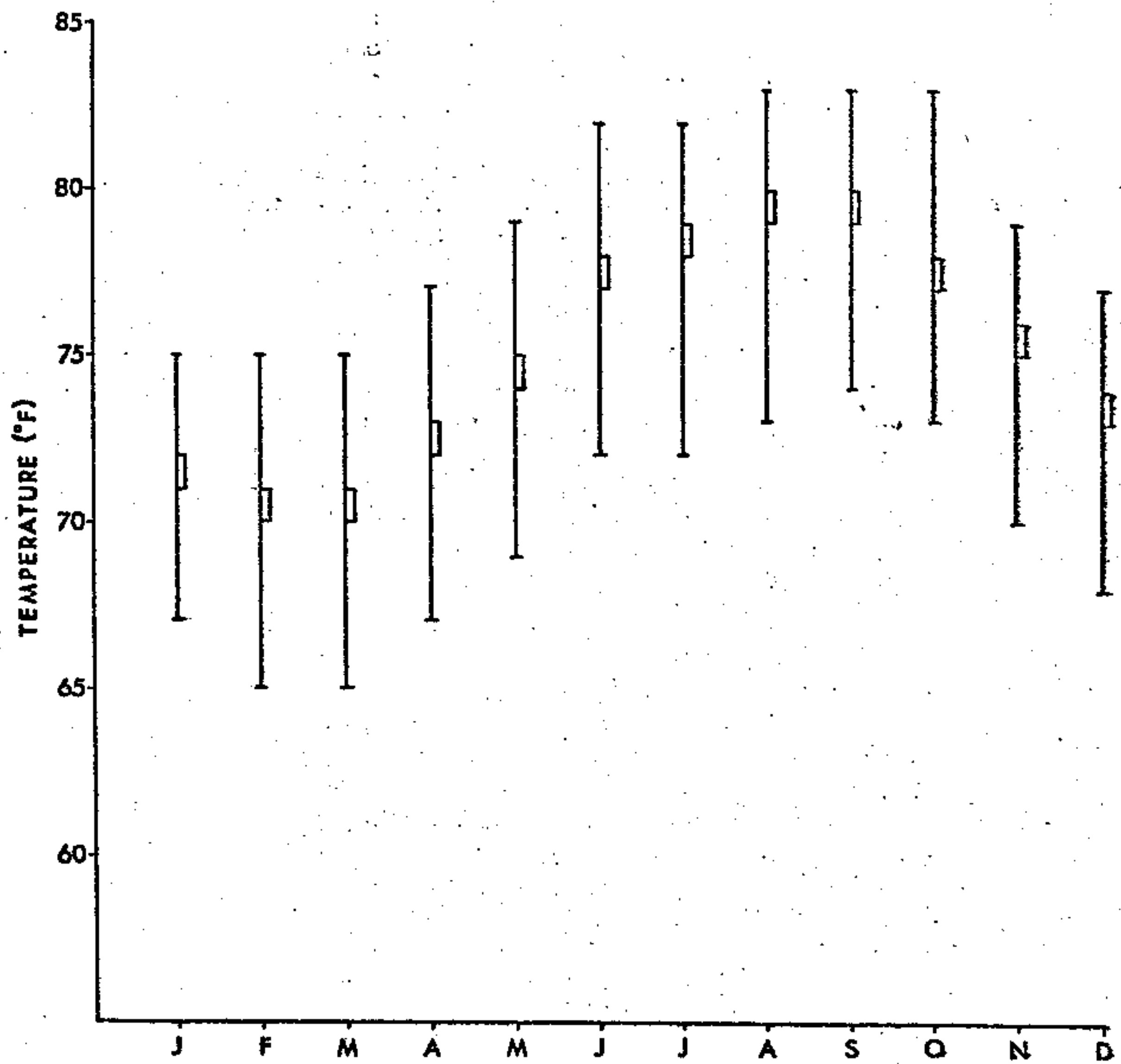


Figure 12.--The mode of the monthly means for a 12-year period, December 1950-December 1962, and the range of the maximum and minimum modes of temperature for French Frigate Shoals (Amerson 1971).

Amerson, Clapp & Wirtz 1974
Fig. 13

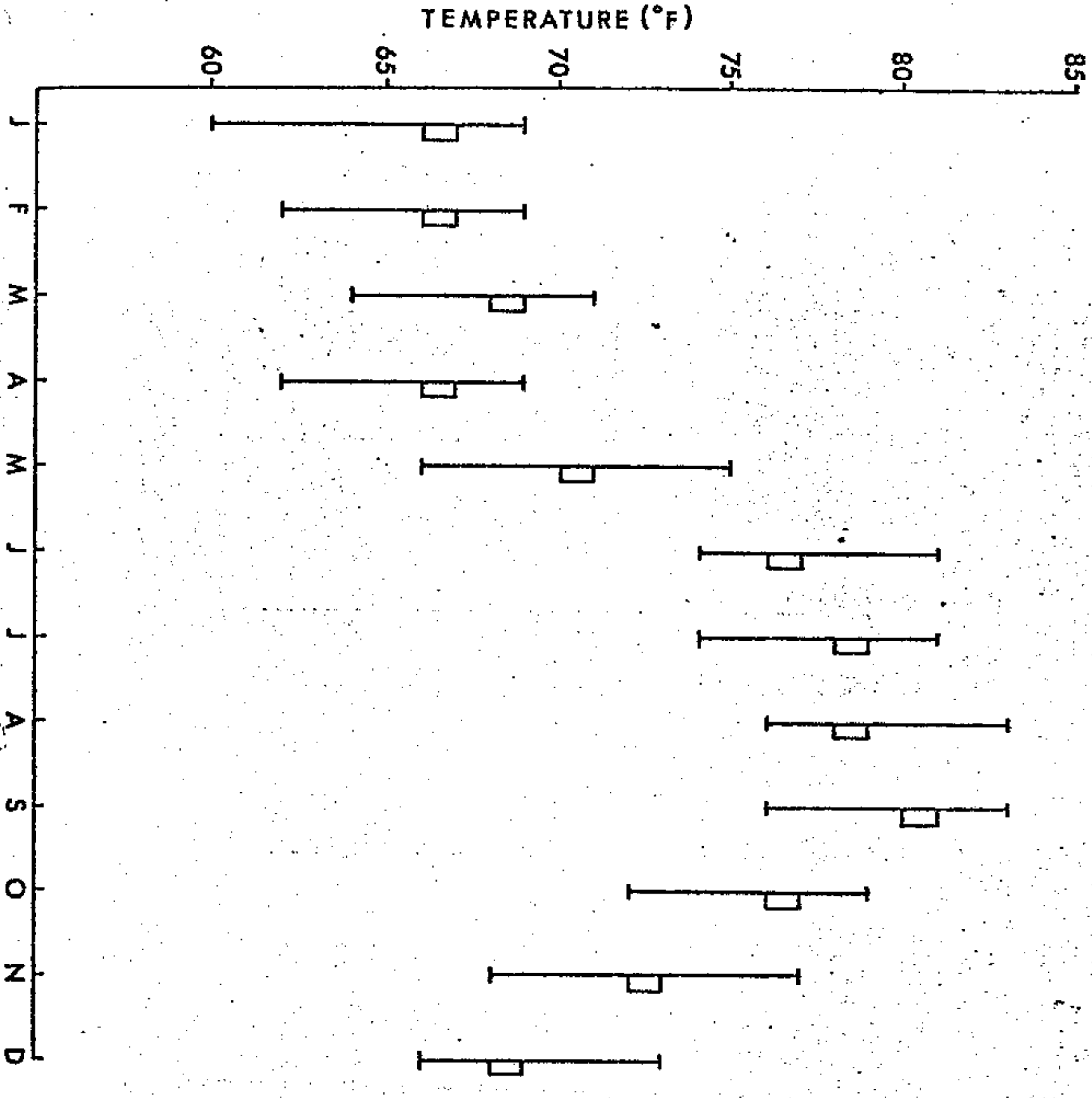


Figure 13.--Monthly temperature means and their maximum and minimum ranges for a 10-year period, 1953 to 1963, at Midway Atoll. (Amerson, Clapp and Wirtz 1974).

Amerson 1971

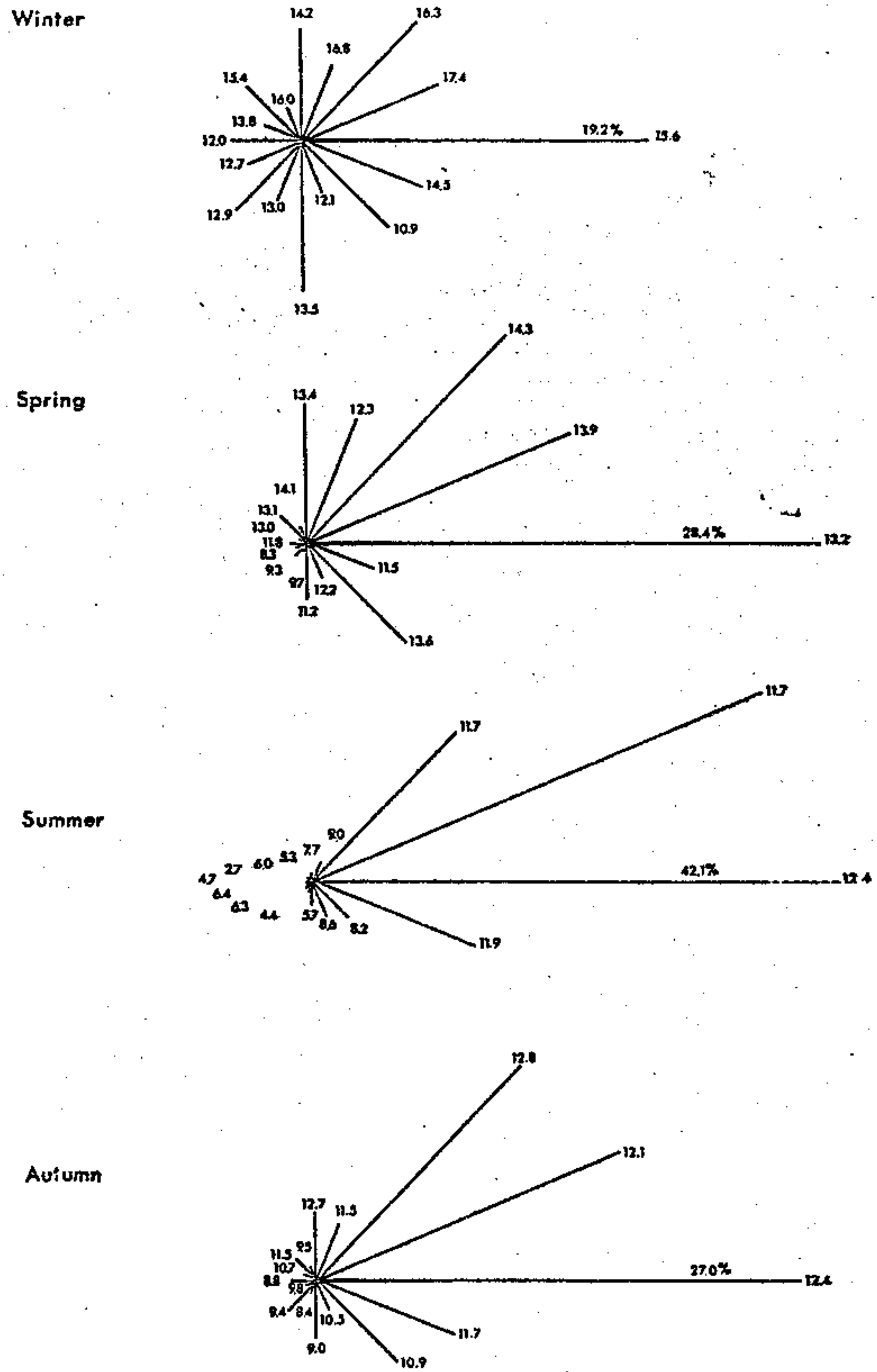


Figure 14.--Wind direction and speed at French Frigate Shoals from December 1950 to December 1952. Length of directional line indicates percent of observations from that direction; figure at end of directional line is mean wind speed in knots (Amerson 1971).

Amerson, Clapp & Wirtz 1974

Fig. 5

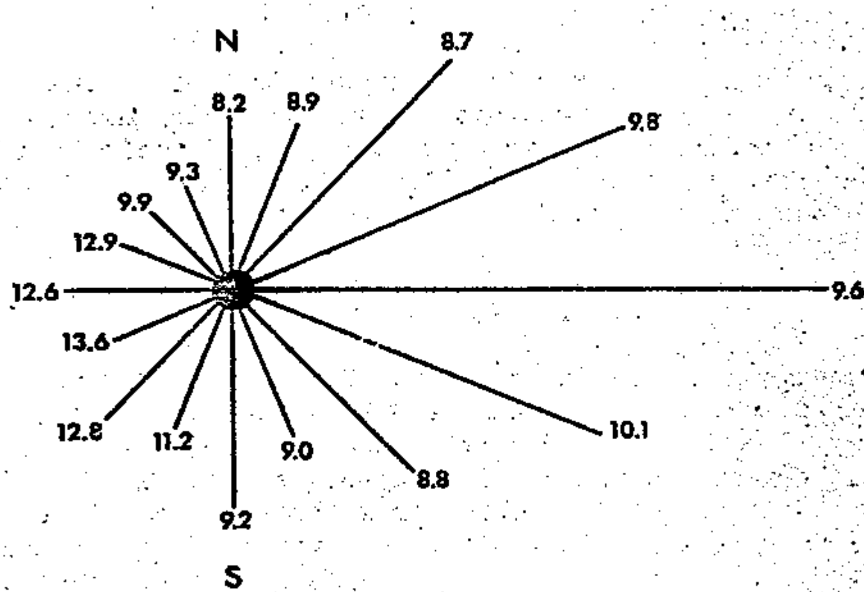


Figure 15.--Wind direction and speed at Midway Atoll from 1953 to 1963. Length of directional line indicates percent of observations from that direction; figure at end of directional line is mean wind speed in knots. (Amerson, Clapp and Wirtz 1974).

Amerson 1971

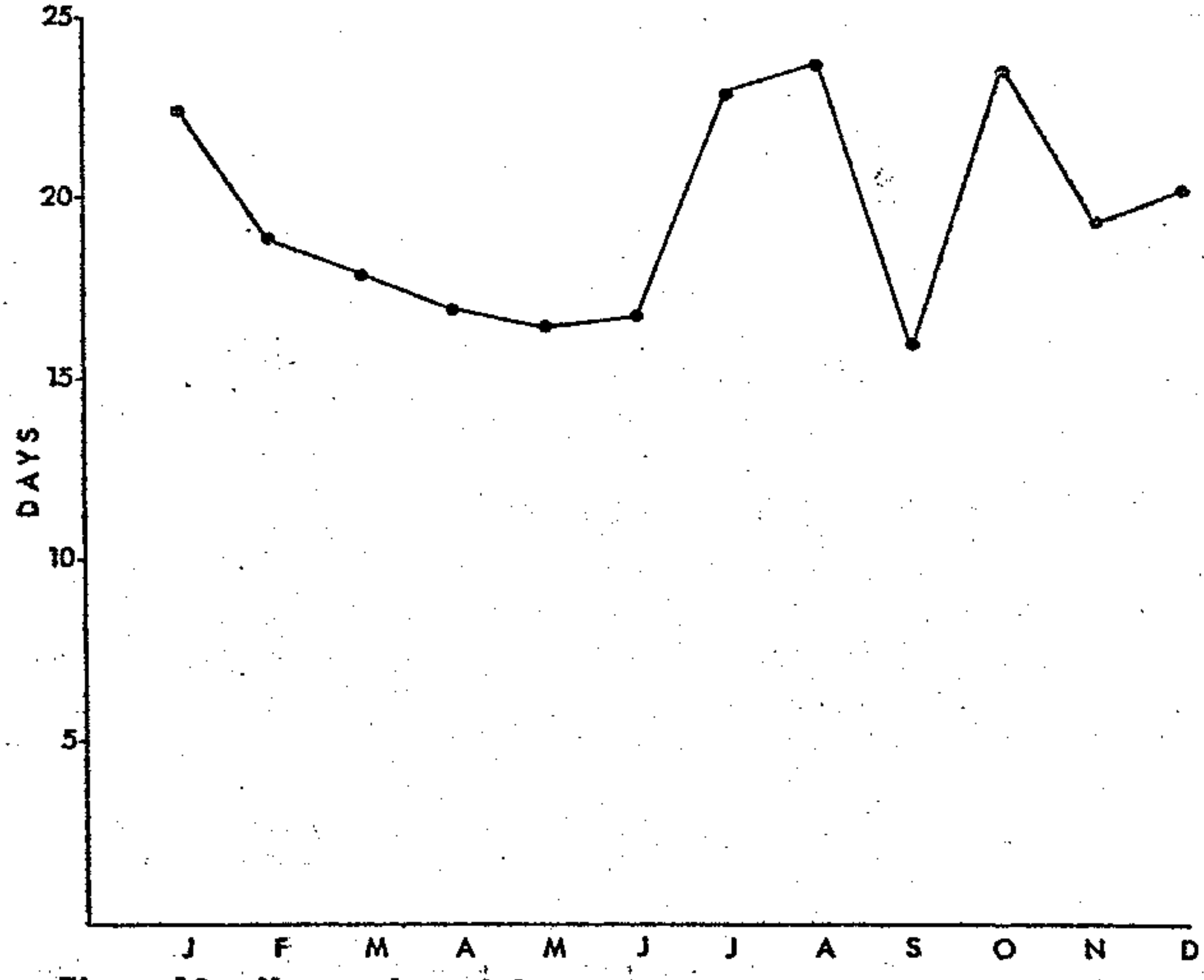


Figure 16.--Mean number of days with measurable precipitation for French Frigate Shoals, June 1954-January 1960, March 1960-December 1962 (Amerson 1971).

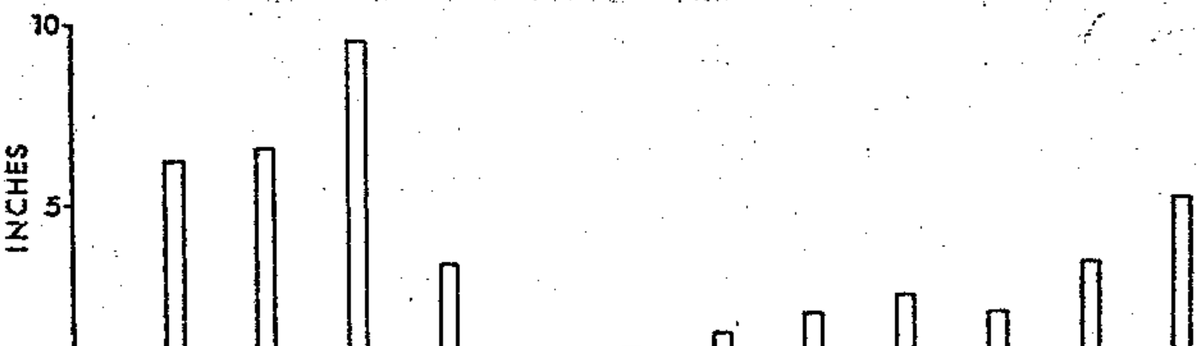


Figure 17.--Mean monthly precipitation in inches for French Frigate Shoals, June 1954-January 1960, March 1960-December 1962 (Amerson 1971).

Amerson, Clapp + Wirtz 1974
Fig. 18

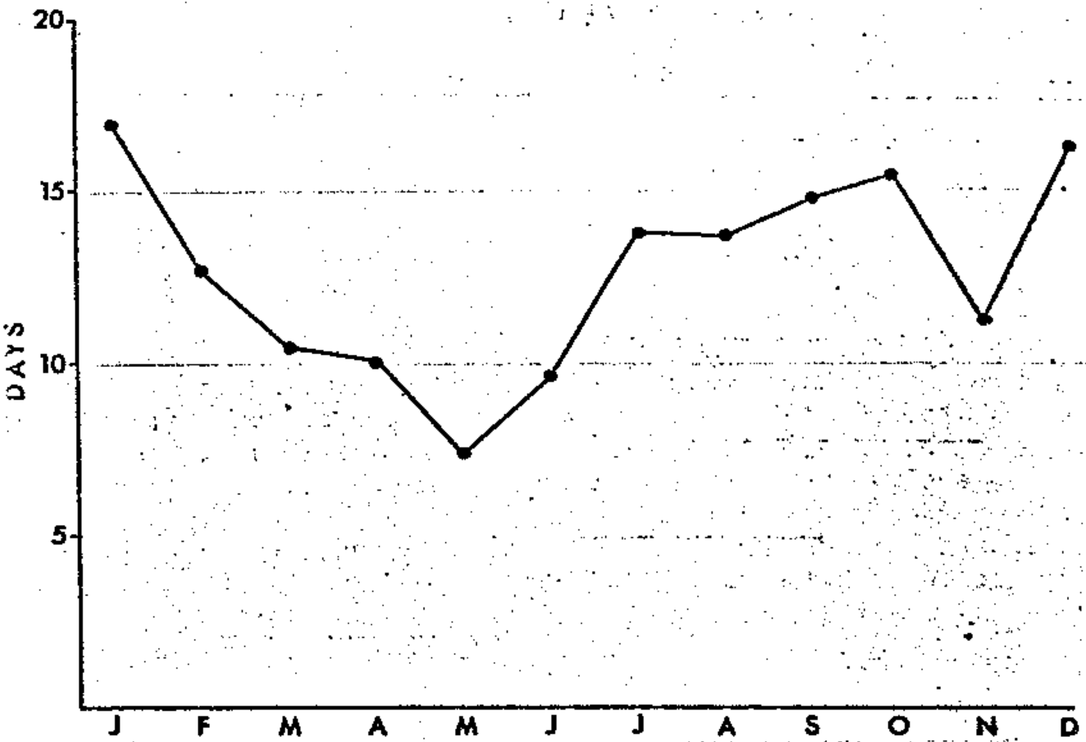
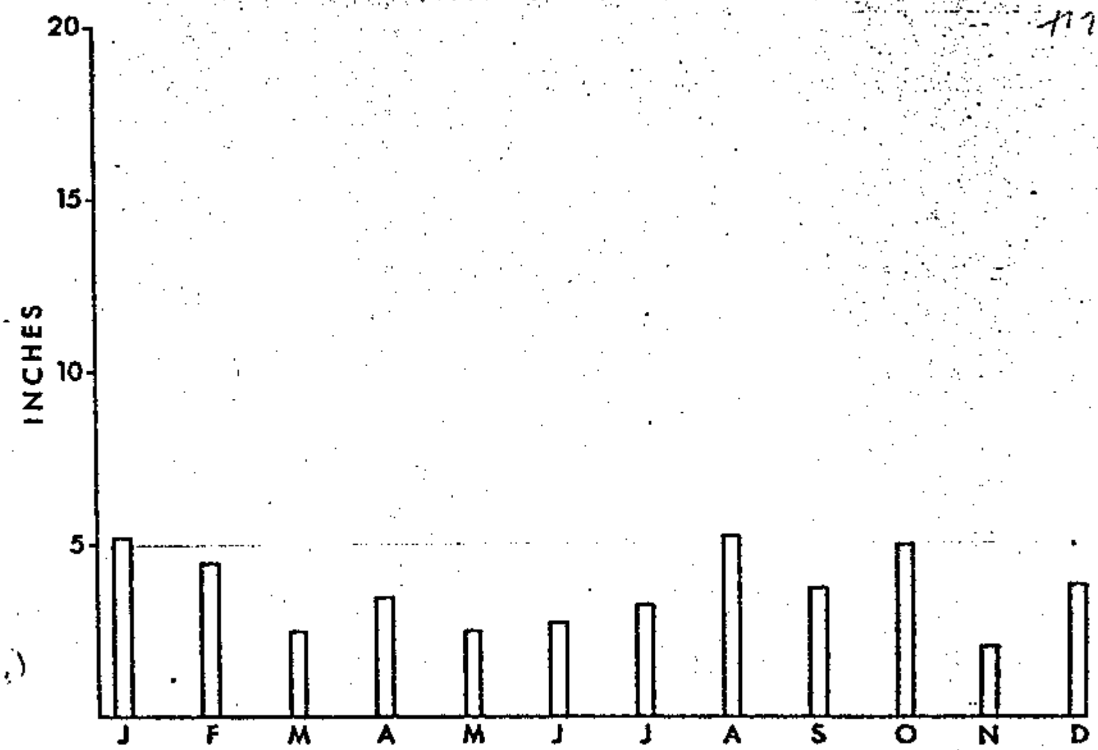


Figure 18.—Mean number of days with measurable precipitation for Midway Atoll, 1953 to 1963 (Amerson, Clapp and Wirtz 1974).

Figure 19.—Mean monthly precipitation in inches for Midway Atoll, 1953 to 1963 (Amerson, Clapp and Wirtz 1974).



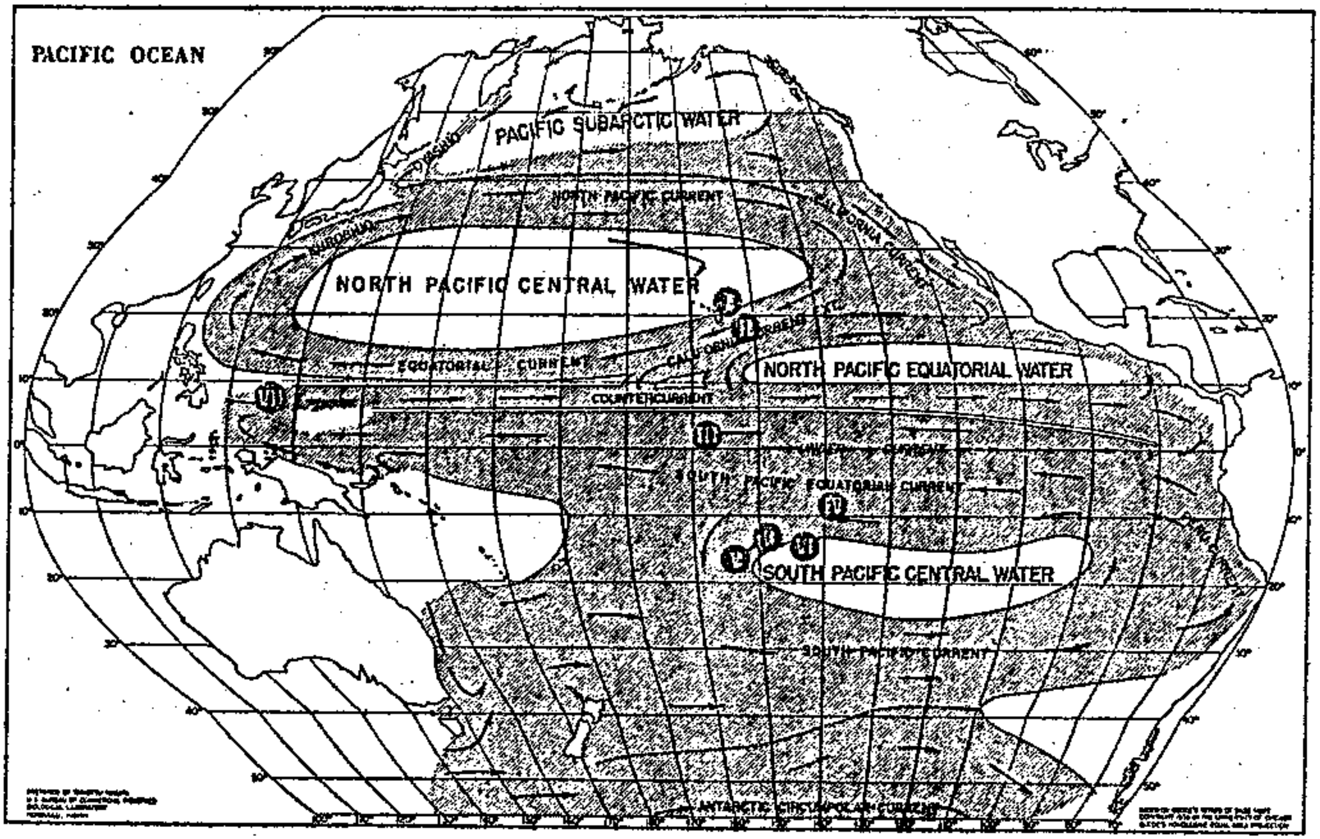


Figure 20.--Major circulation features of the Pacific Ocean (Bureau of Commercial Fisheries 1963).

BCF 1963
Fig. 20

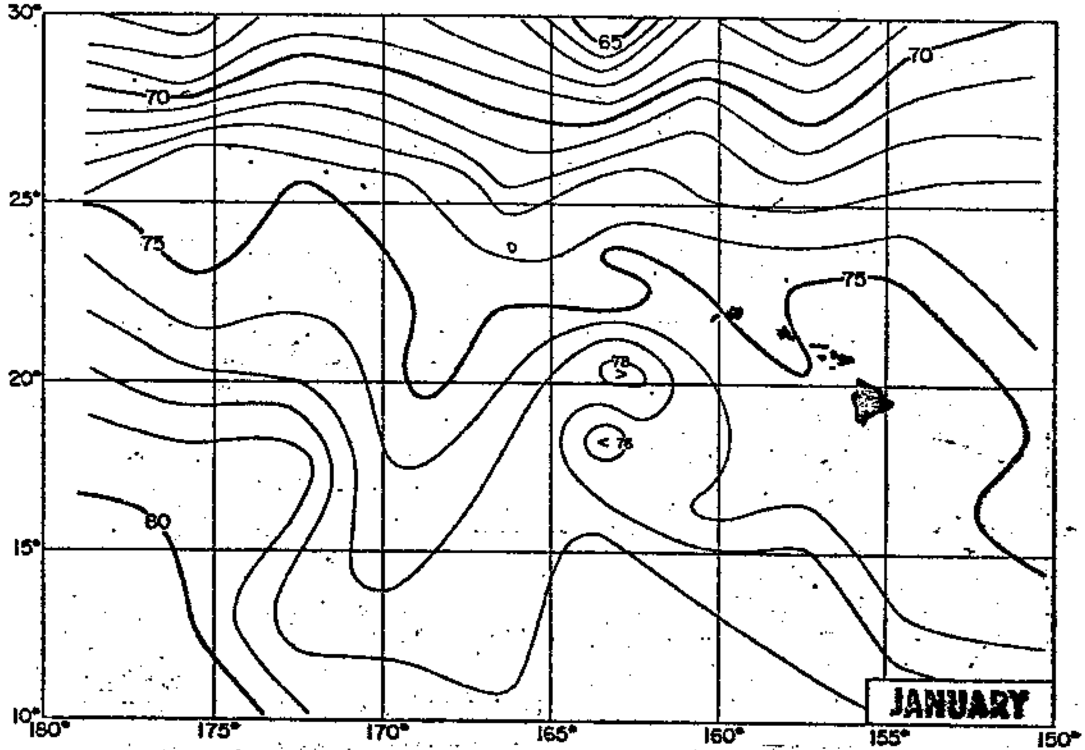


Figure 21a.--Distribution of surface temperature (°F) in January (Seckel 1962).

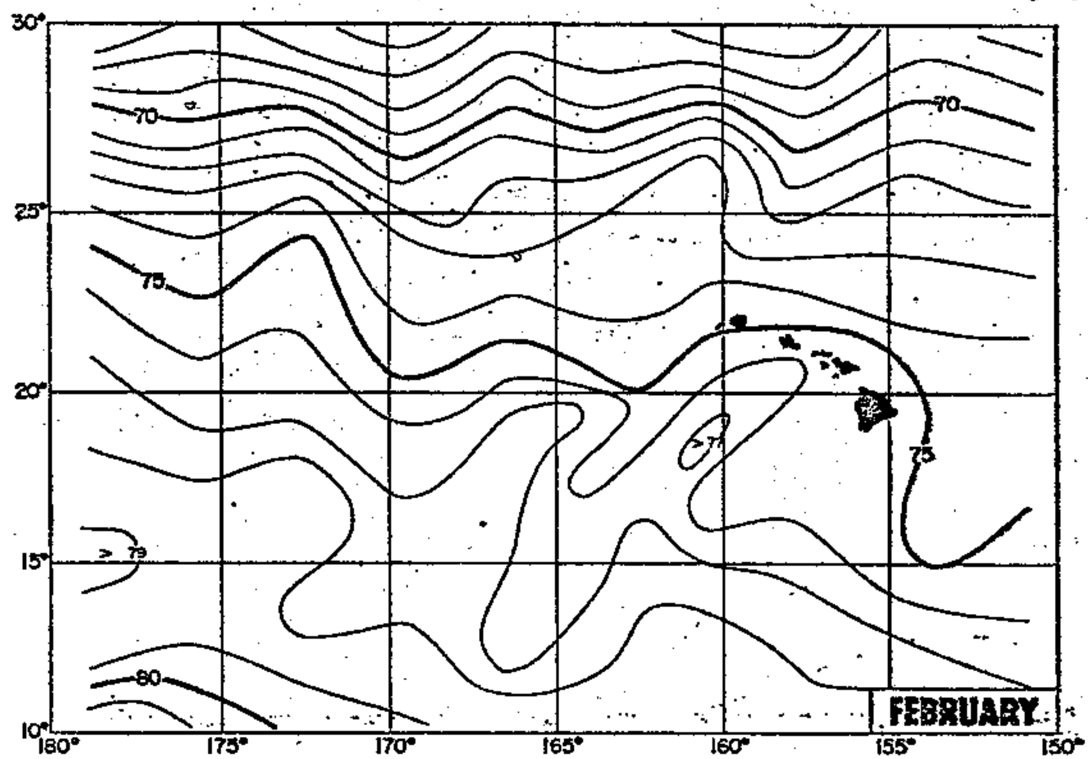


Figure 21b.--Distribution of surface temperature (°F) in February (Seckel 1962).

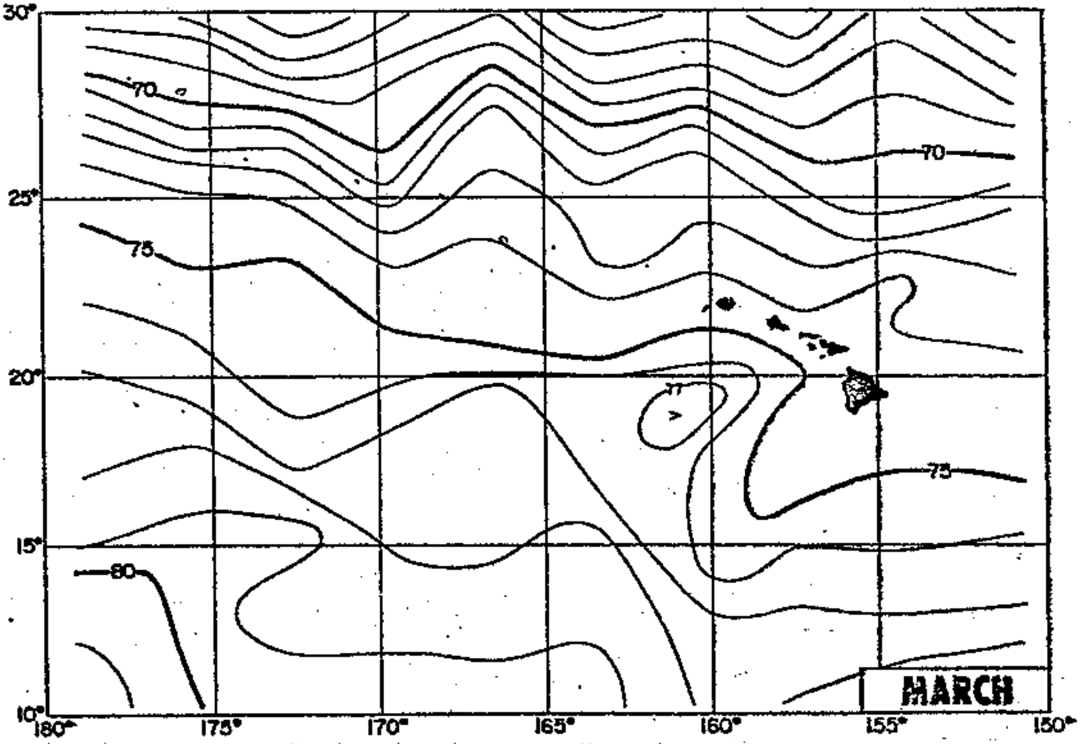


Figure 21c.--Distribution of surface temperature (°F) in March (Seckel 1962).

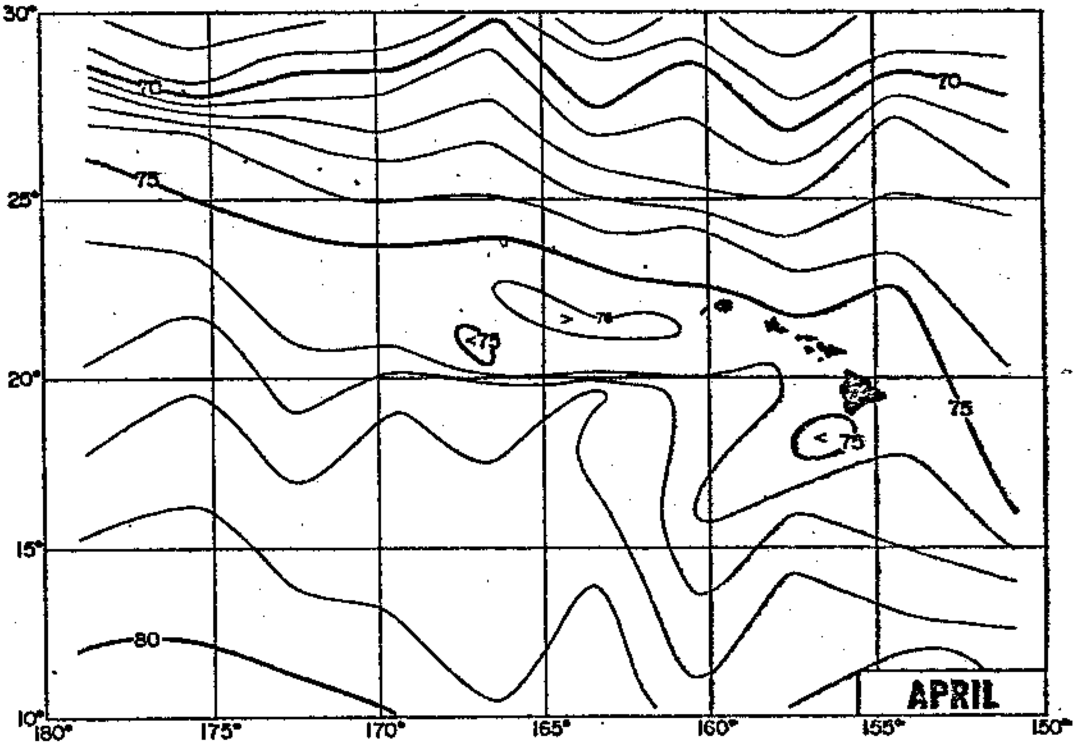


Figure 21d.--Distribution of surface temperature (°F) in April (Seckel 1962).

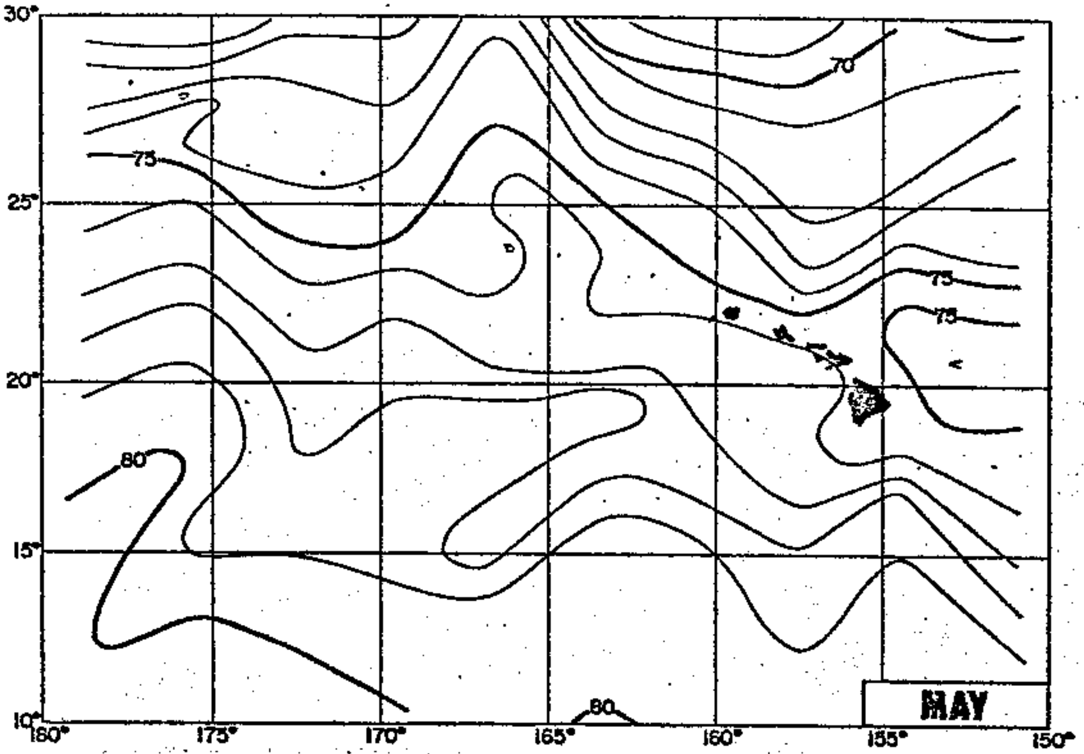


Figure 21e.--Distribution of surface temperature (°F) in May (Seckel 1962).

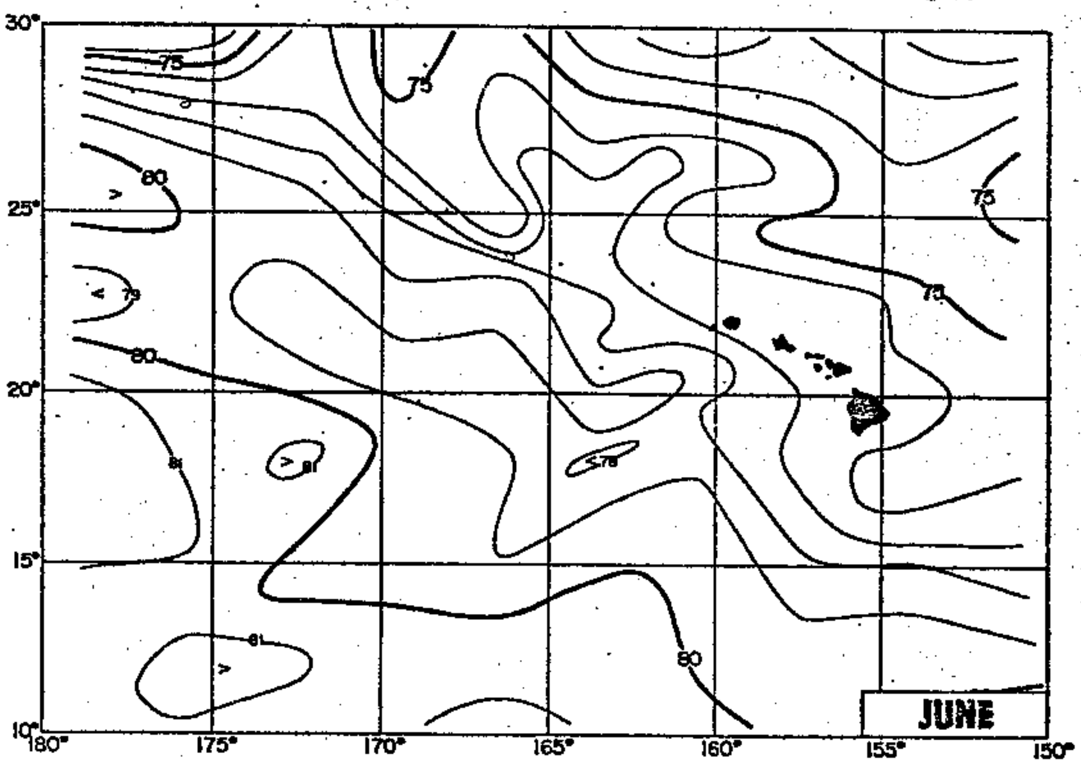


Figure 21f.--Distribution of surface temperature (°F) in June (Seckel 1962).

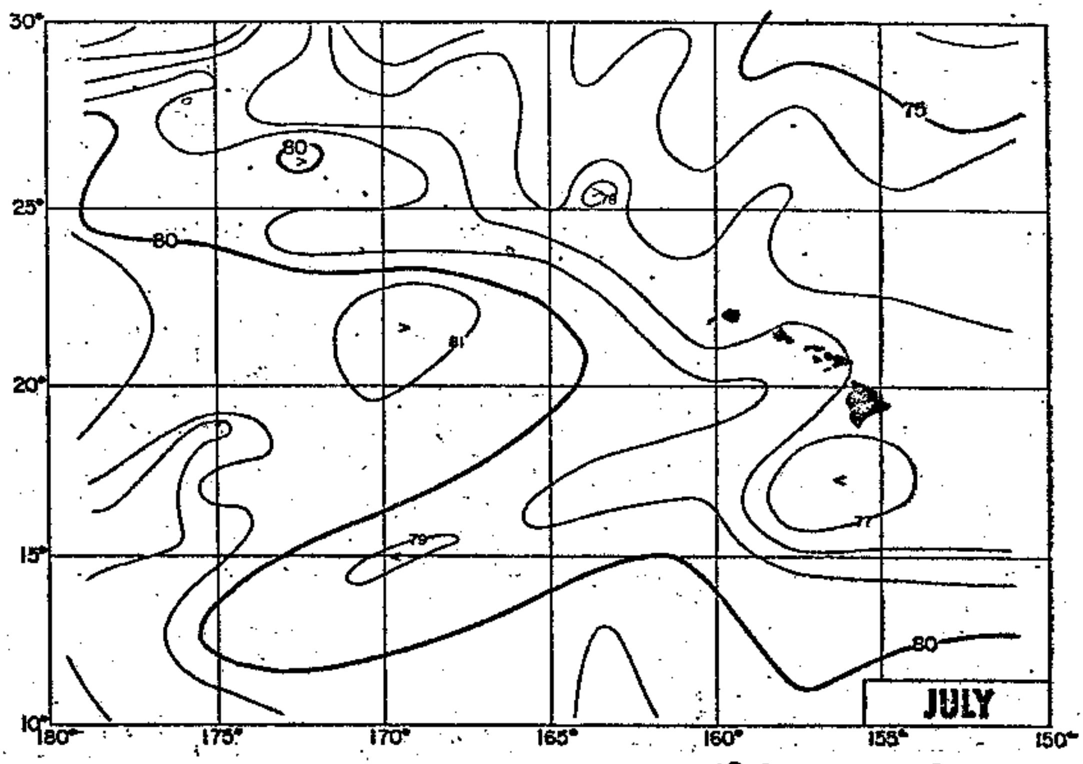


Figure 21g.--Distribution of surface temperature (°F) in July (Seckel 1962).

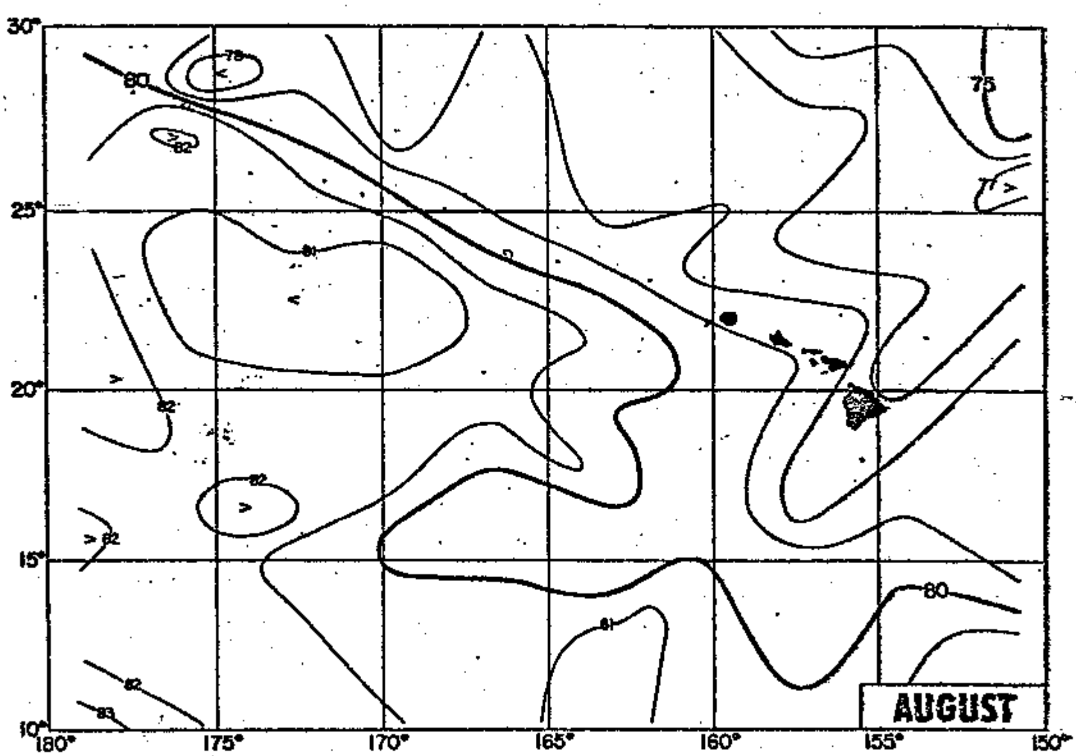


Figure 21h.--Distribution of surface temperature (°F) in August (Seckel 1962).

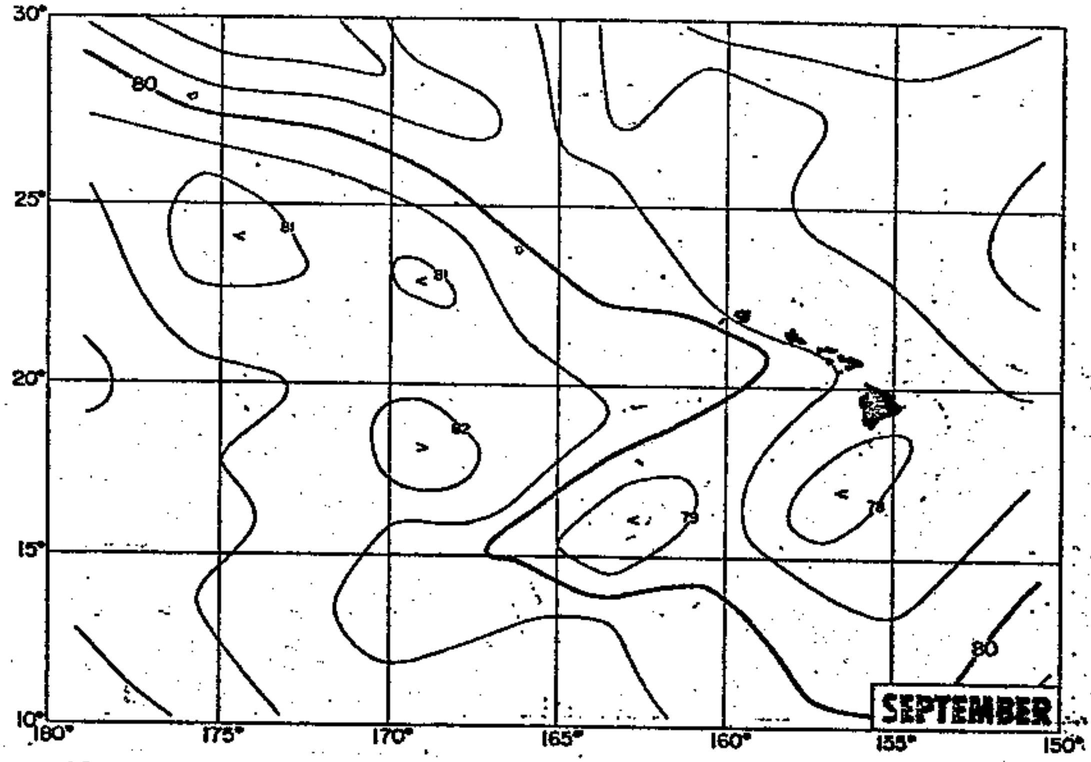


Figure 21i.--Distribution of surface temperature (°F) in September (Seckel 1962)

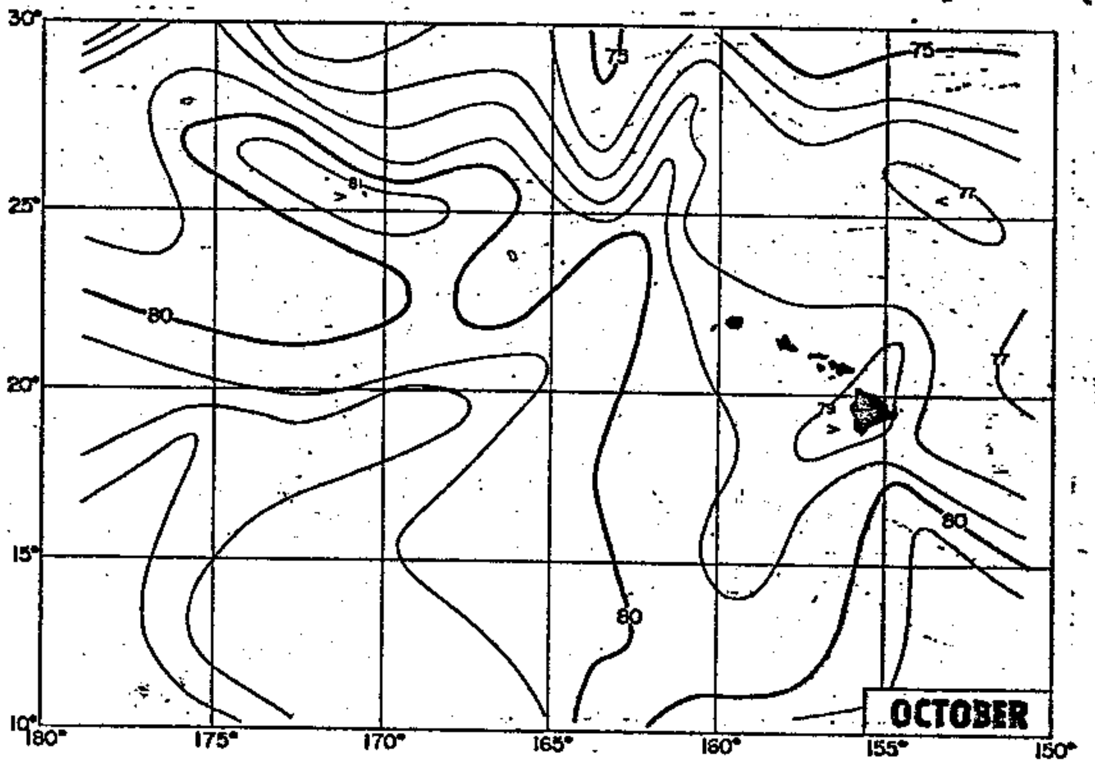


Figure 21j.--Distribution of surface temperature (°F) in October (Seckel 1962)

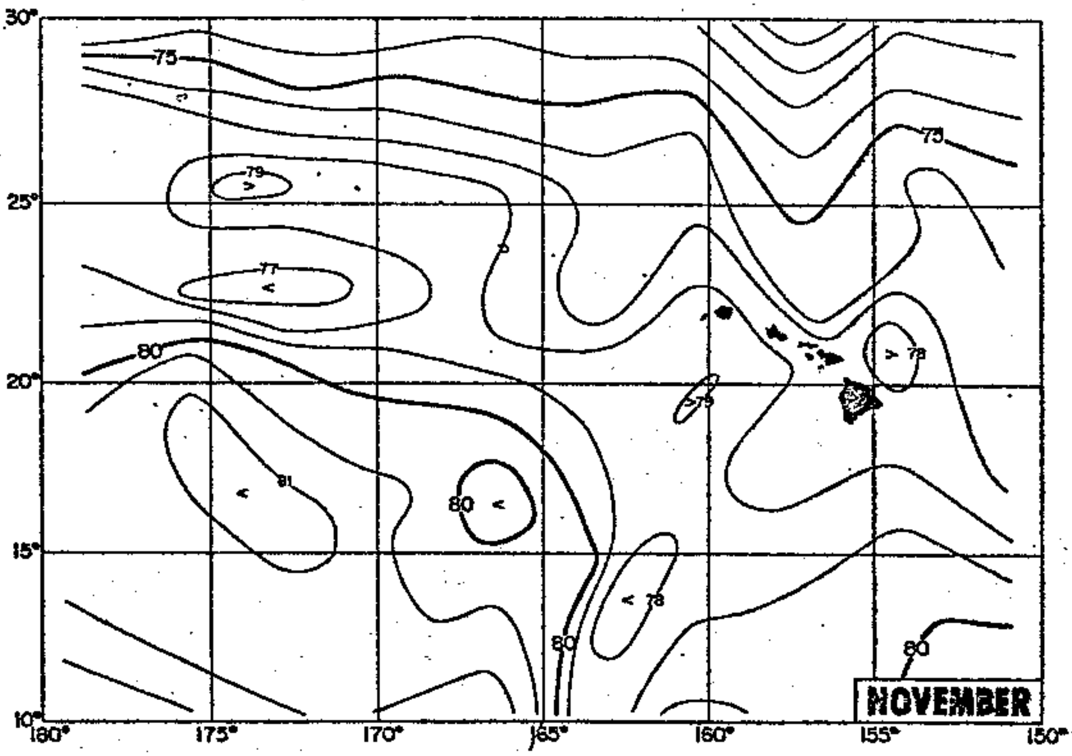


Figure 21k.--Distribution of surface temperature (°F) in November (Seckel 1962).

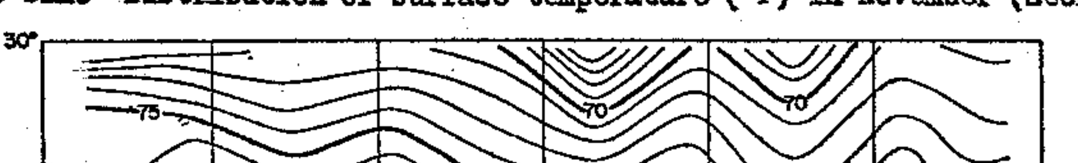


Figure 21l.--Distribution of surface temperature (°F) in December (Seckel 1962).

Seckel 1962
Fig. 22

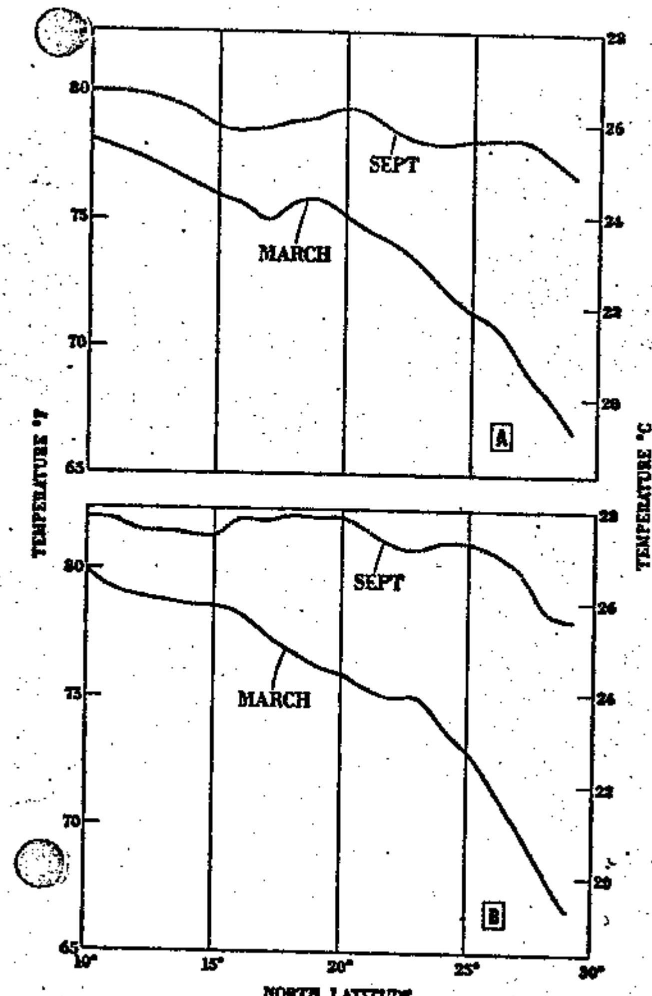


Figure 22.—Meridional profile of the surface temperature in March and September, lat. 10° to 30° N: Panel A, long. 153°–161° W; Panel B, long. 168°–176° W (Seckel 1962).

Seckel 1962
Fig 23

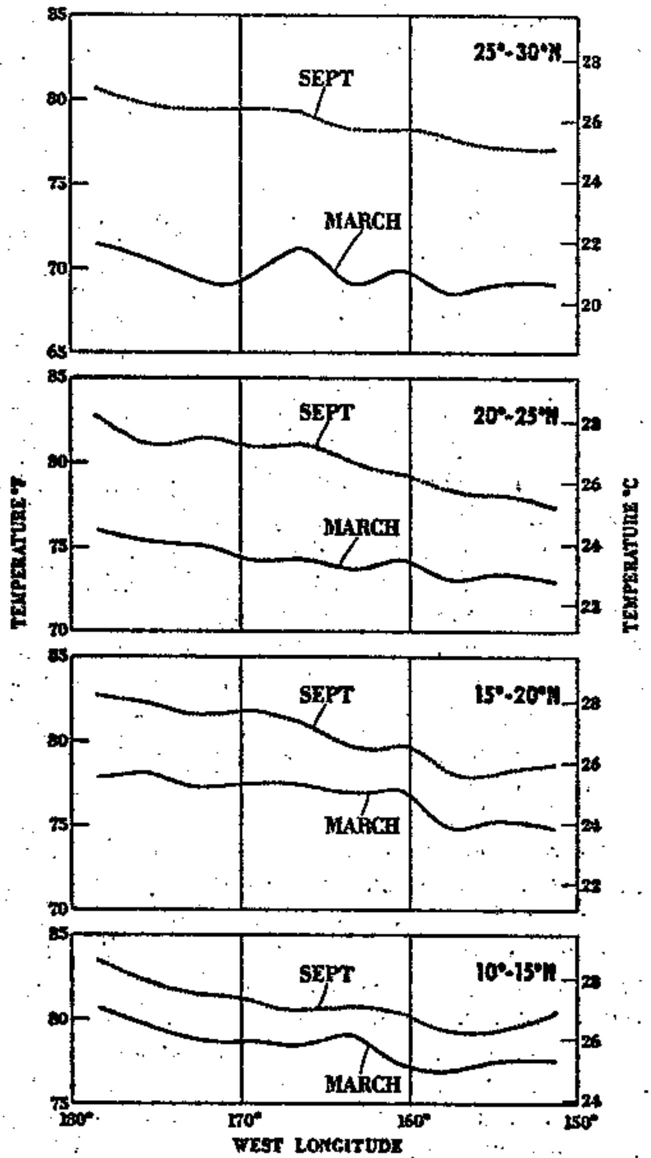


Figure 23.--Zonal profile of the surface temperature in March and September, lat. 10°-15° N, lat. 15°-20° N, lat. 20°-25° N, lat. 25°-30° N, and long. 150° W to 180° (Seckel 1962).

Seckel 1962
Fig. 24

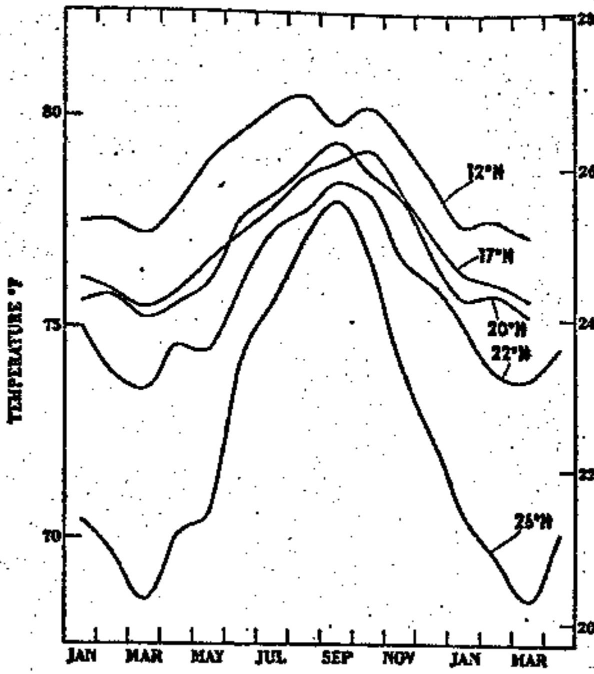
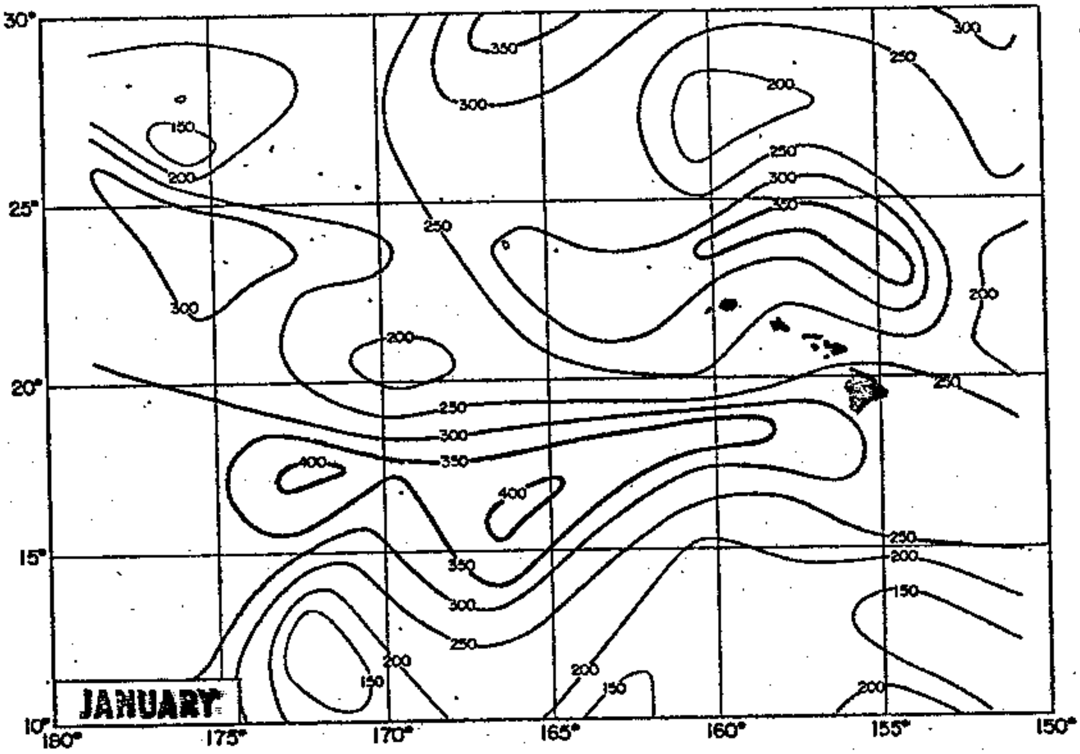


Figure 24.—Seasonal variation of the surface temperature at lat. 12°, lat. 17°, lat. 20°, lat. 22° and lat. 26° N between long. 153° and 161° W (Seckel 1962).

Figure 25a.—Distribution of the depth of the mixed layer (ft) in January (Seckel 1962).



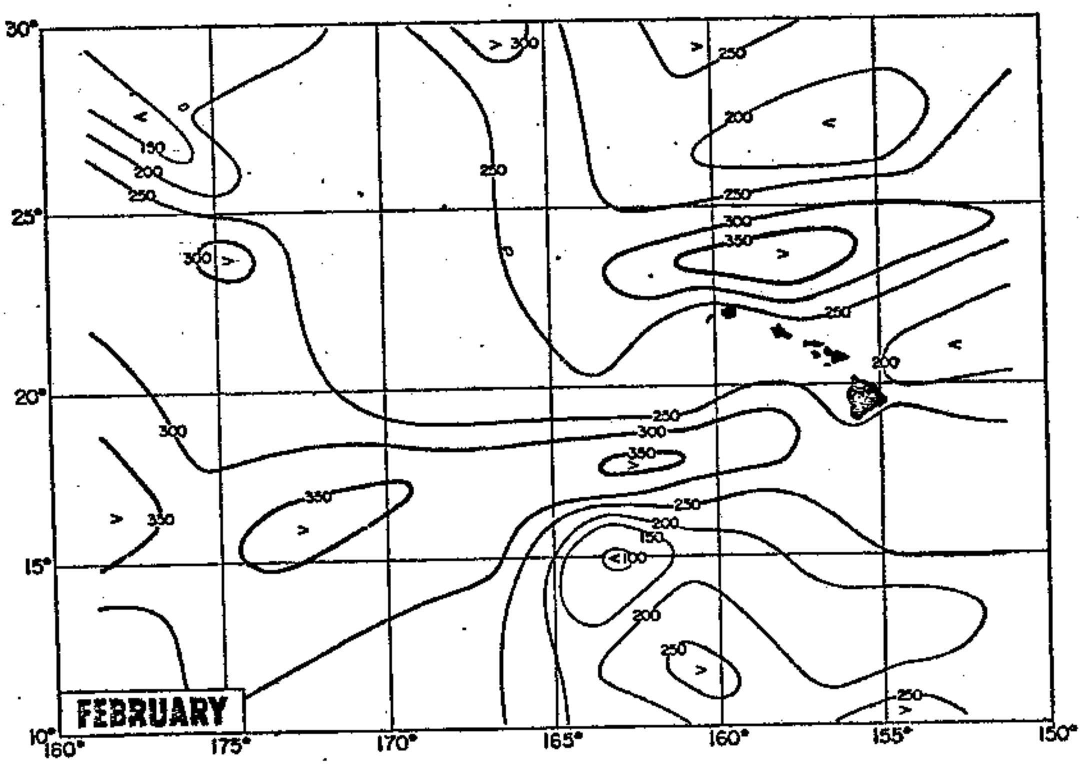
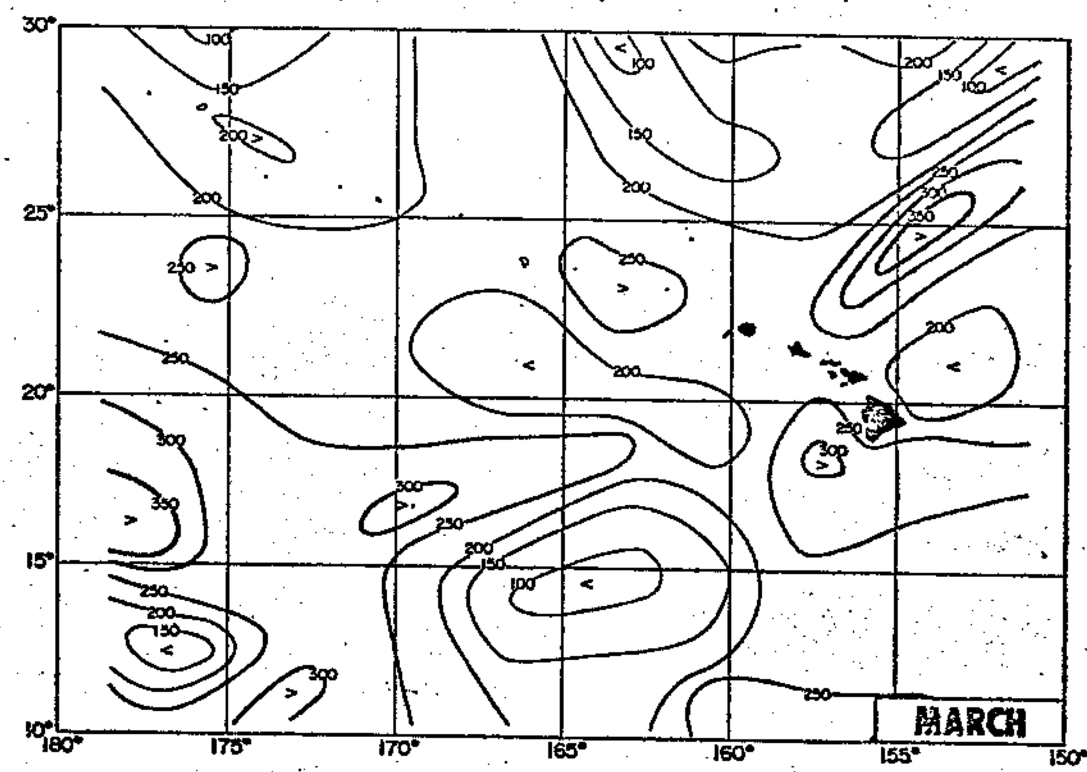


Figure 25b.—Distribution of the depth of the mixed layer (ft) in February (Seckel 1962).

Figurse 25c.--Distribution of the depth of the mixed layer (ft) in March (Seckel 1962).



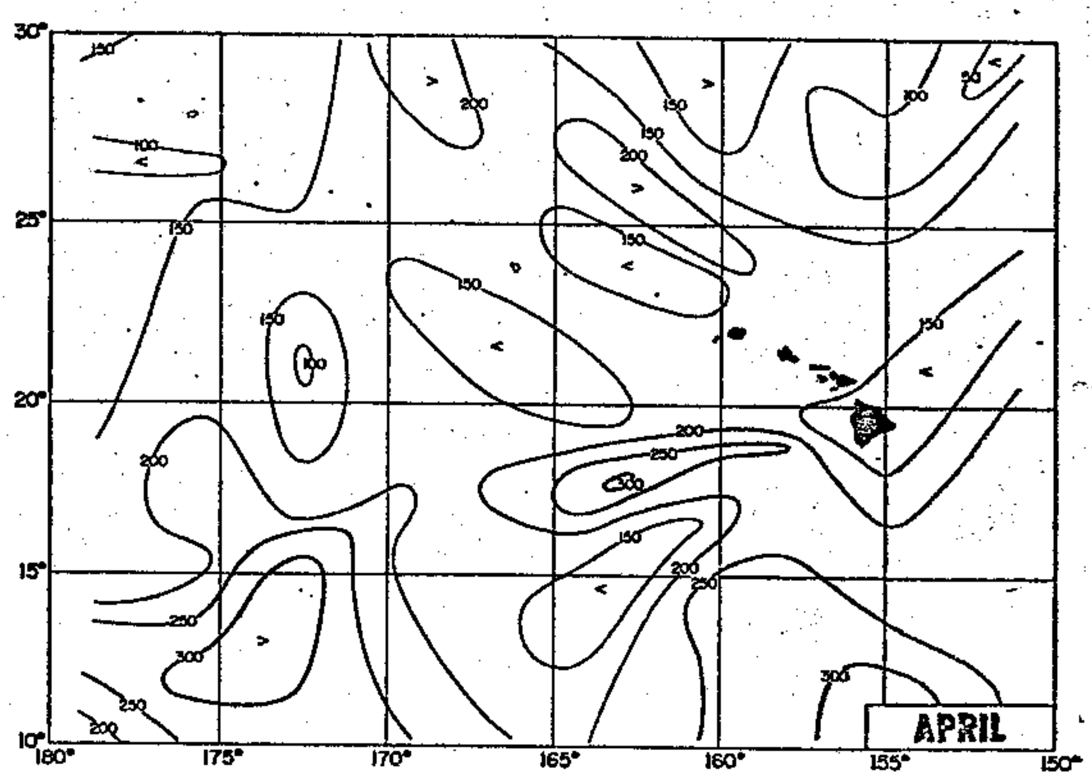
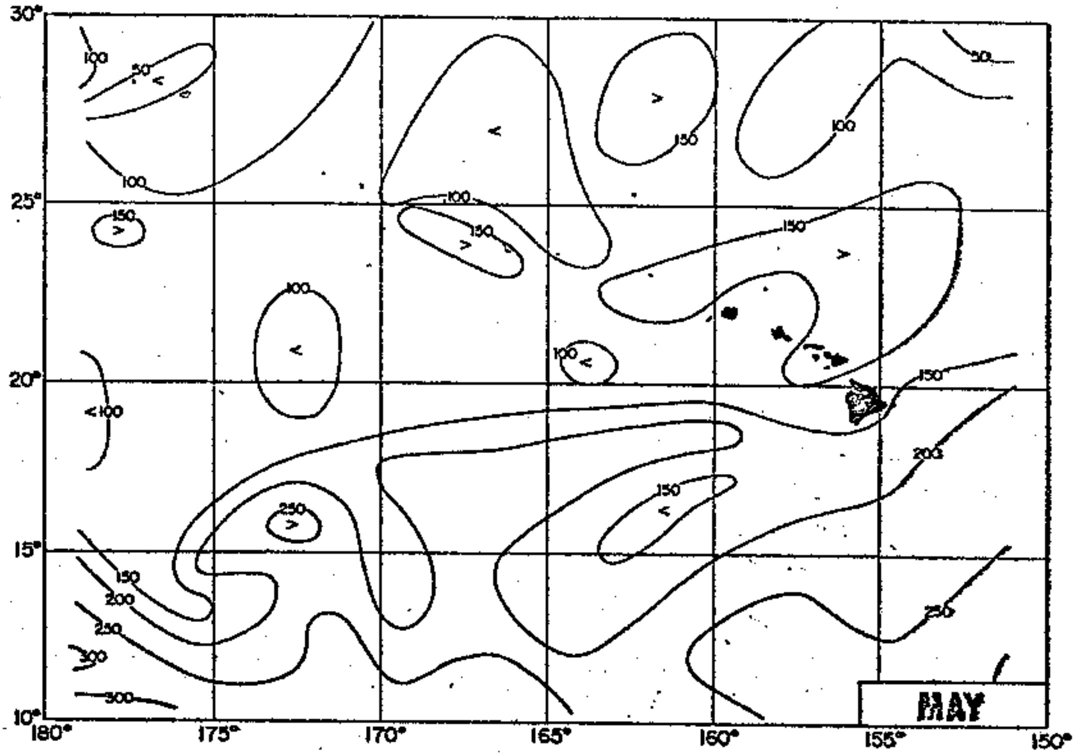


Figure 25d.--Distribution of the depth of the mixed layer (ft) in April (Seckel 1962).

Figure 25e.—Distribution of the depth of the mixed layer (ft) in May (Seckel 1962).



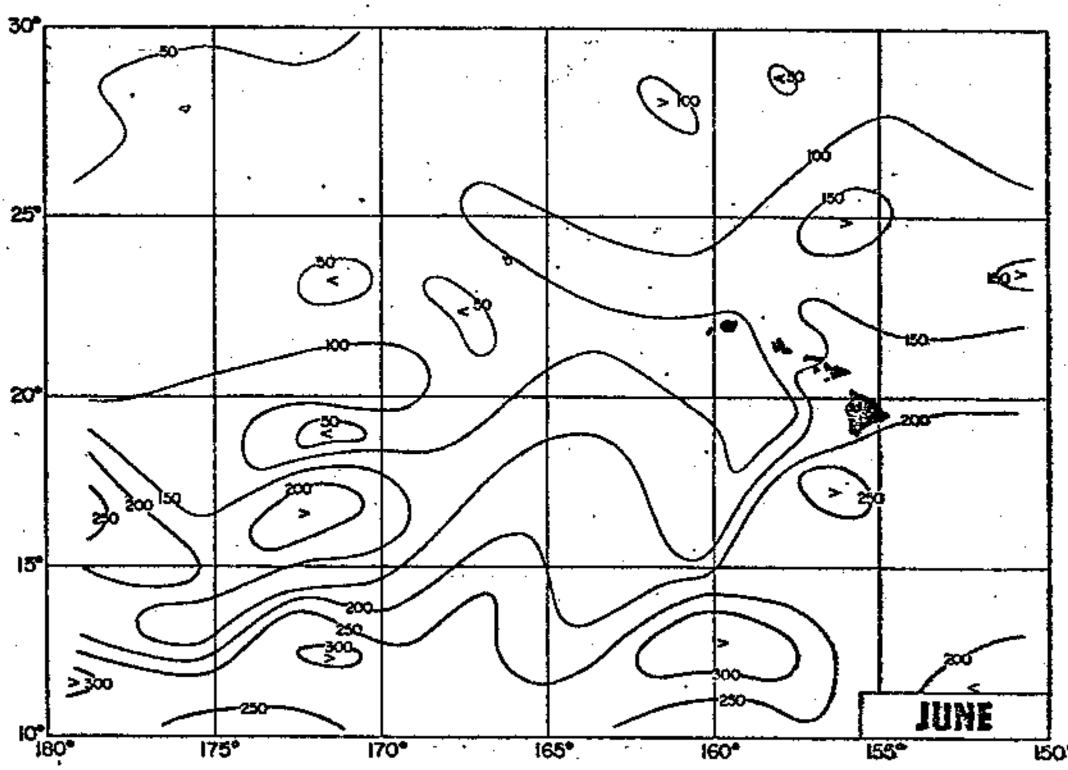
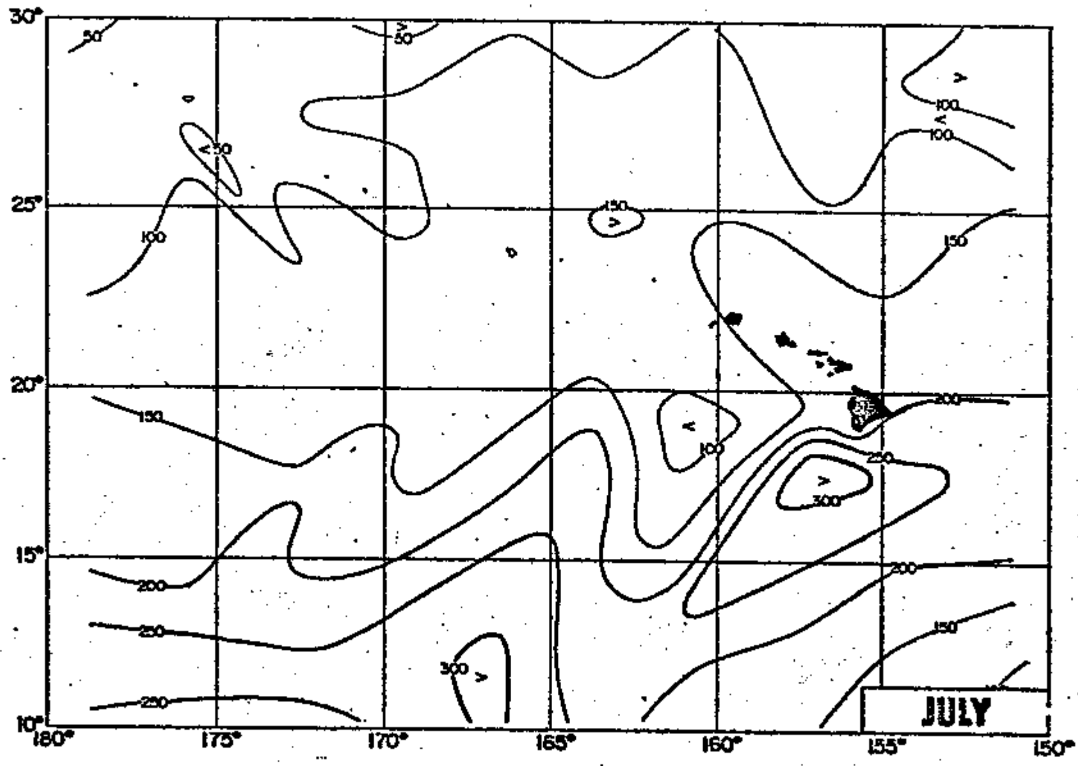


Figure 25f.—Distribution of the depth of the mixed layer (ft) in June (Seckel 1962).

Figure 25g.—Distribution of the depth of the mixed layer (ft) in July (Seckel 1952).



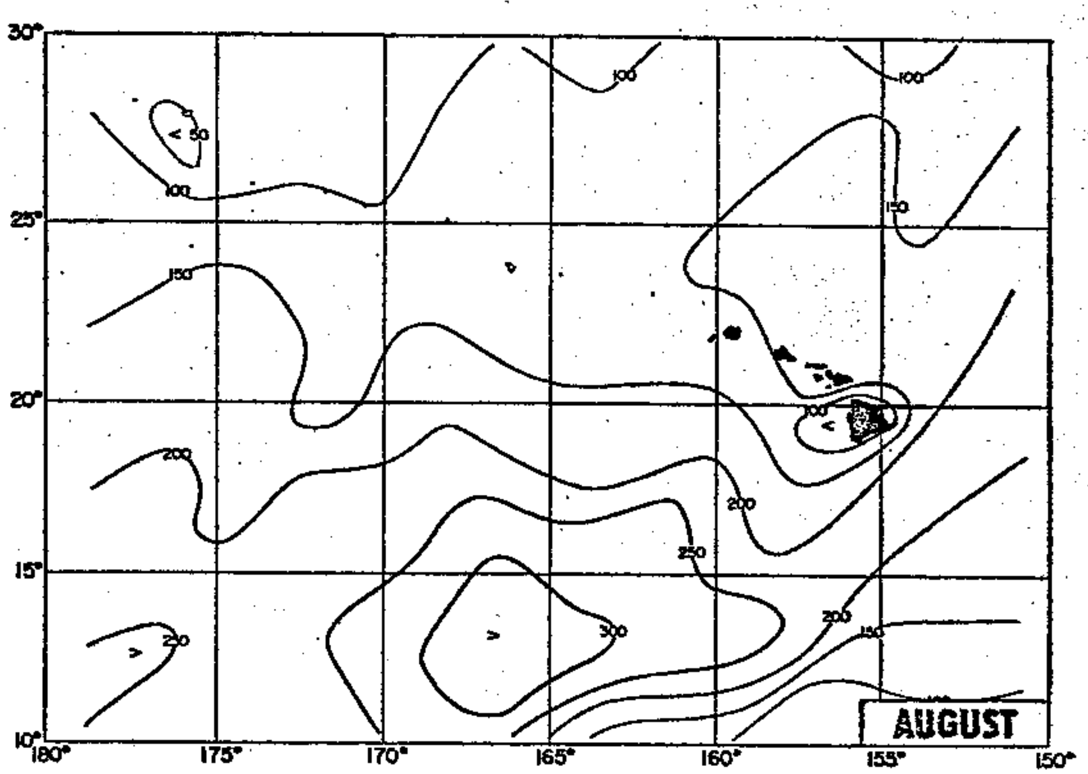
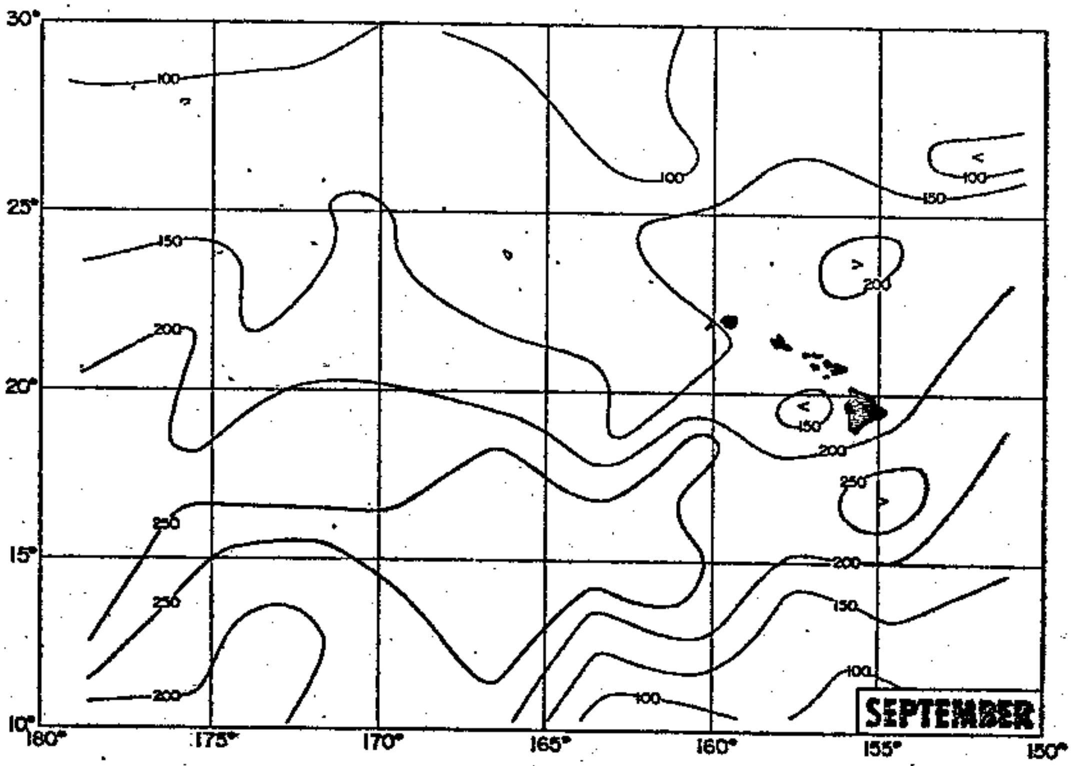


Figure 25h.—Distribution of the depth of the mixed layer (ft) in August (Seckel 1952).

Figure 25i.—Distribution of the depth of the mixed layer (ft) in September (Seckel 1962).



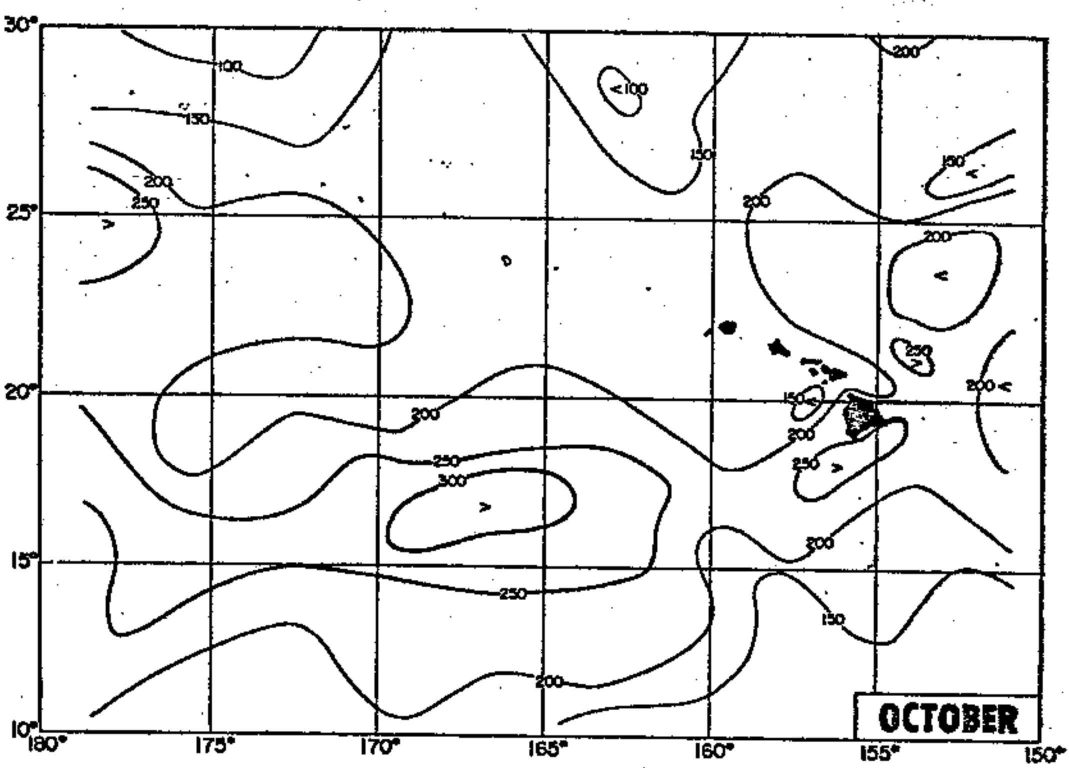
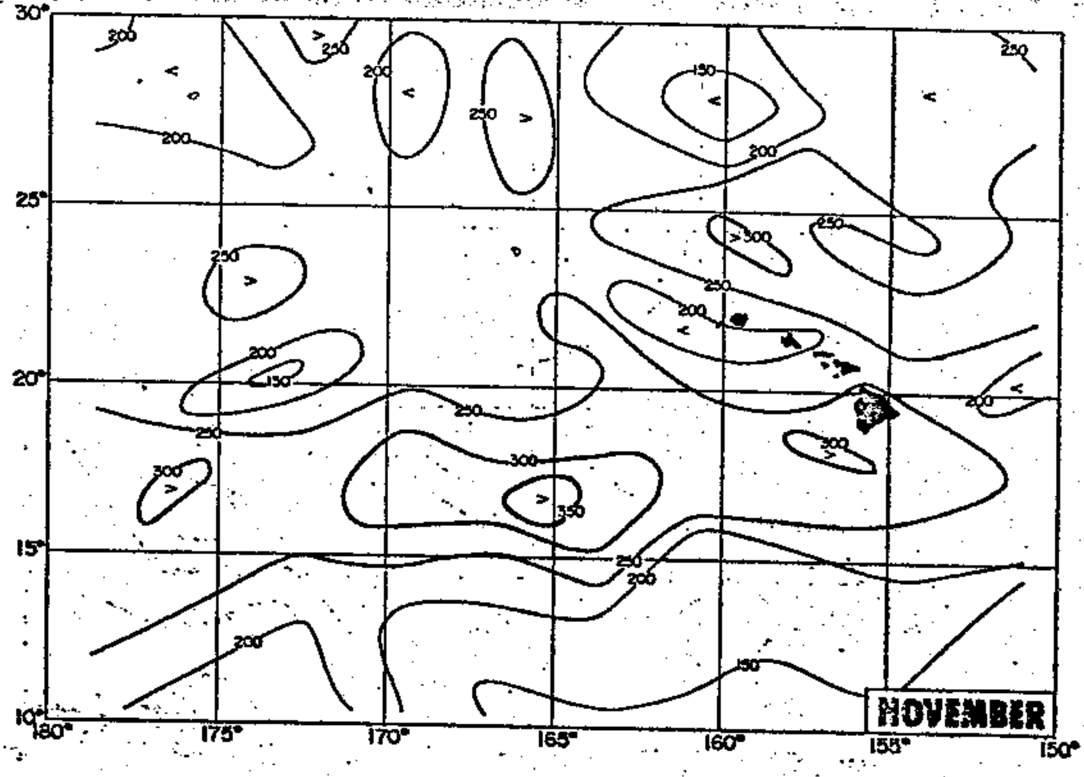


Figure 25j.—Distribution of the depth of the mixed layer (ft) in October (Seckel 1962).

Figure 25k.—Distribution of the depth of the mixed layer (ft) in November (Seckel 1962).



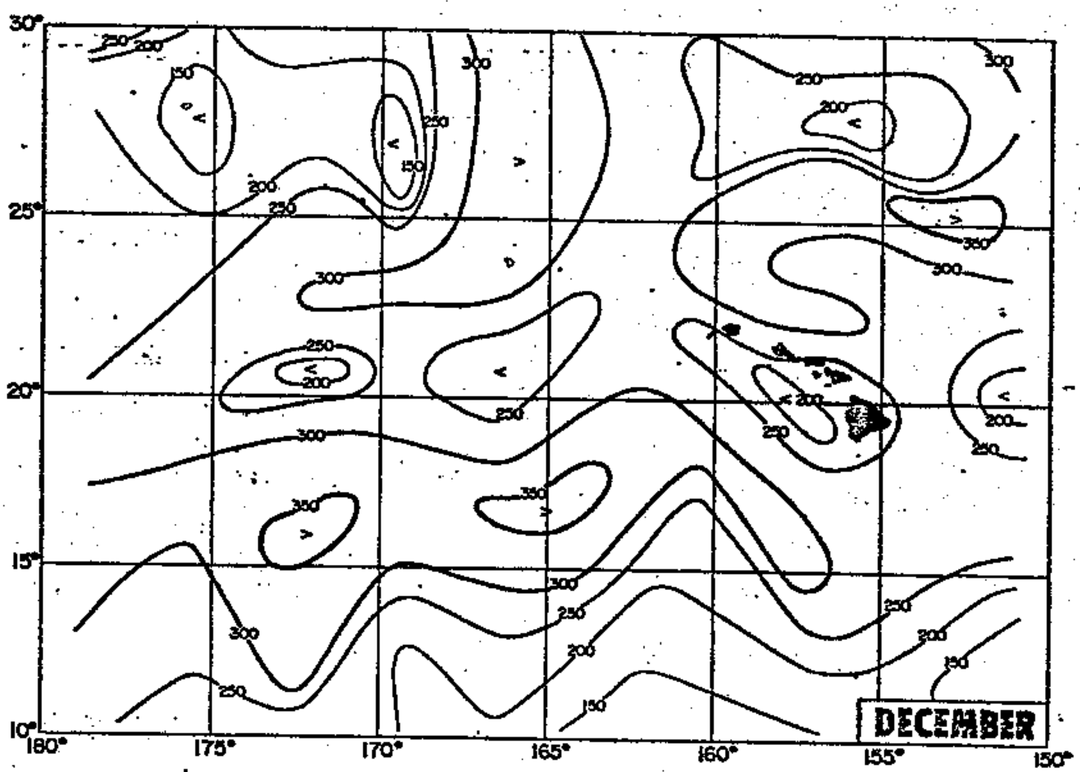


Figure 25l.—Distribution of the depth of the mixed layer (ft) in December (Seckel 1962).

Seckel 1962
Fig. 26

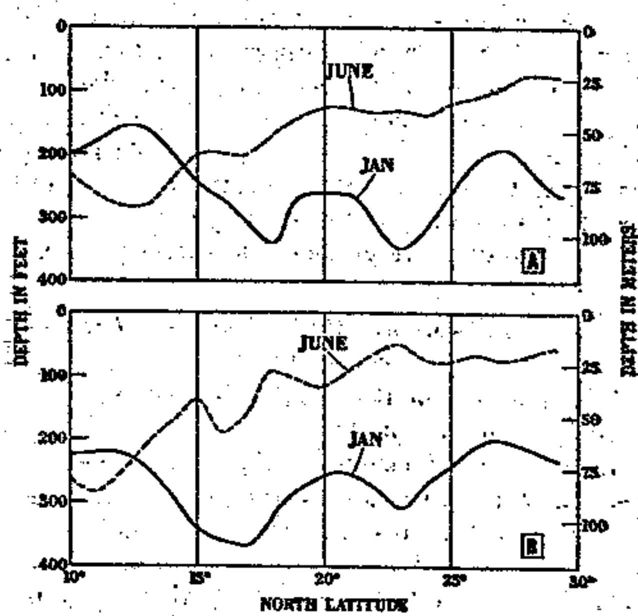


Figure 26.—Meridional profile of the depth of mixed layer in January and June, lat 10° to 30° N. Panel A, long 153°-161° W; Panel B, long 168°-176° W. (Seckel 1962).

Seckel 1962
7-27

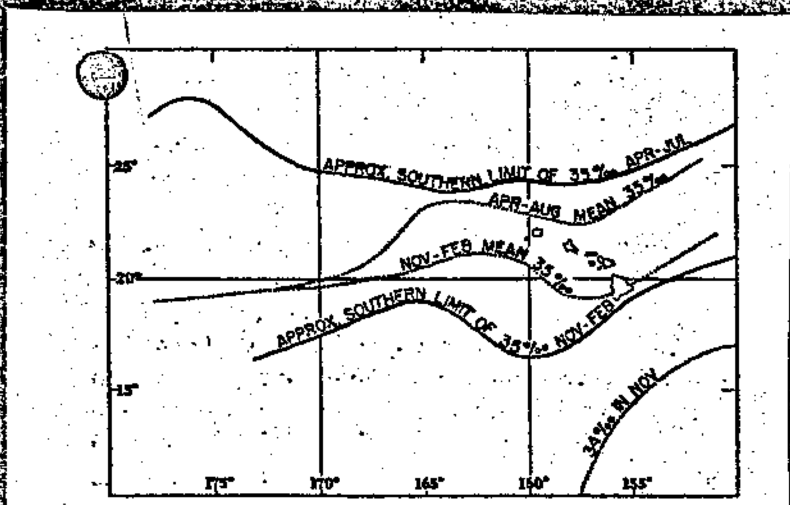


Figure 27.--Southern limit of the 35 °/oo salinity isopleth in April-July and November-February, and mean location of the 35 °/oo isopleth in April-August and November-February (Seckel 1962).

Seckel 1962
Fig. 28

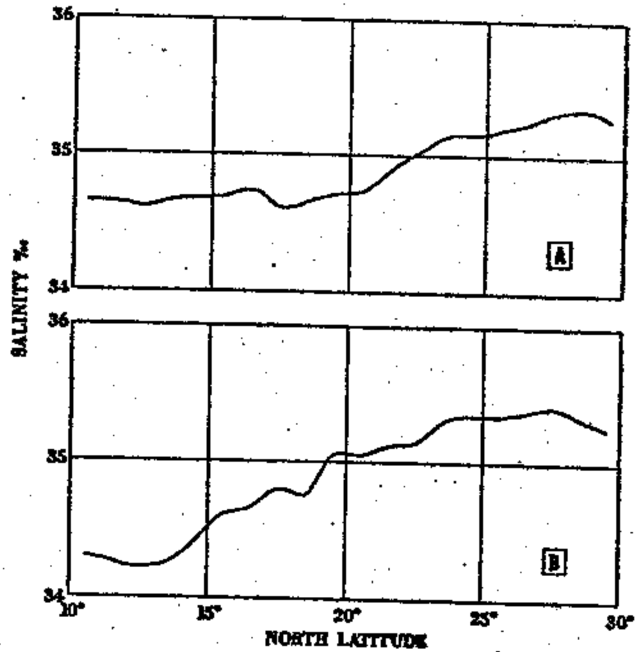
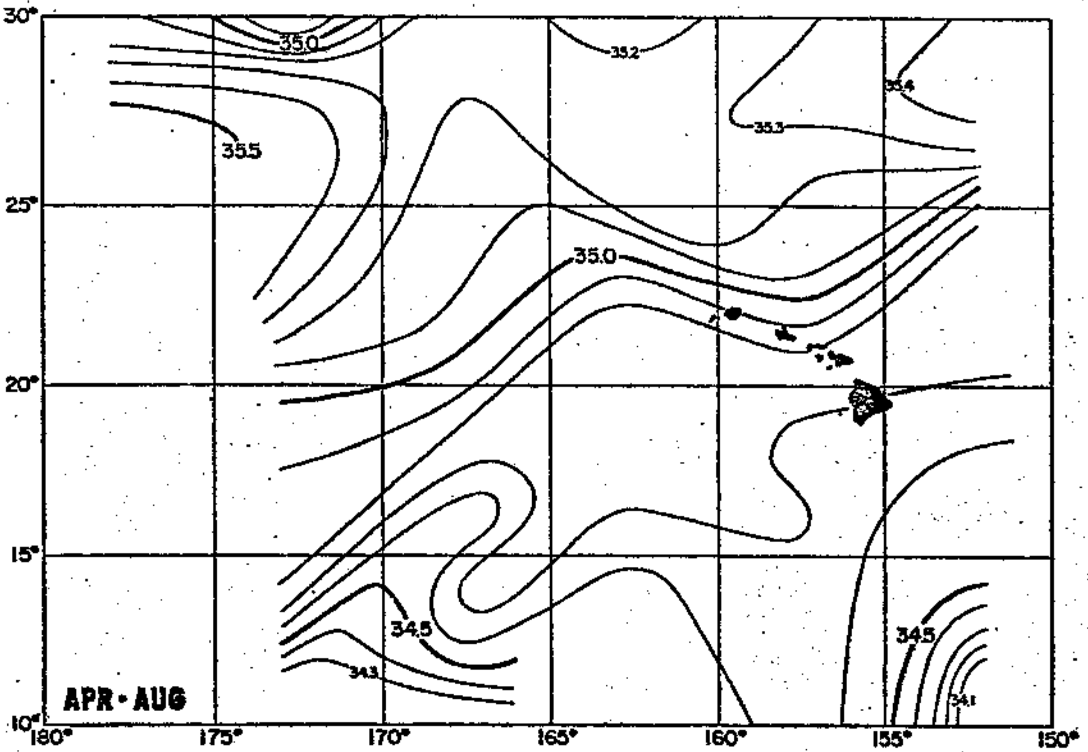


Figure 28.—Mean meridional salinity profile at lat. 10° to 30° N between long. 155° and 160° W. Panel A, April to August; panel B, November to February (Seckel 1962).

Figure 29a.—Distribution of surface salinity (o/oo) in April-August (Seckel 1962).



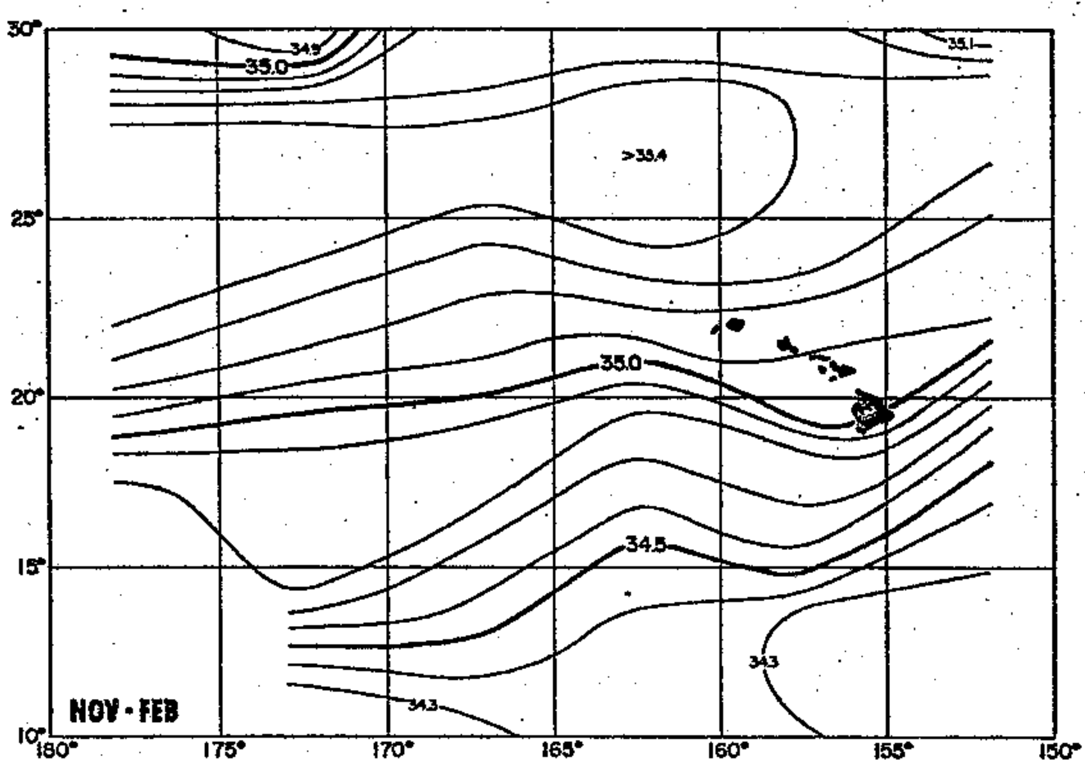


Figure 29b.—Distribution of surface salinity (o/oo) in November-February (Seckel 1962).

June 1951
Fig. 30a

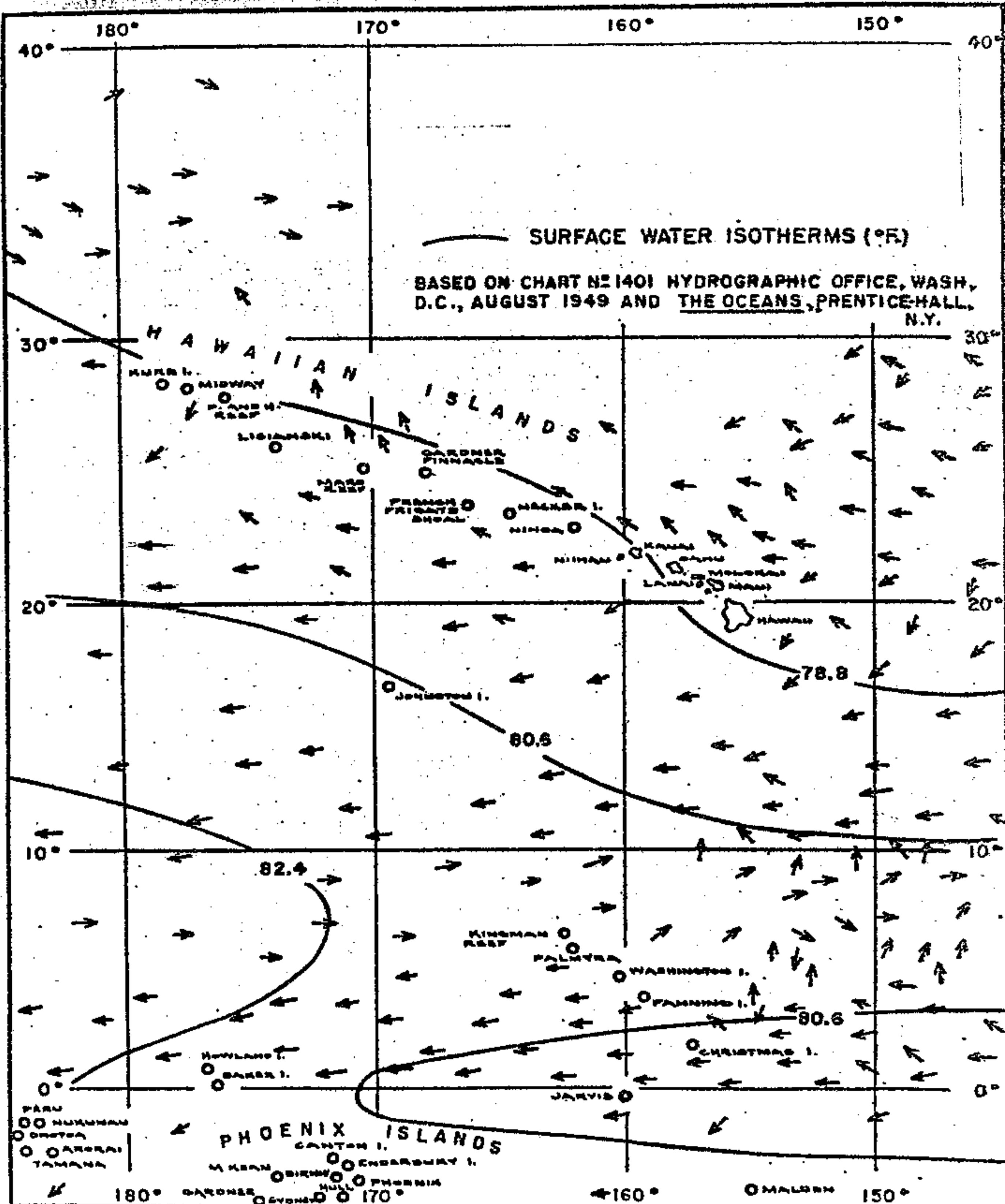


Figure 30a.--Surface currents during summer in the central Pacific Ocean (June 1951).

June 1951

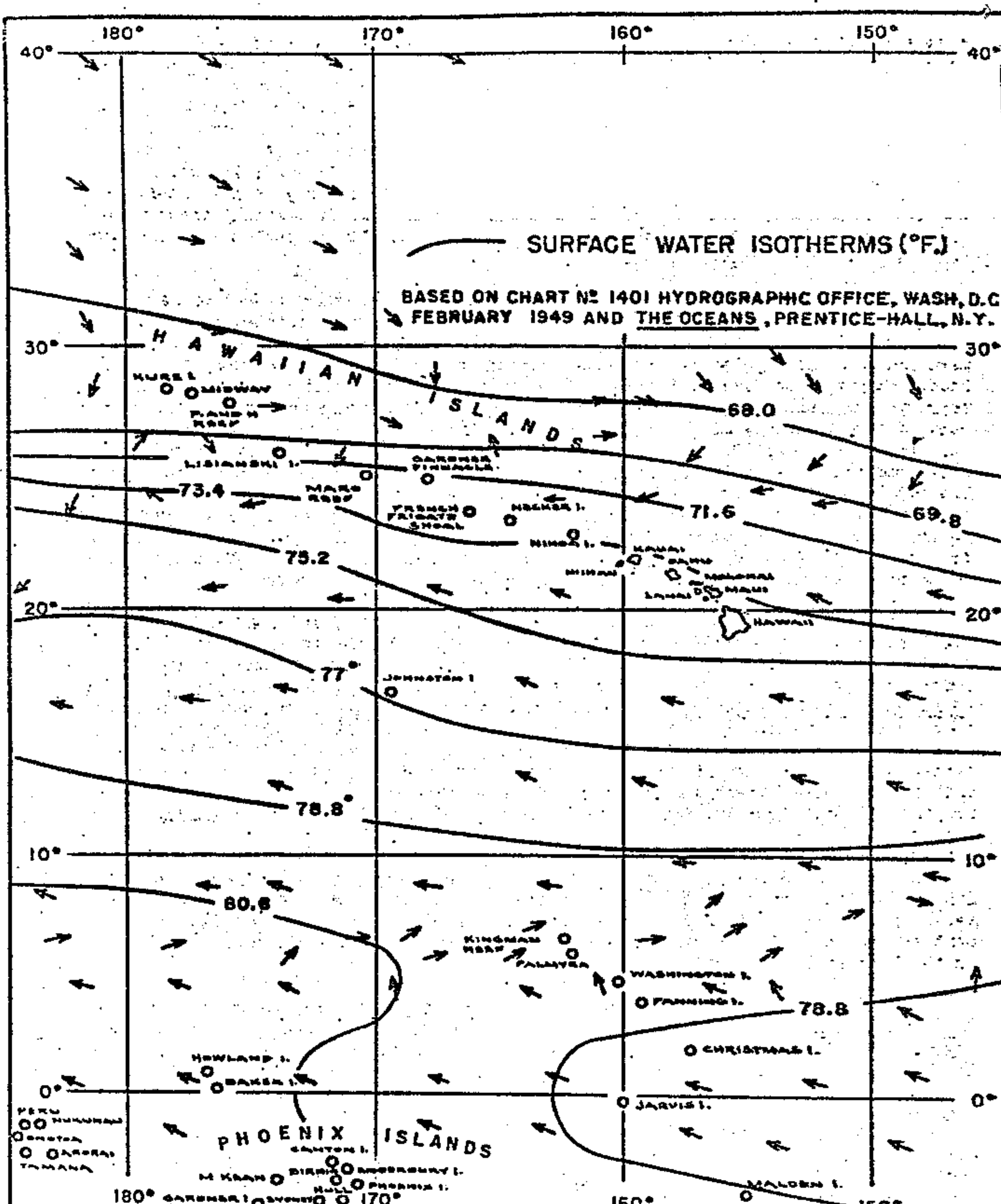


Figure 30b.--Surface currents during winter in the central Pacific Ocean (June 1951).

U. S. Navy Hydrographic Office 1950

Figure 31a.—Surface drift vectors for January (U. S. Navy Hydrographic Office 1950).

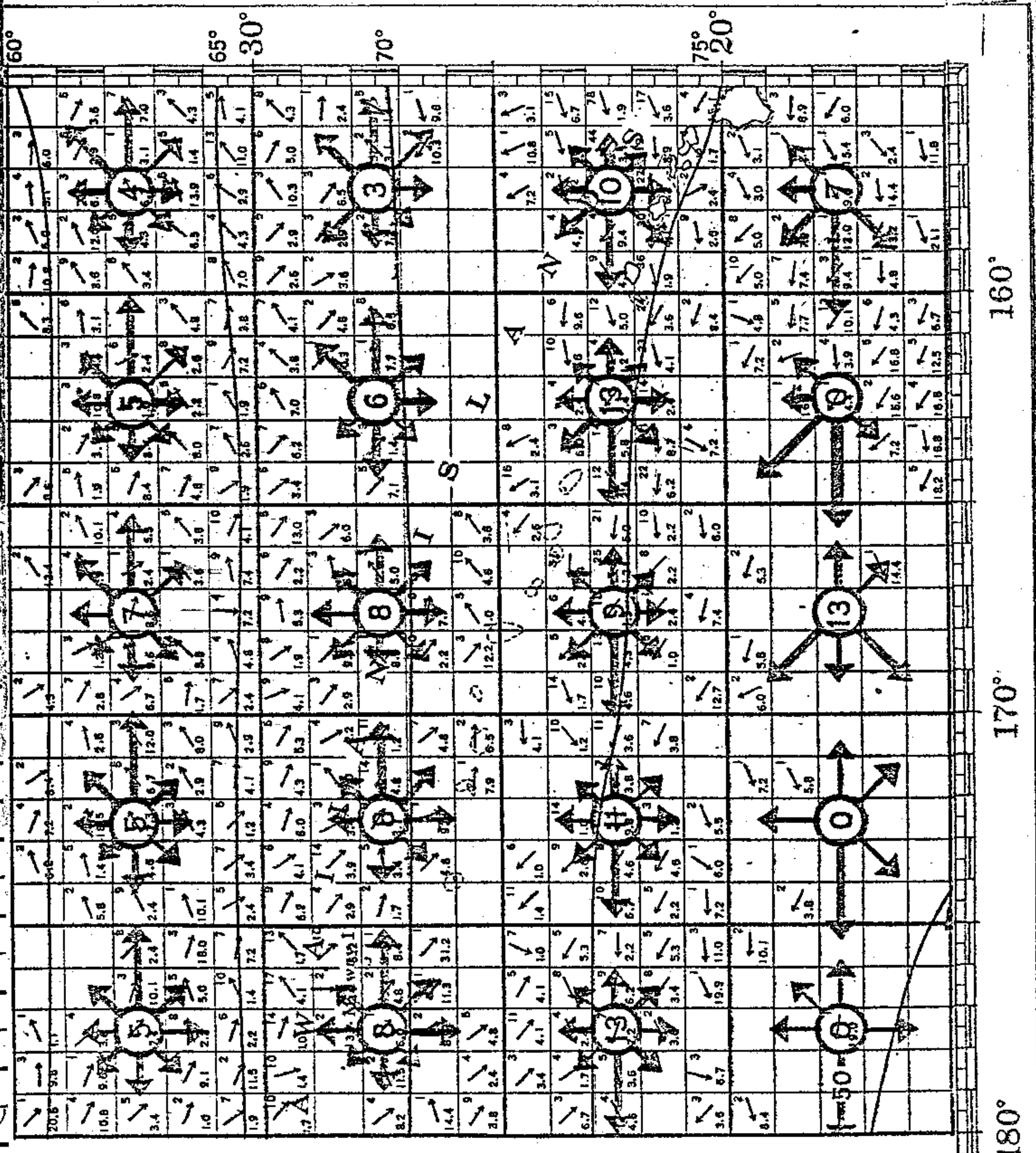


Figure 31b.—Surface drift vectors for February (U. S. Navy Hydrographic Office 1950).

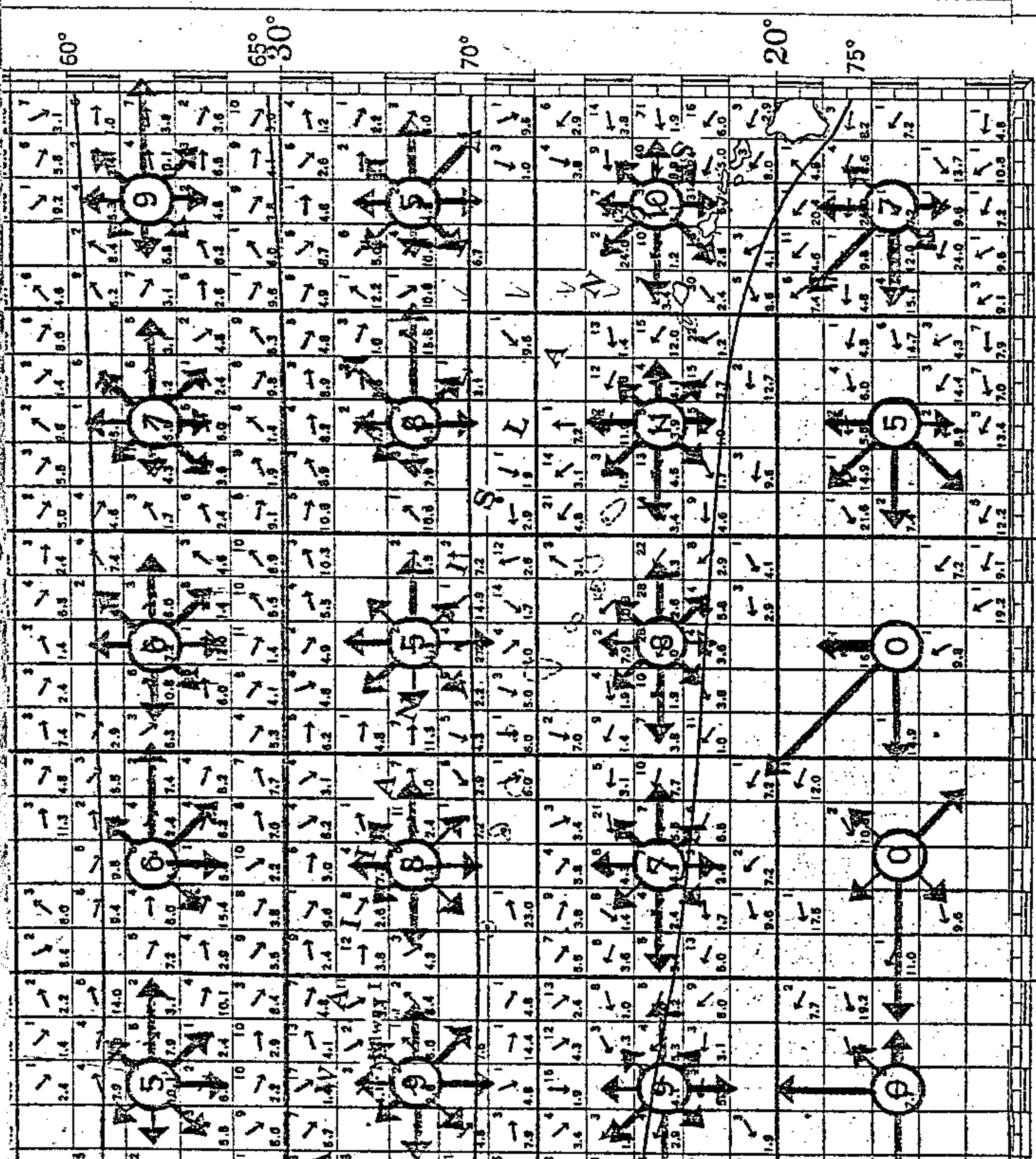


Figure 31c.--Surface drift vectors for March (U. S. Navy Hydrographic Office 1950).

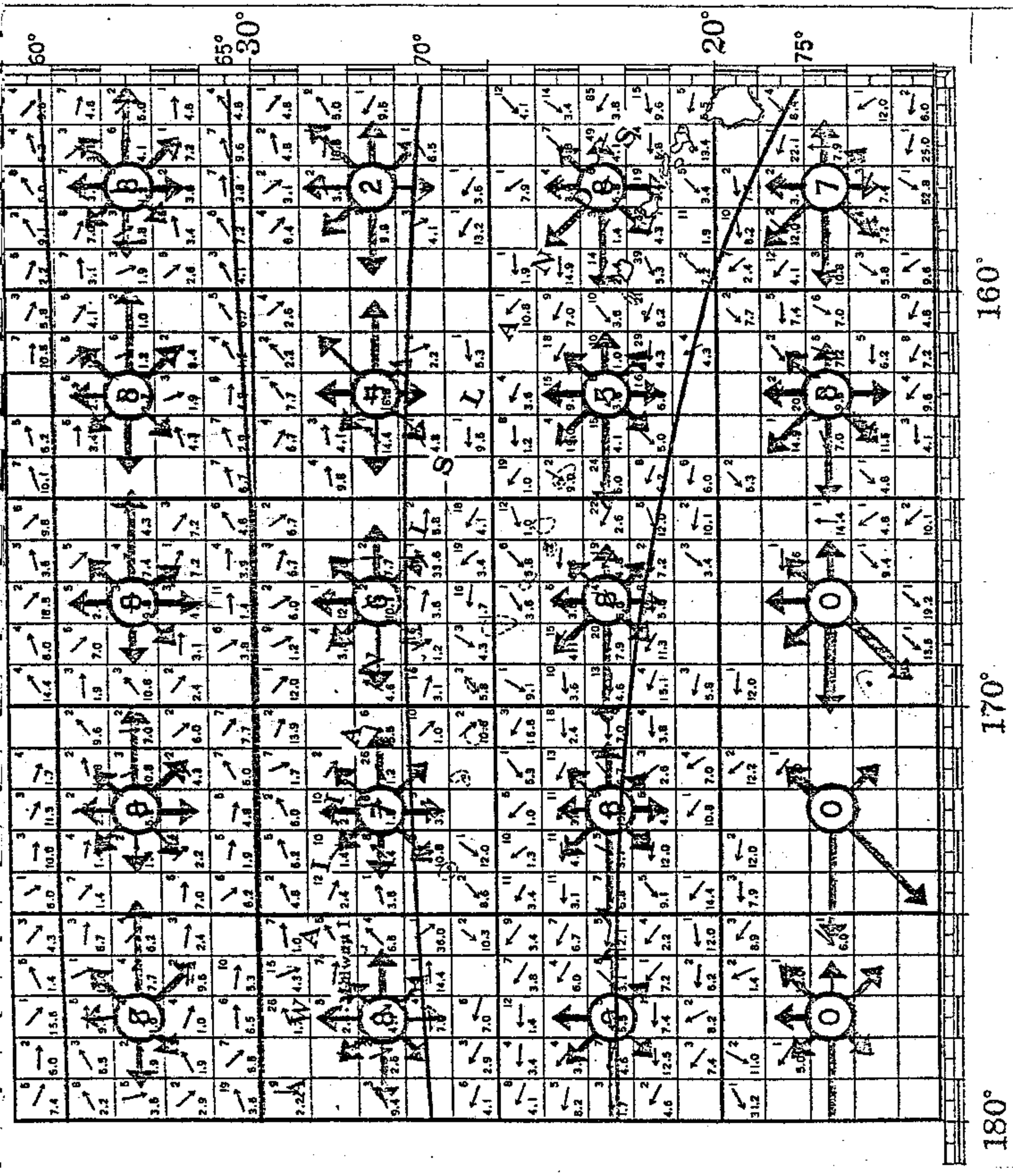


Figure 31d.—Surface drift vectors for April (U. S. Navy Hydrographic Office 1950).

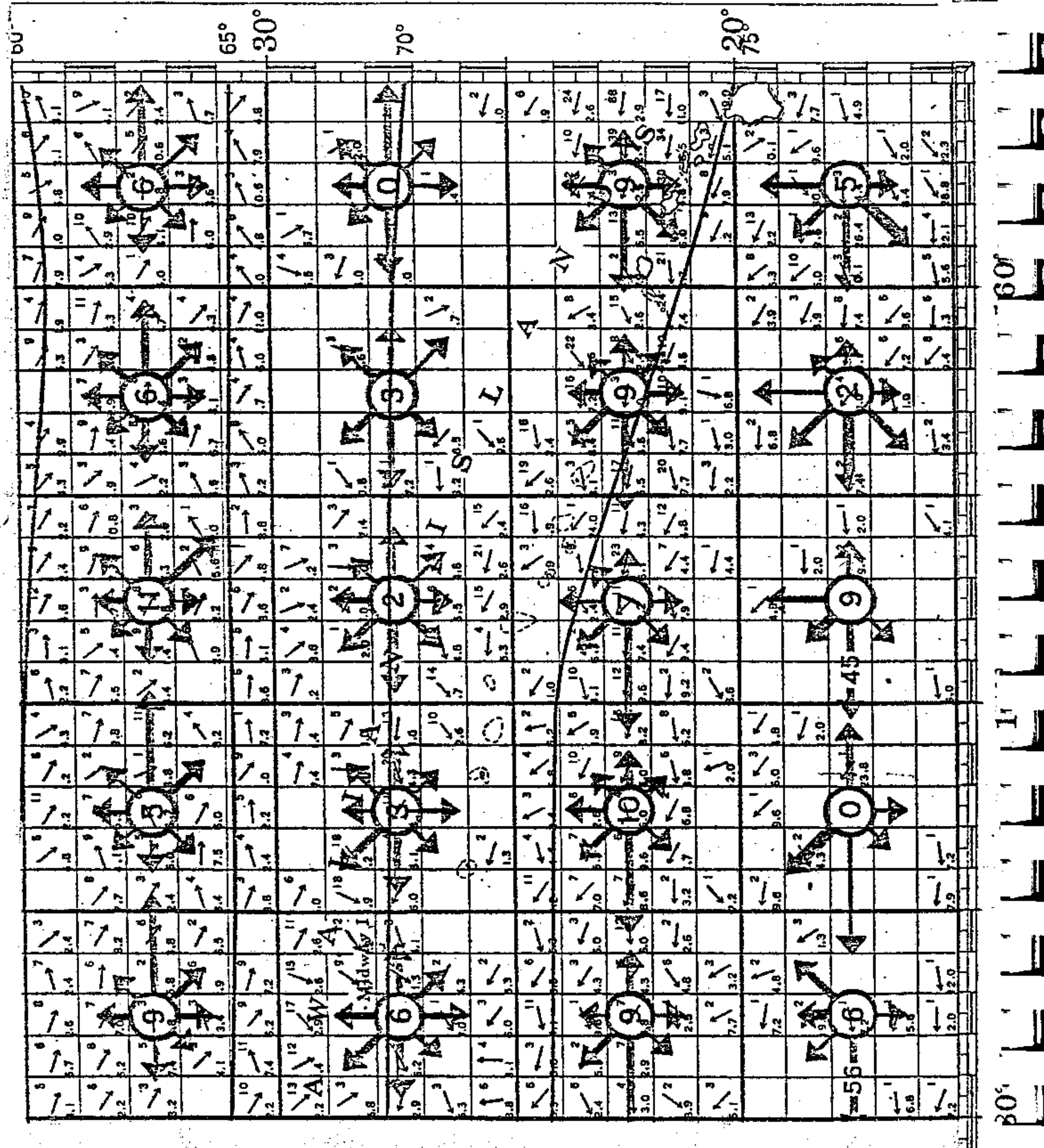


Figure 31e.—Surface drift vectors for May (U. S. Navy Hydrographic Office 1950).

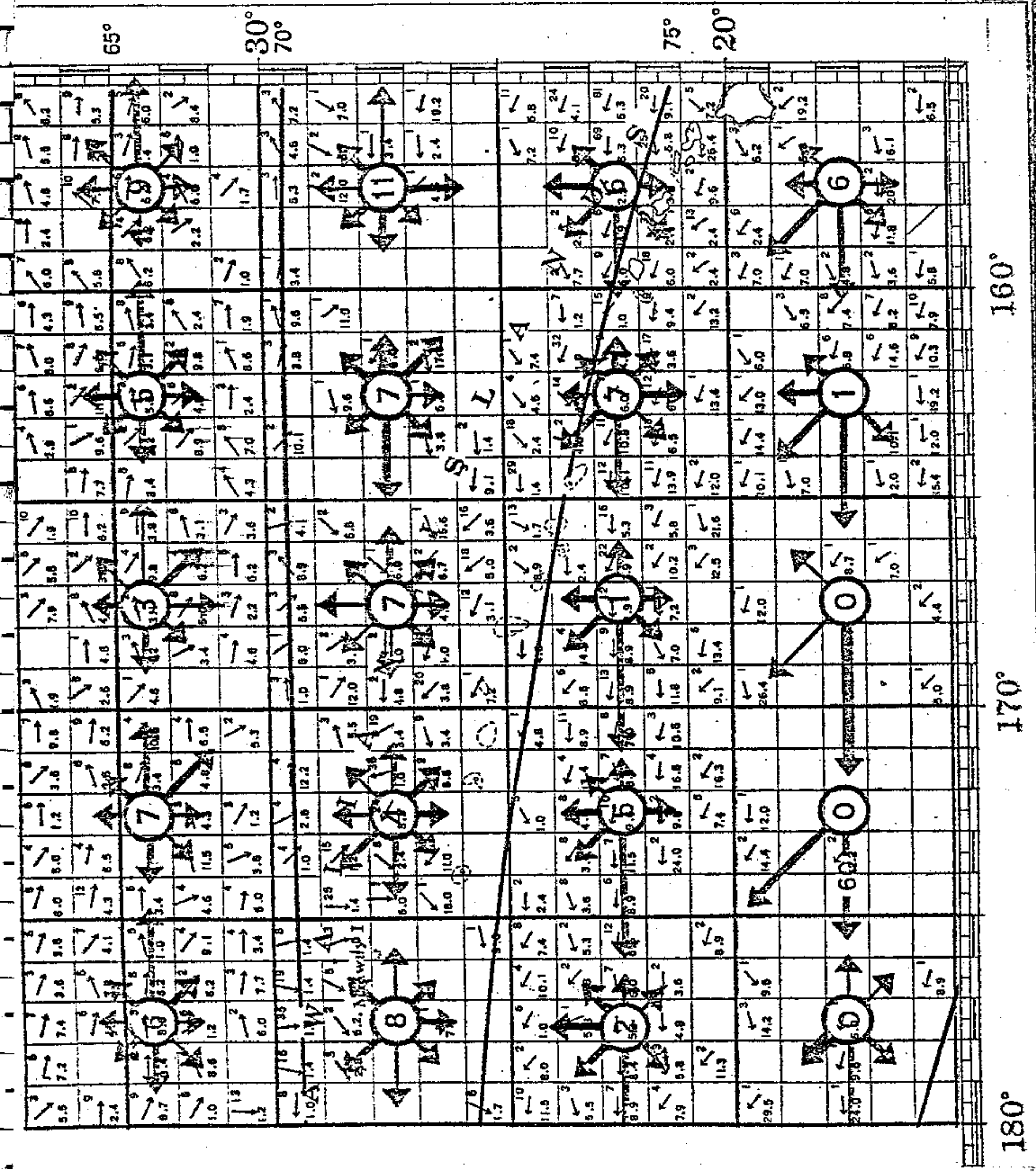


Figure 31f.--Surface drift vectors for June (U. S. Navy Hydrographic Office 1950).

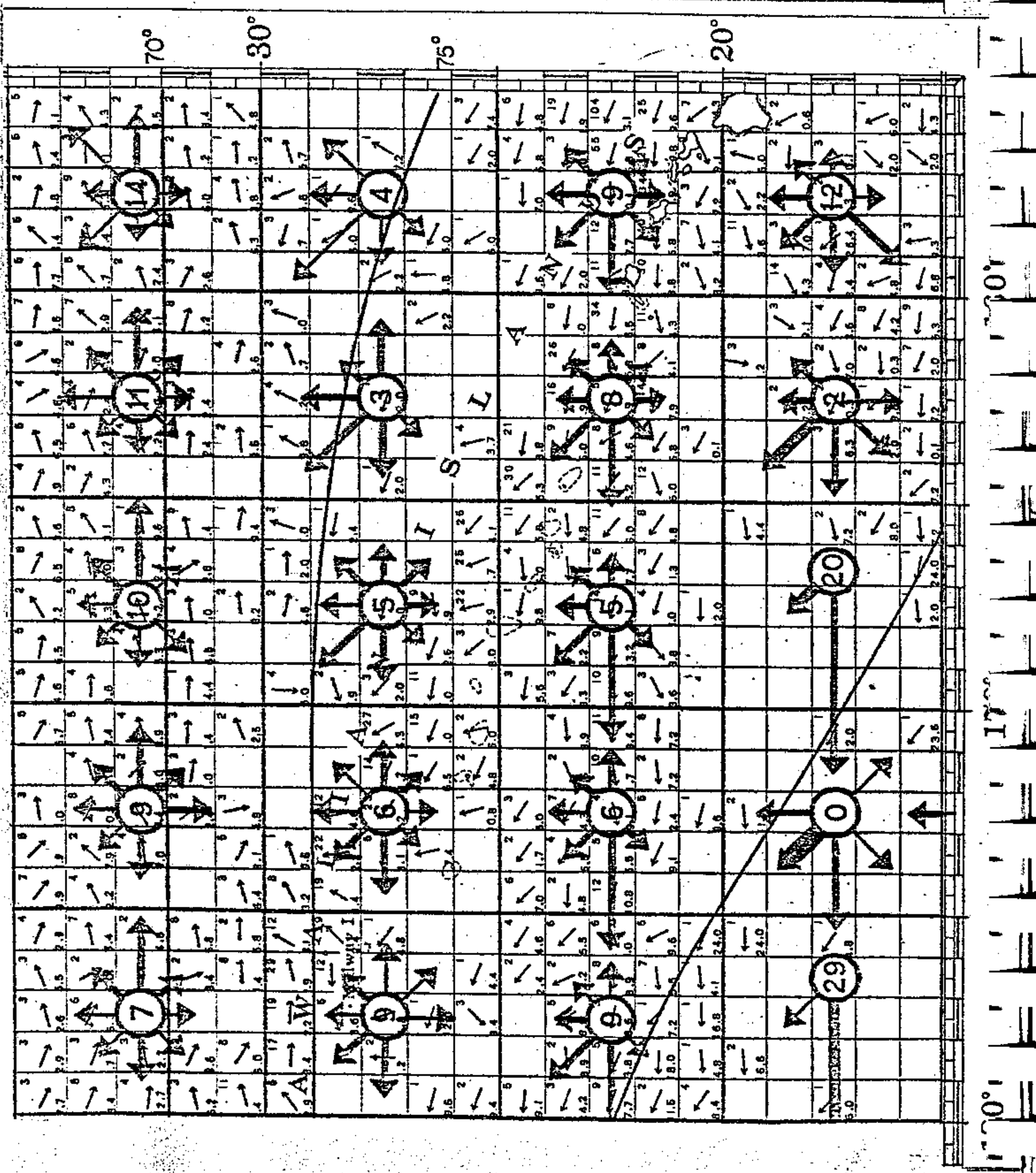


Figure 31g.—Surface drift vectors for July (U. S. Navy Hydrographic Office 1950).

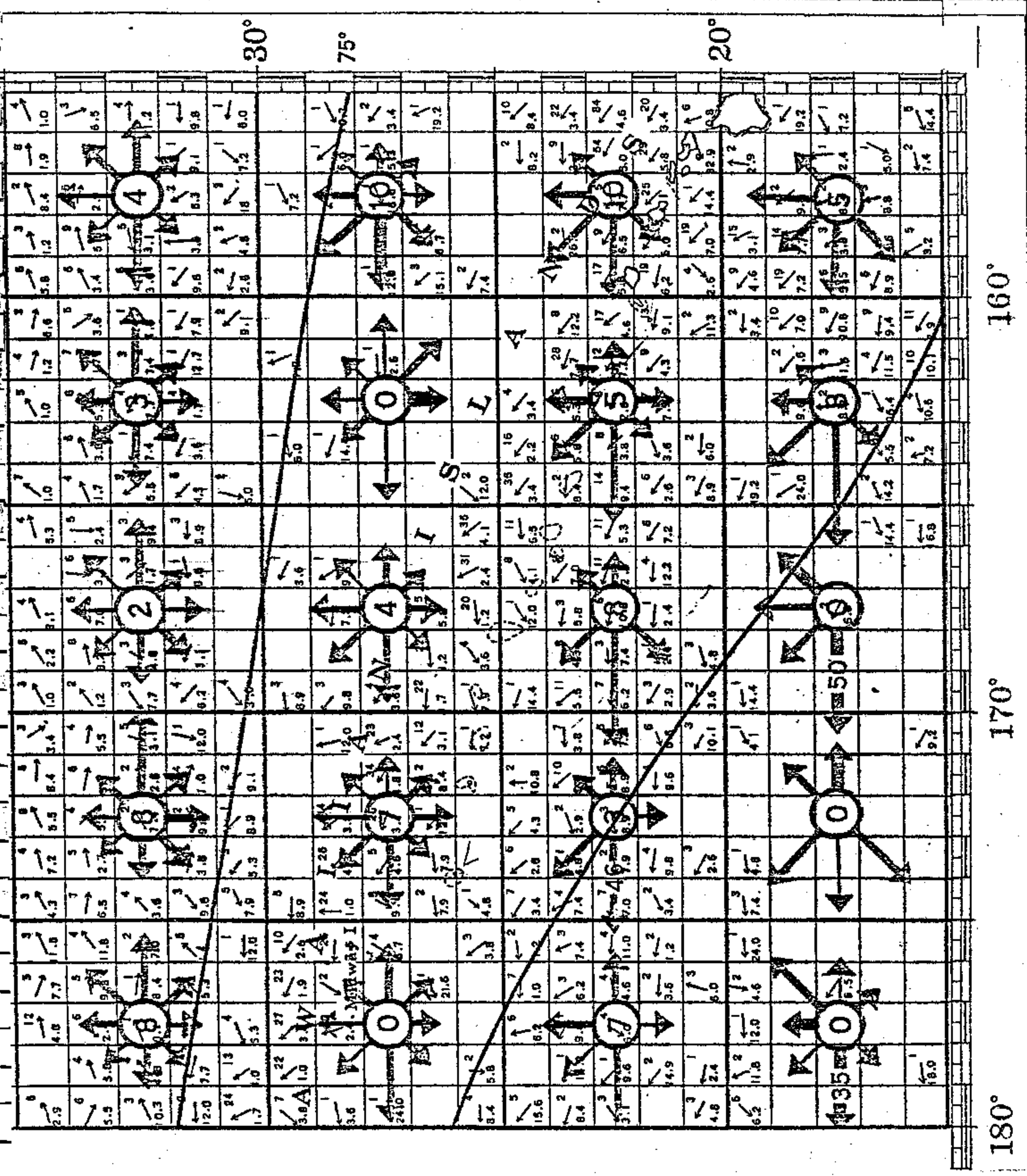


Figure 31h.—Surface drift vectors for August (U. S. Navy Hydrographic Office 1950).

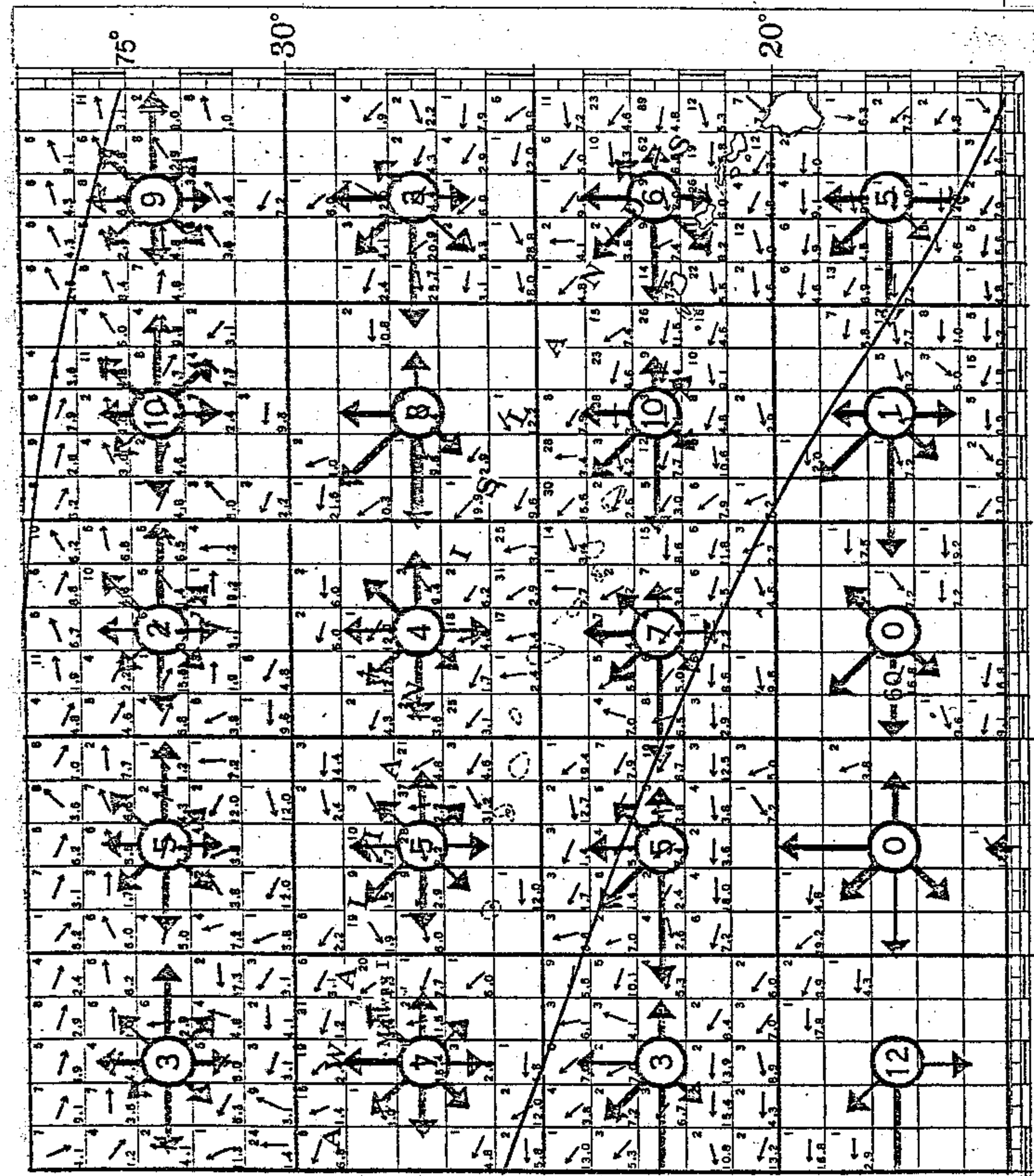


Figure 31i.—Surface drift vectors for September (U. S. Navy Hydrographic Office 1950).

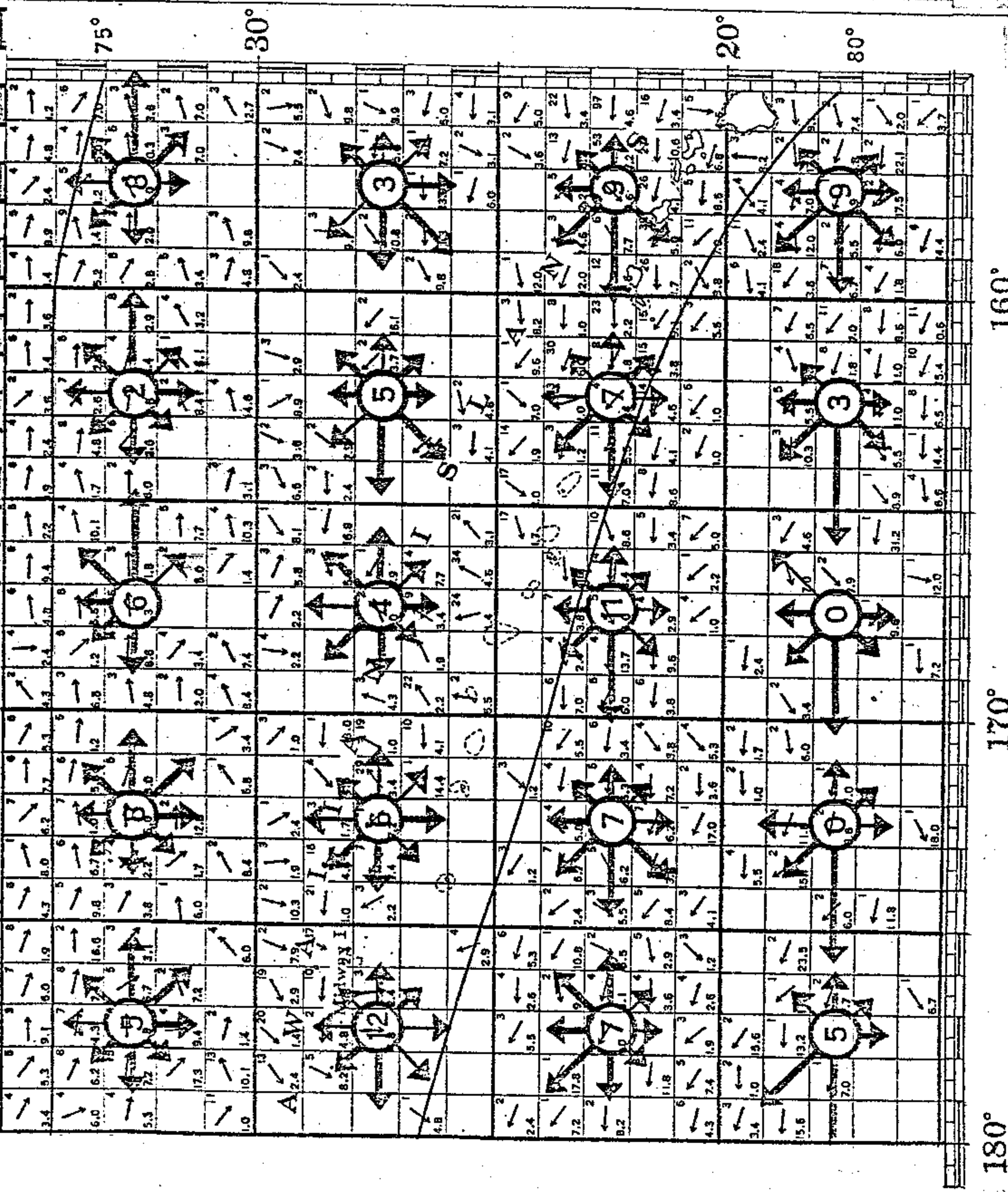


Figure 31j.—Surface drift vectors for October (U. S. Navy Hydrographic Office 1950).

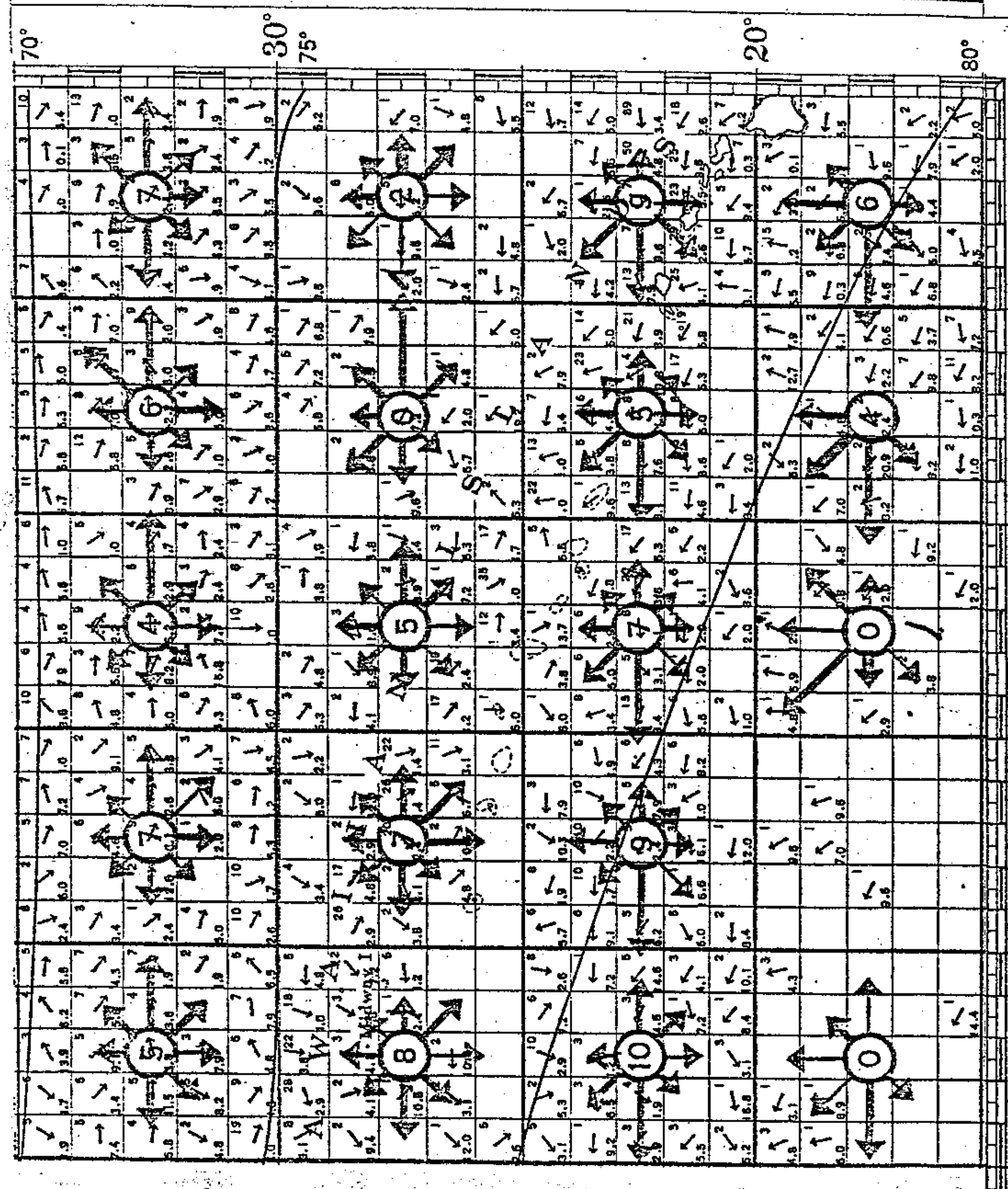


Figure 31k.—Surface drift vectors for November (U. S. Navy Hydrographic Office 1950).

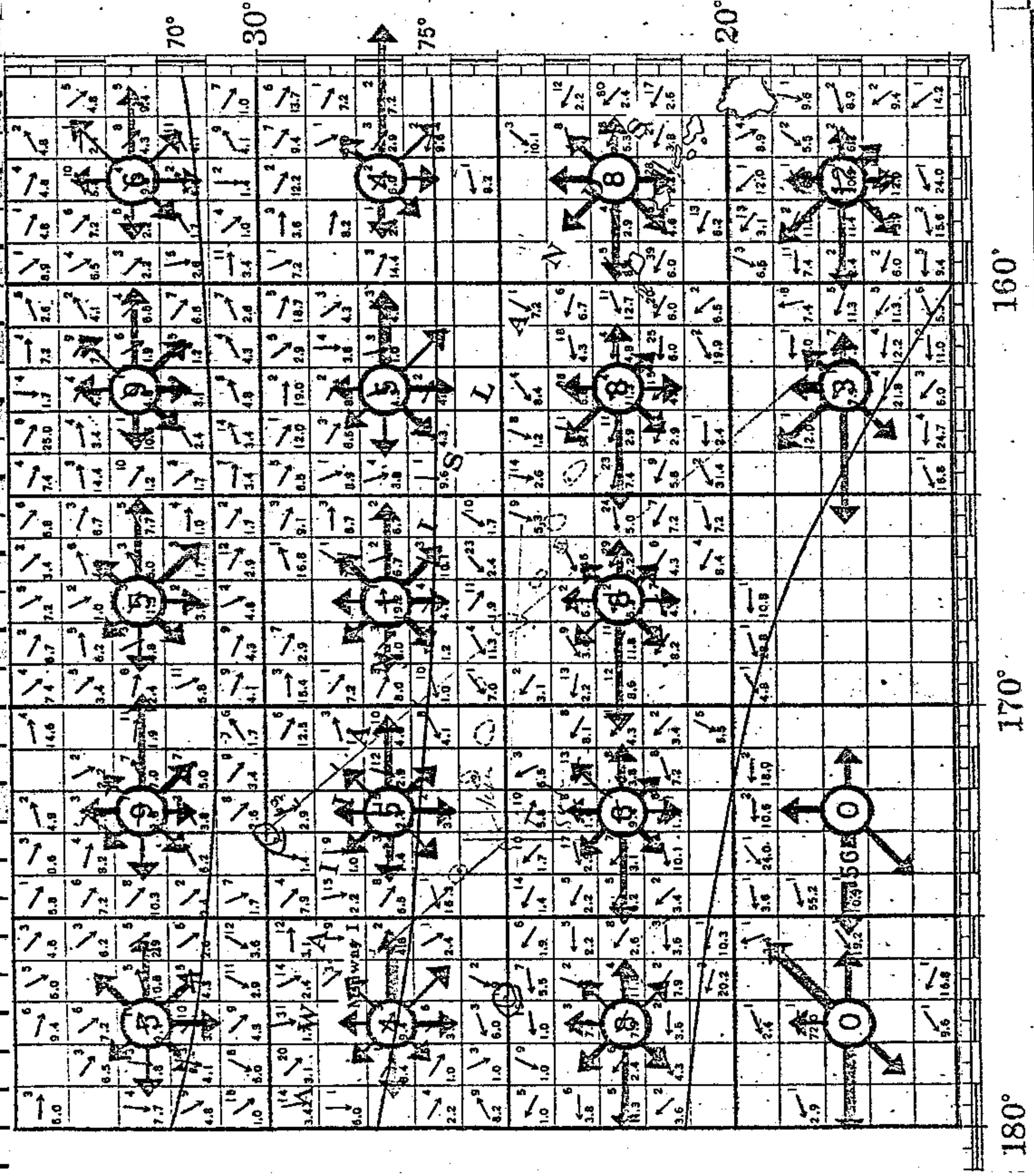
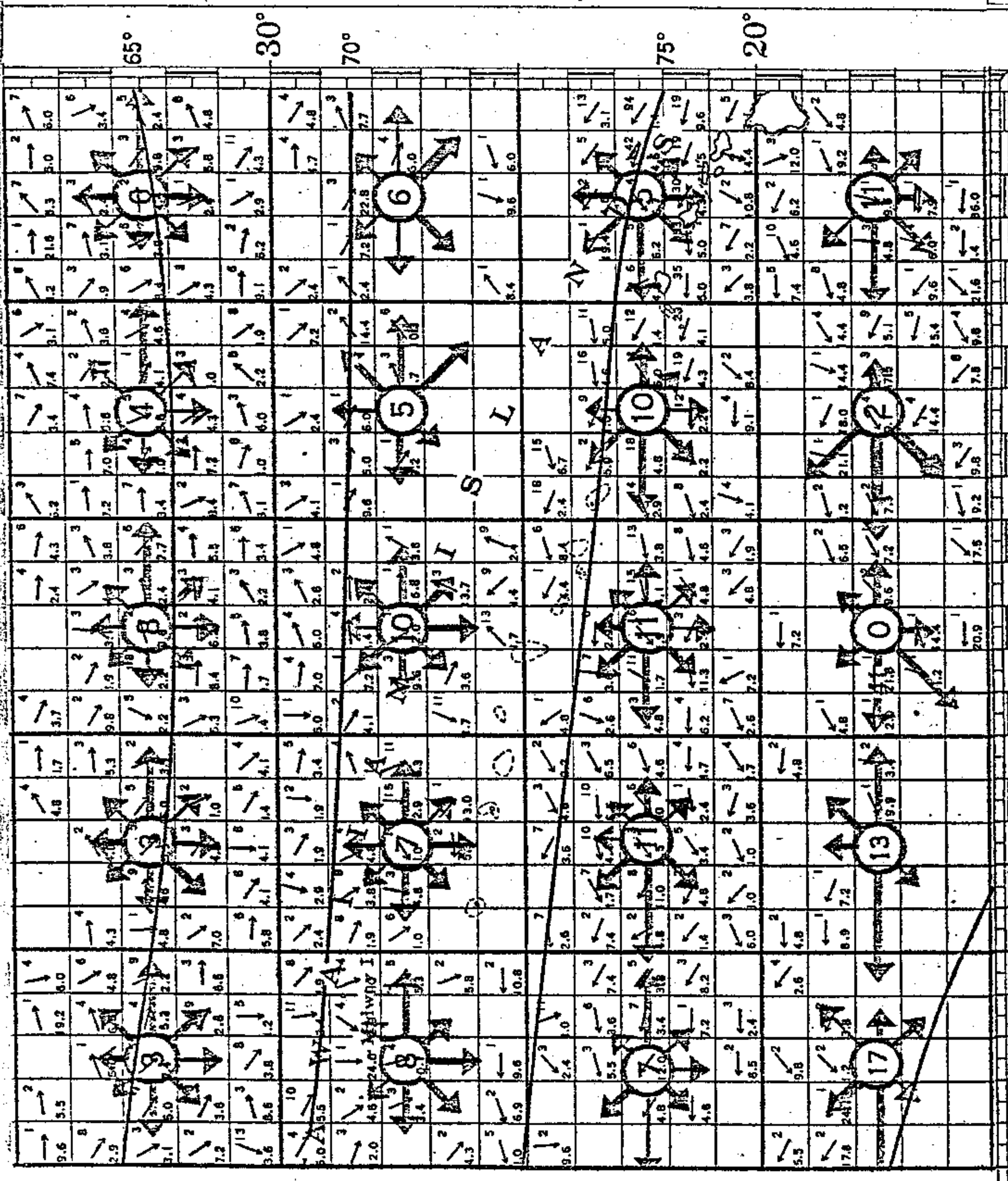


Figure 31ℓ.—Surface drift vectors for December (U. S. Navy Hydrographic Office 1950).



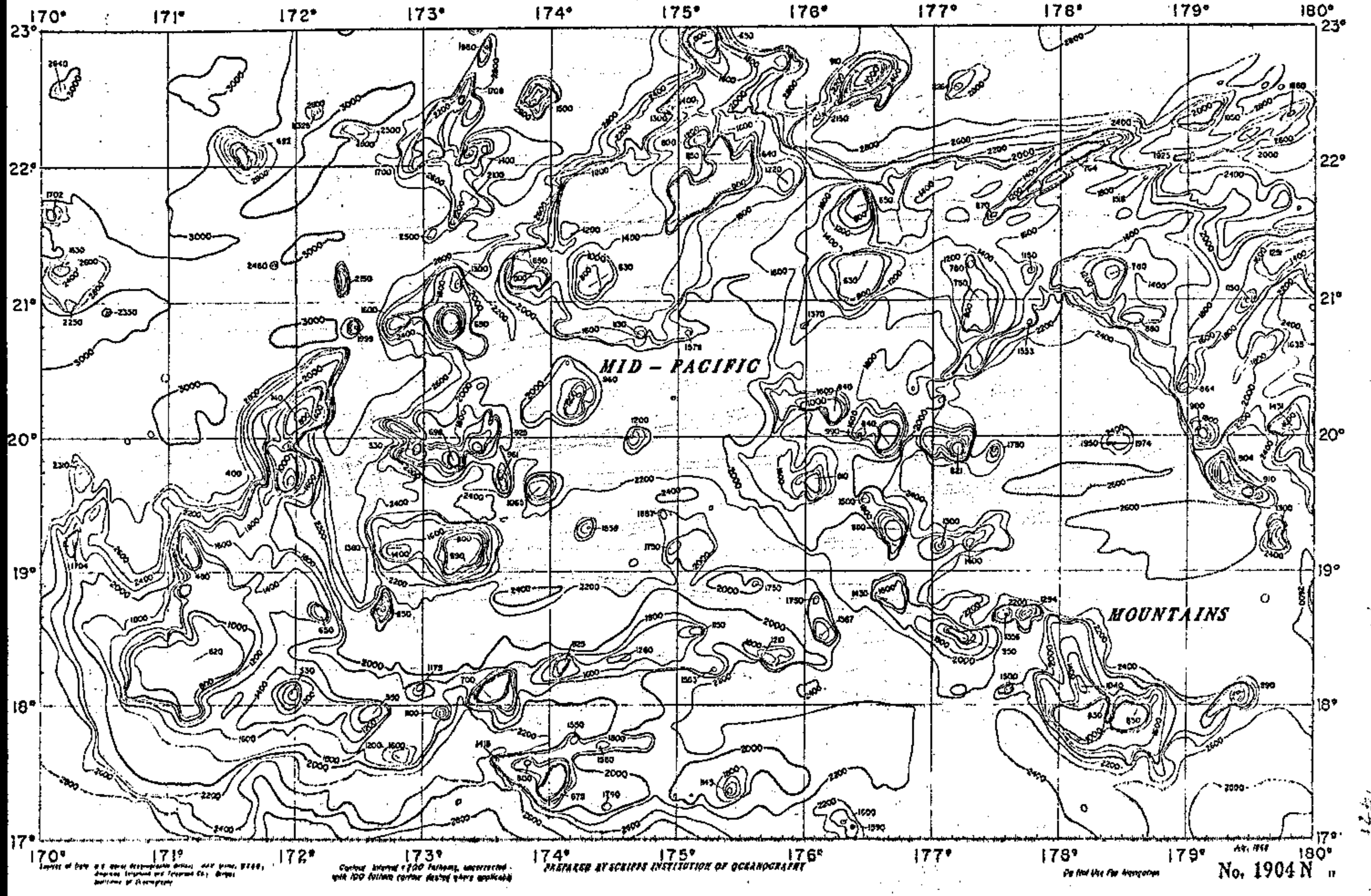


Figure 32a.—Bathymetric features in lat 17°-23° N, long 170° E-180°

(Scripps Institution of Oceanography 1971).

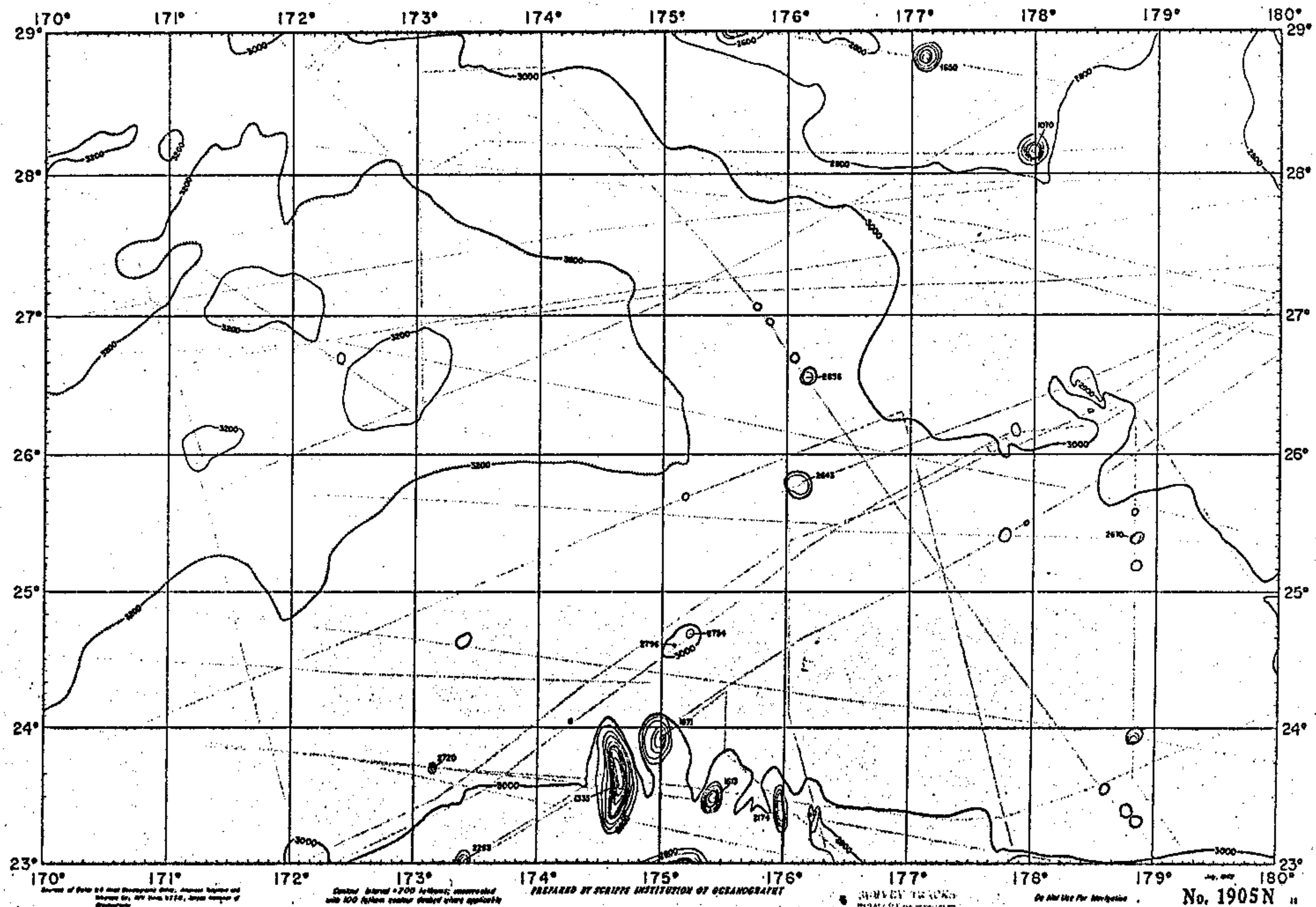


Figure 32b.--Bathymetric features in lat 23°-29° N, long 170° E-180°.

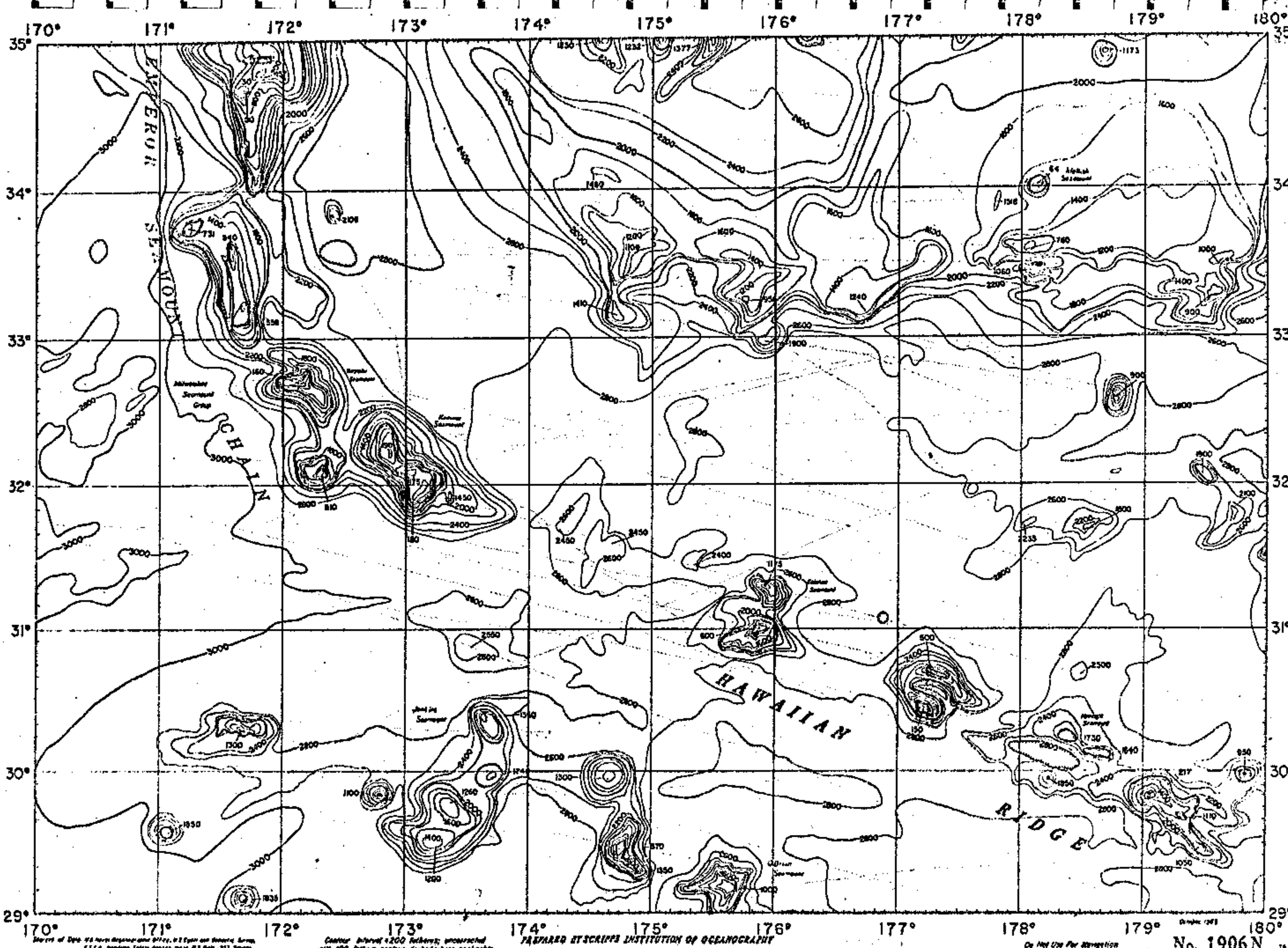


Figure 32c.—Bathymetric features in lat. 29°-35° N, long. 170° E-180°
(Scripps Institution of Oceanography 1971).

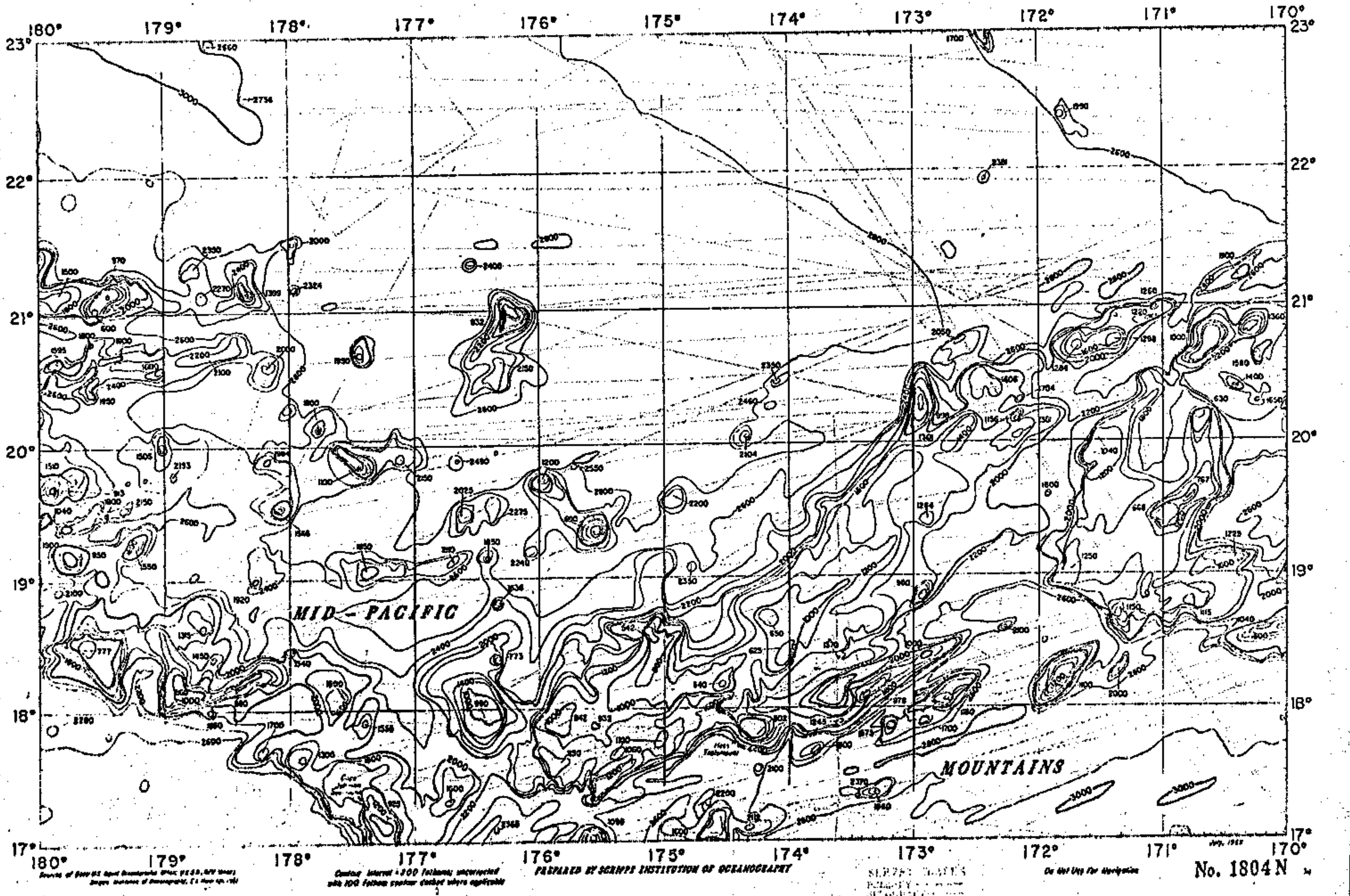


Figure 32d.—Bathymetric features in lat. 17°–23° N, long. 170° W–180°

(Scripps Institution of Oceanography 1977)

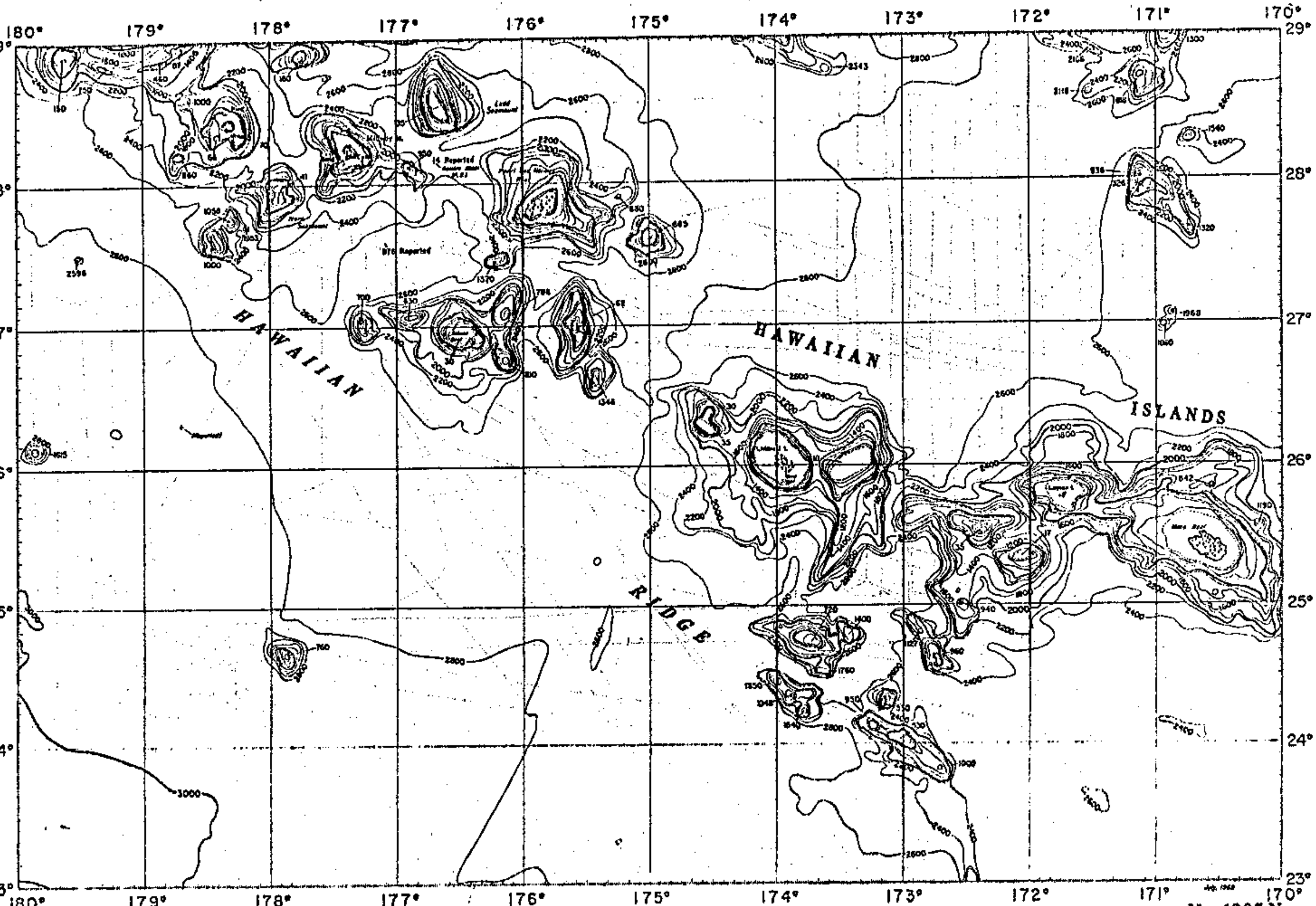


Figure 32e.—Bathymetric features in lat. 23°-29° N, long. 170° W-180°

(Scripps Institution of Oceanography 1971).

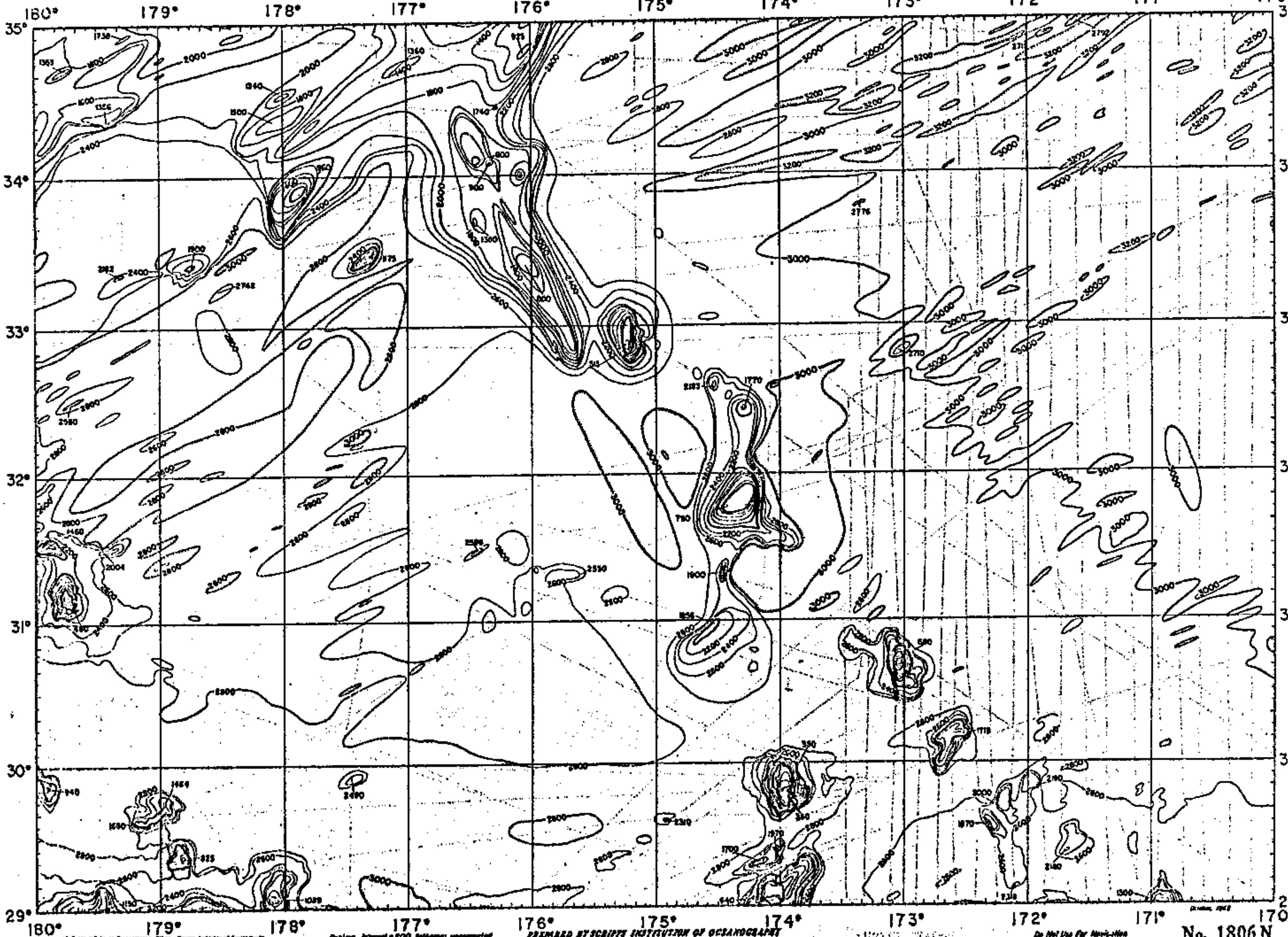


Figure 32f.--Bathymetric features in lat. 29°-35° N, long. 170° W-180°

(Sc ps itu n o. ear an 71)

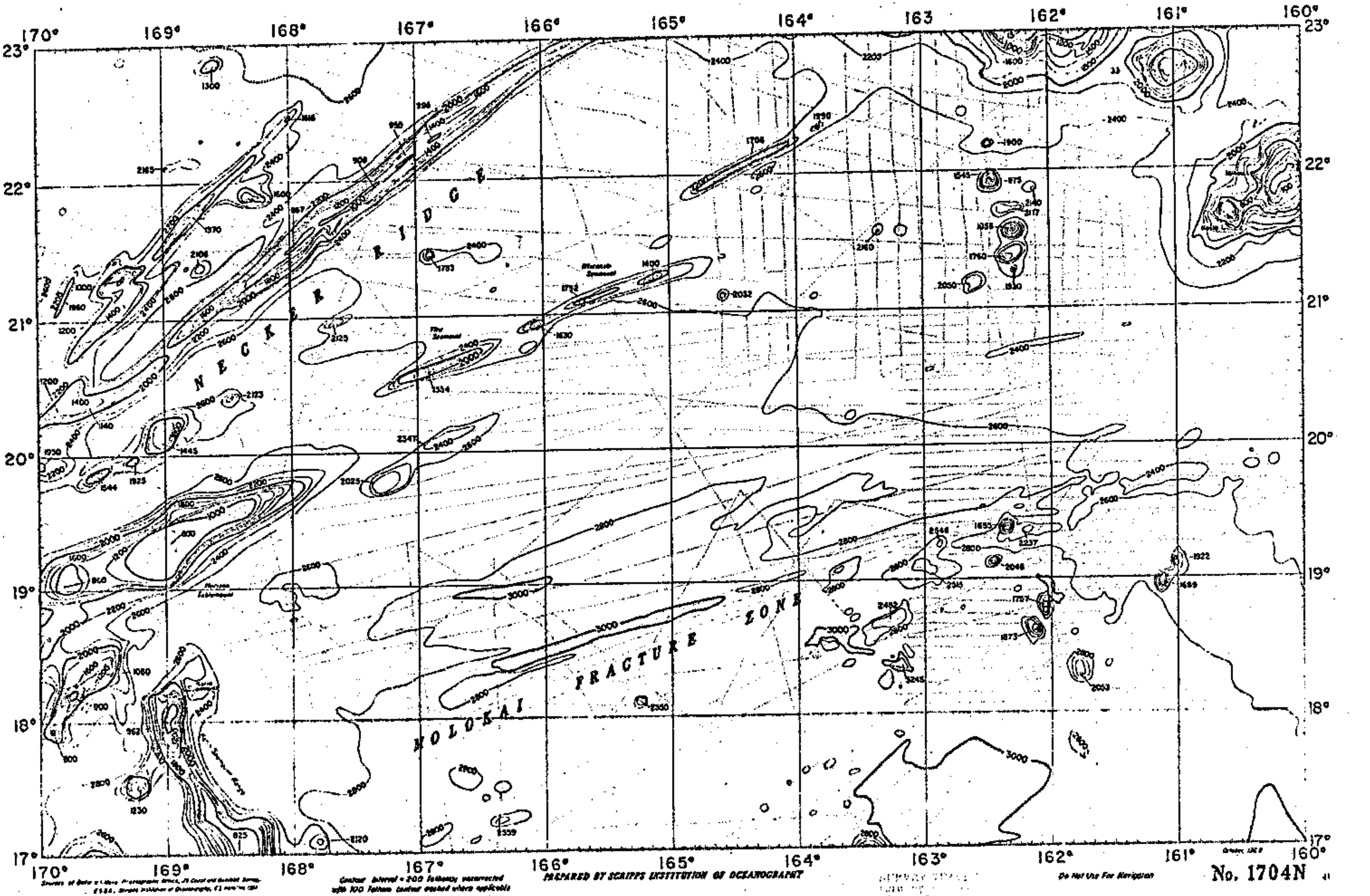


Figure 32g.—Bathymetric features in lat. 17°–23° N., long. 160°–170° W

(Scripps Institution of Oceanography 1971).

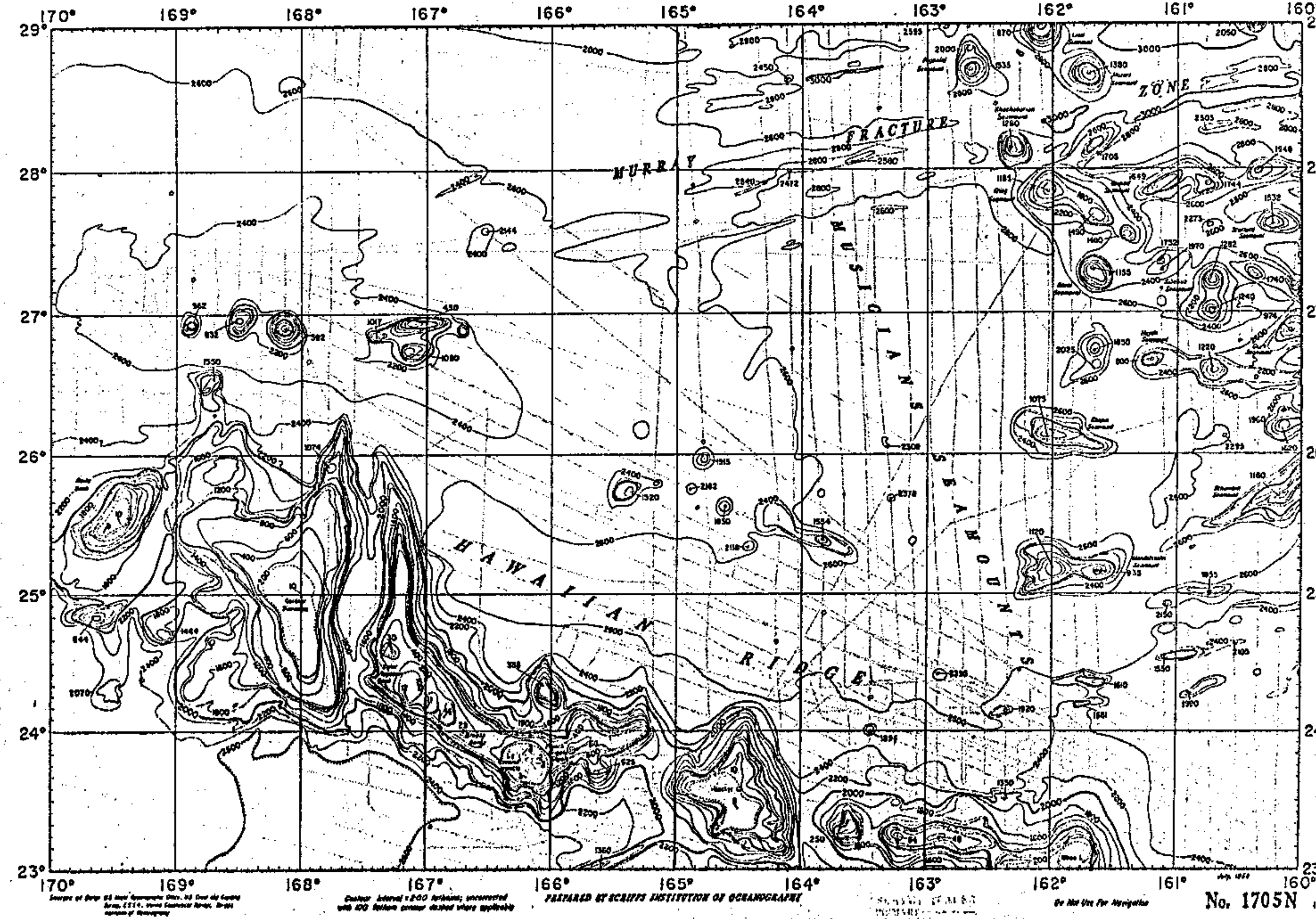


Figure 32h.—Bathymetric features in lat. 23°-29° N, long. 160°-170° W

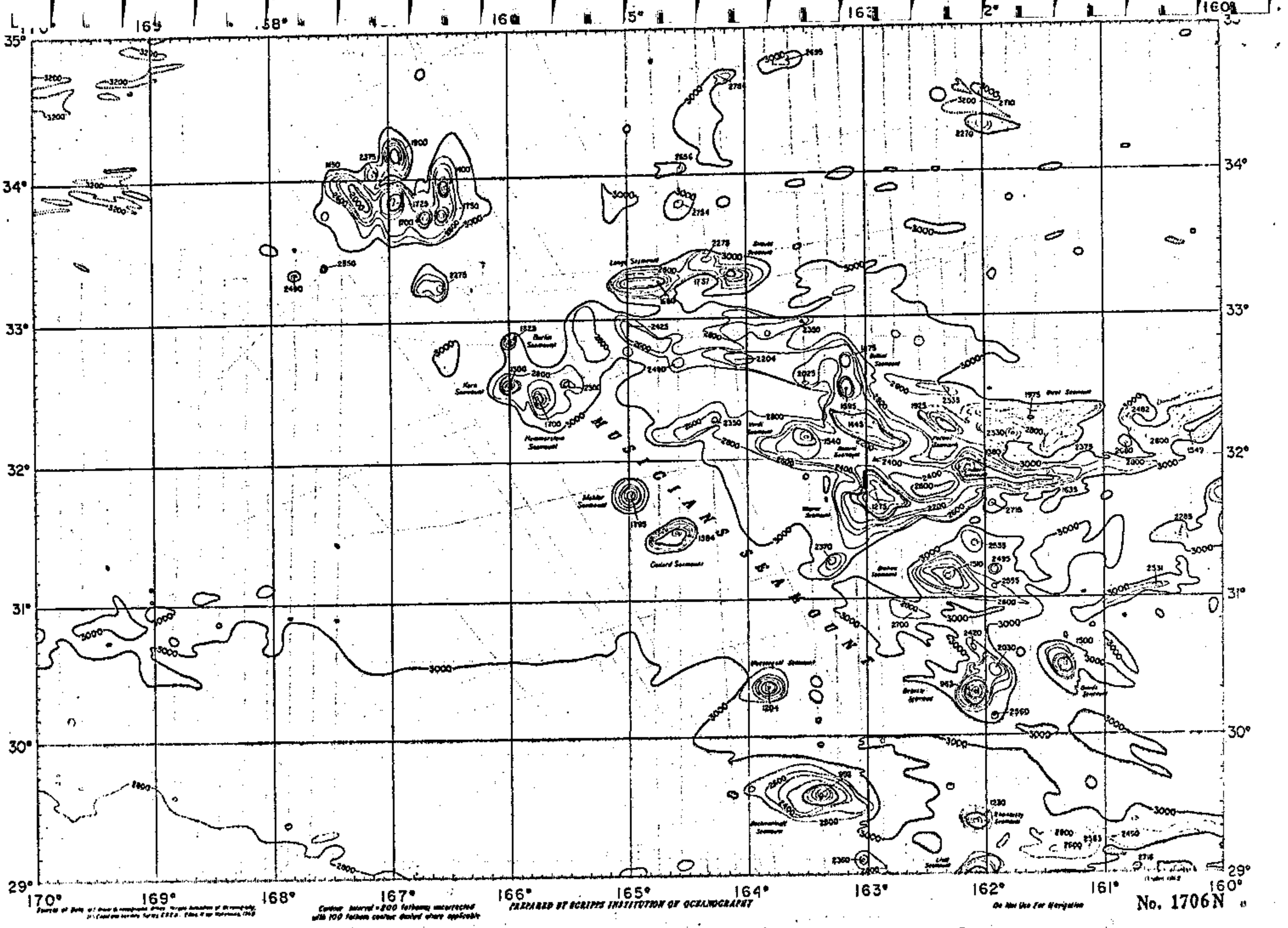


Figure 321.--Bathymetric features in lat. 29°-35° N, long. 160°-170° W

(Scripps Institution of Oceanography 1971).

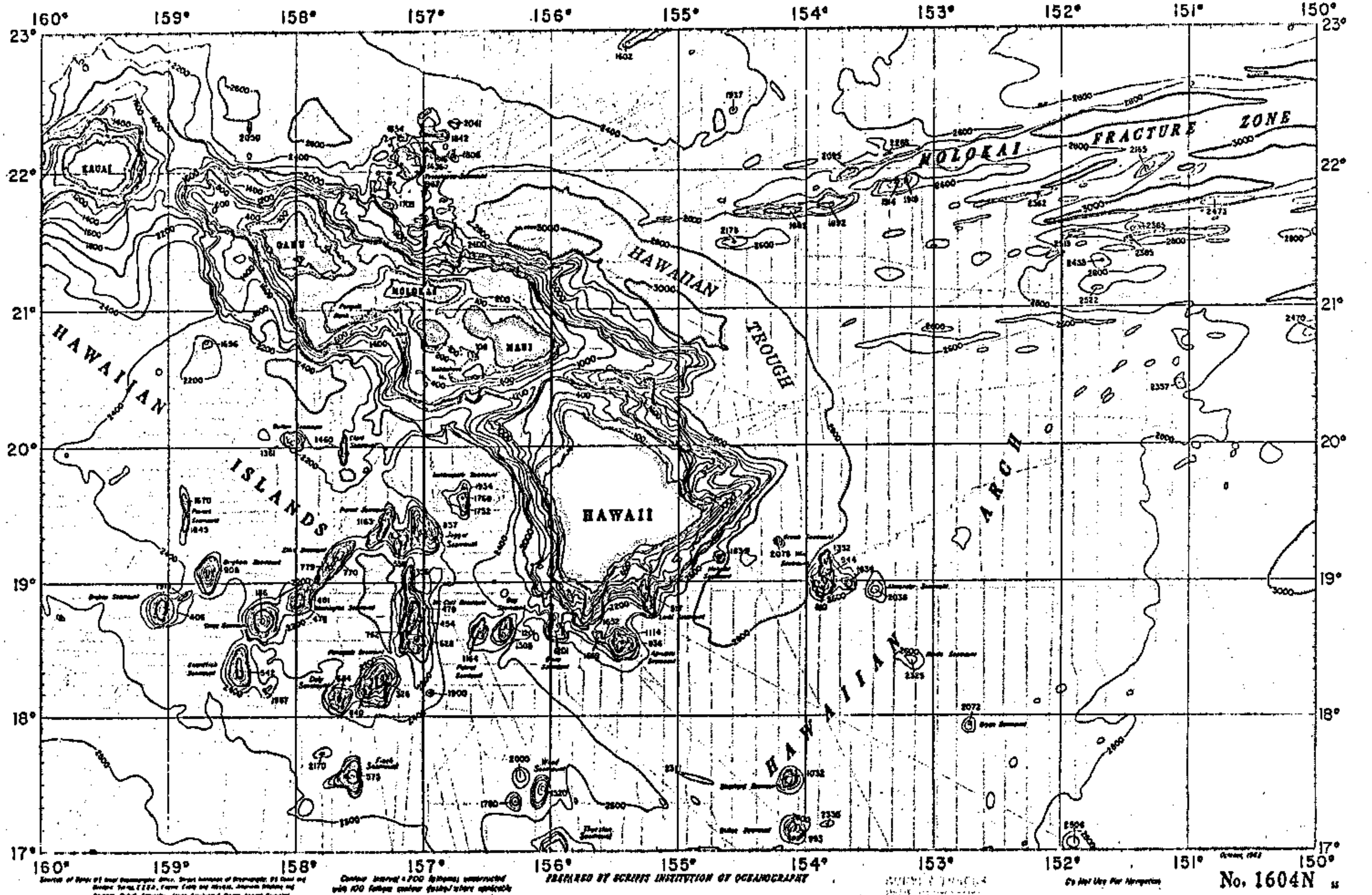


Figure 32j.—Bathymetric features in lat 17°-23° N, long 150°-160° W

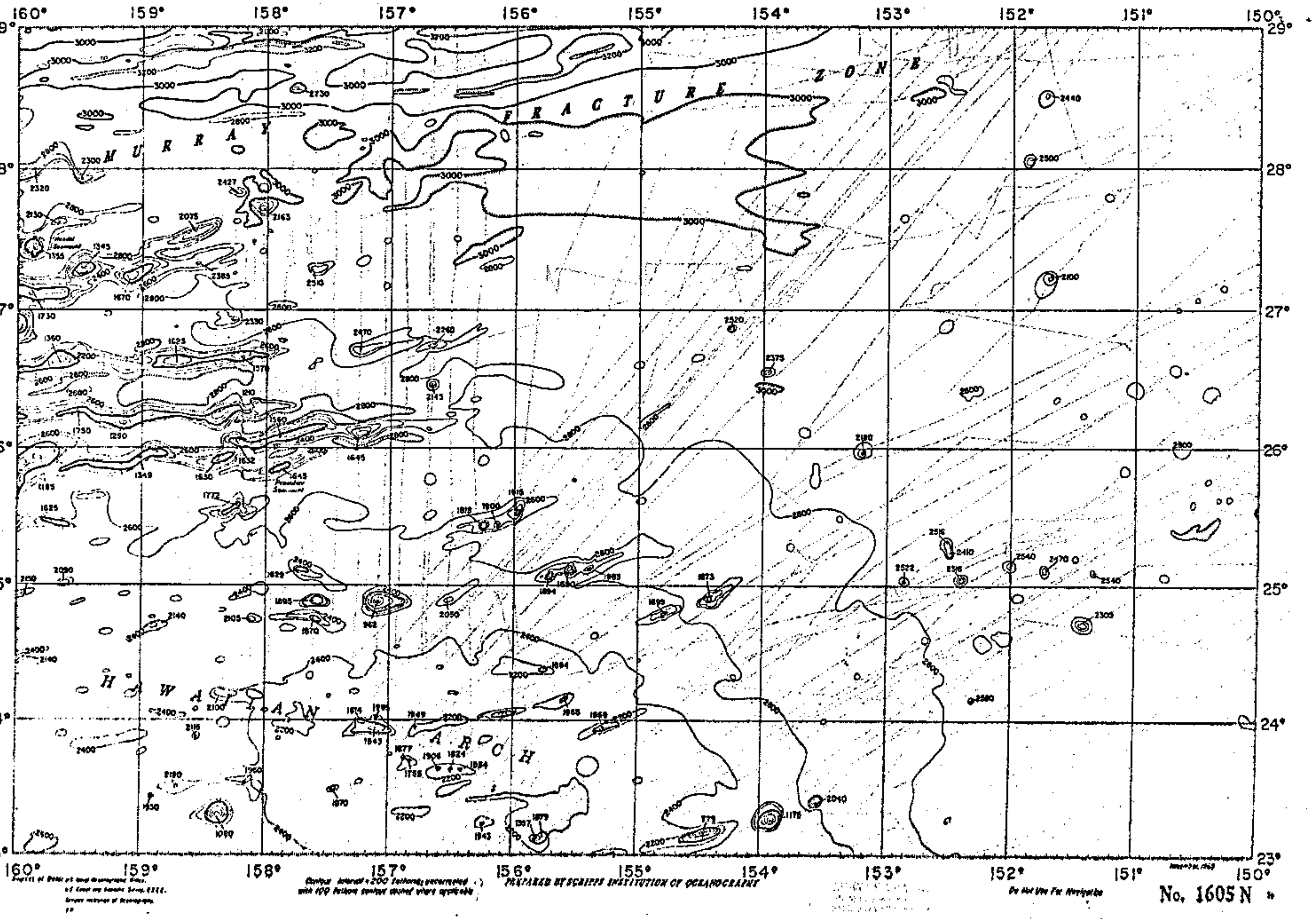


Figure 32k.—Bathymetric features in lat 23°-29° N, long 150°-160° W

(Scripps Institution of Oceanography 1971).

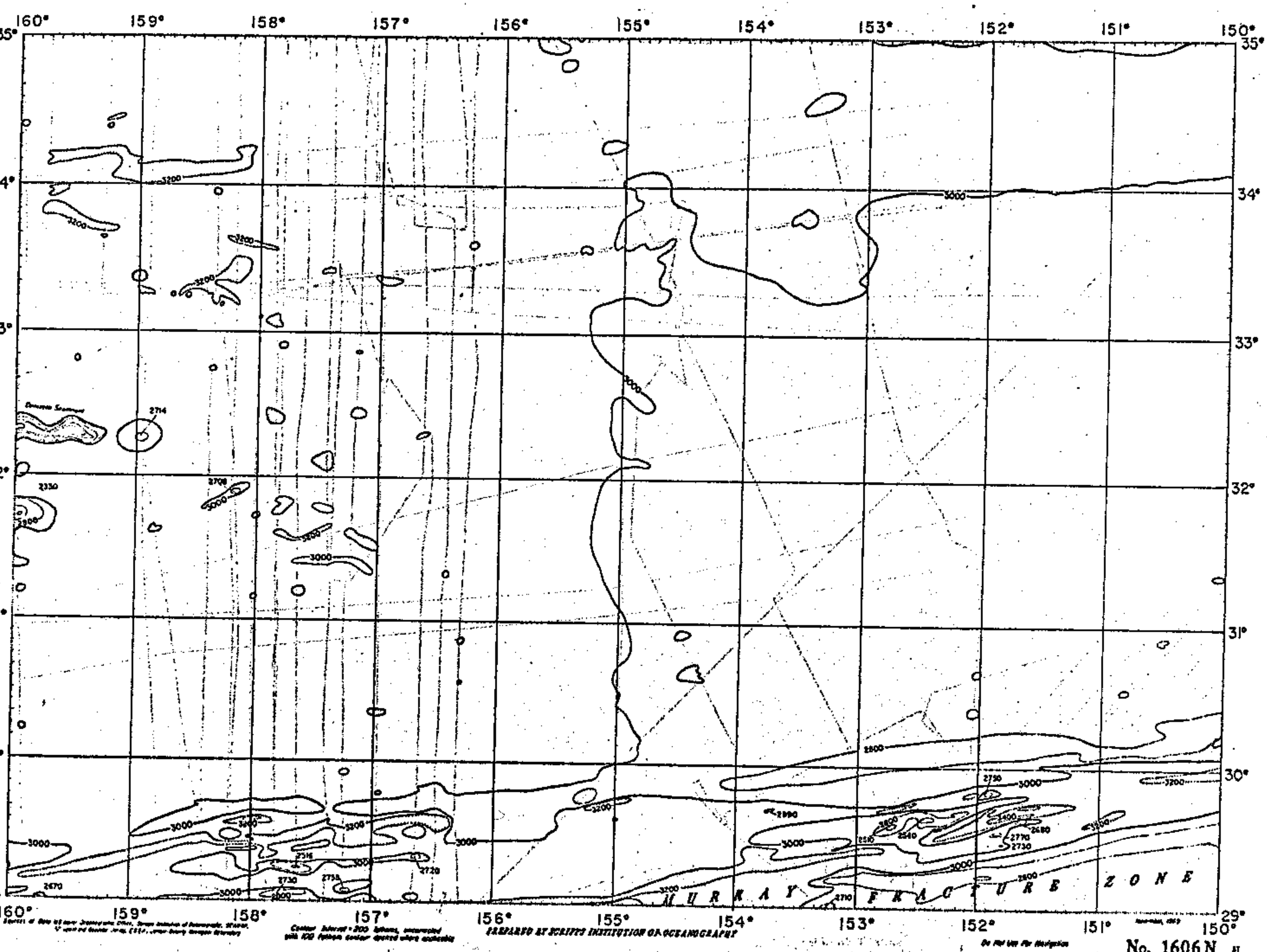


Figure 32 .—Bathymetric features in lat 29°-35° N, long 150°-160° W

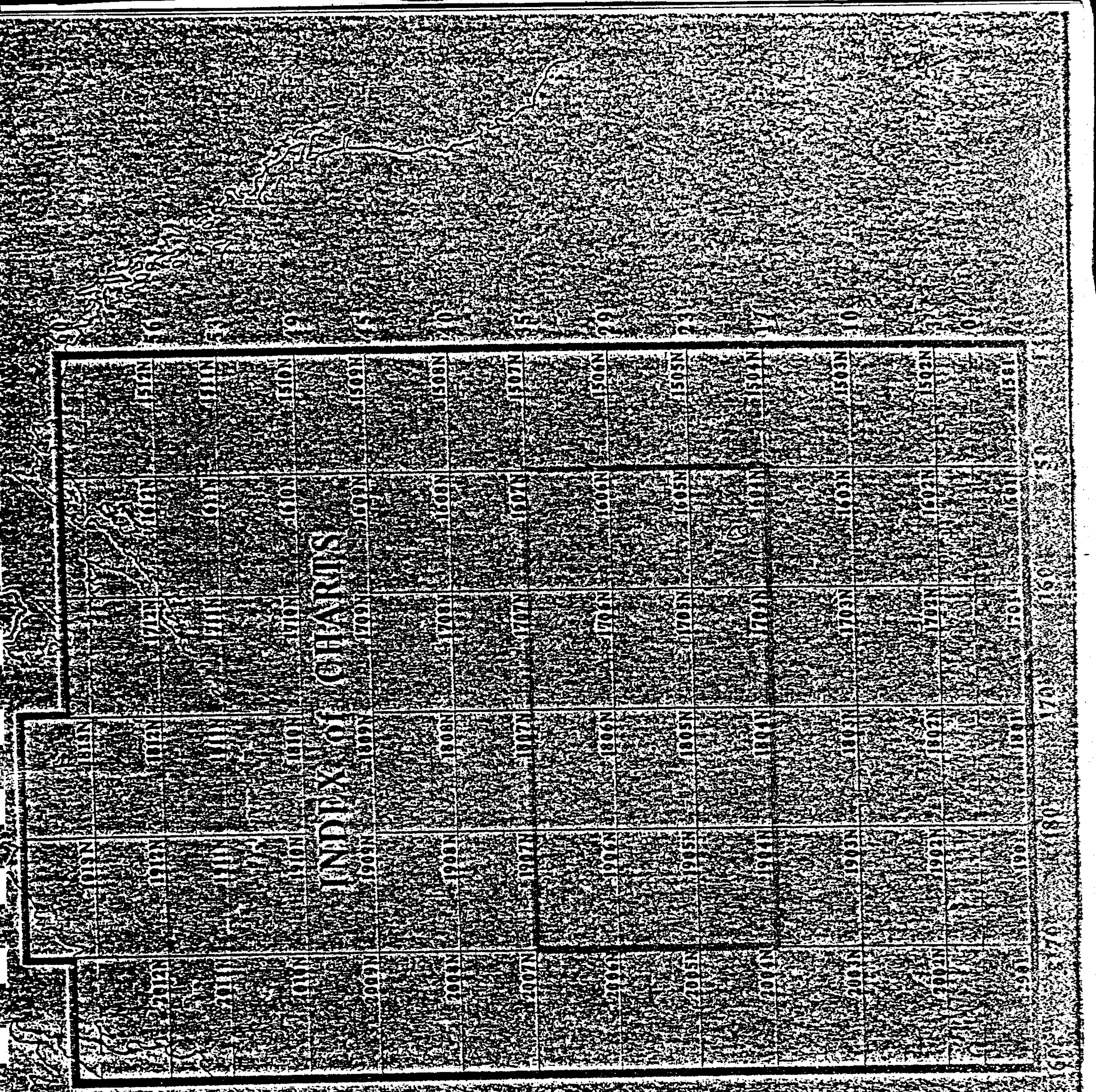


Figure 33.--The locations of the individual bathymetric charts, shown in Figures 32a-32l, in relation to the rest of the northcentral [illegible]

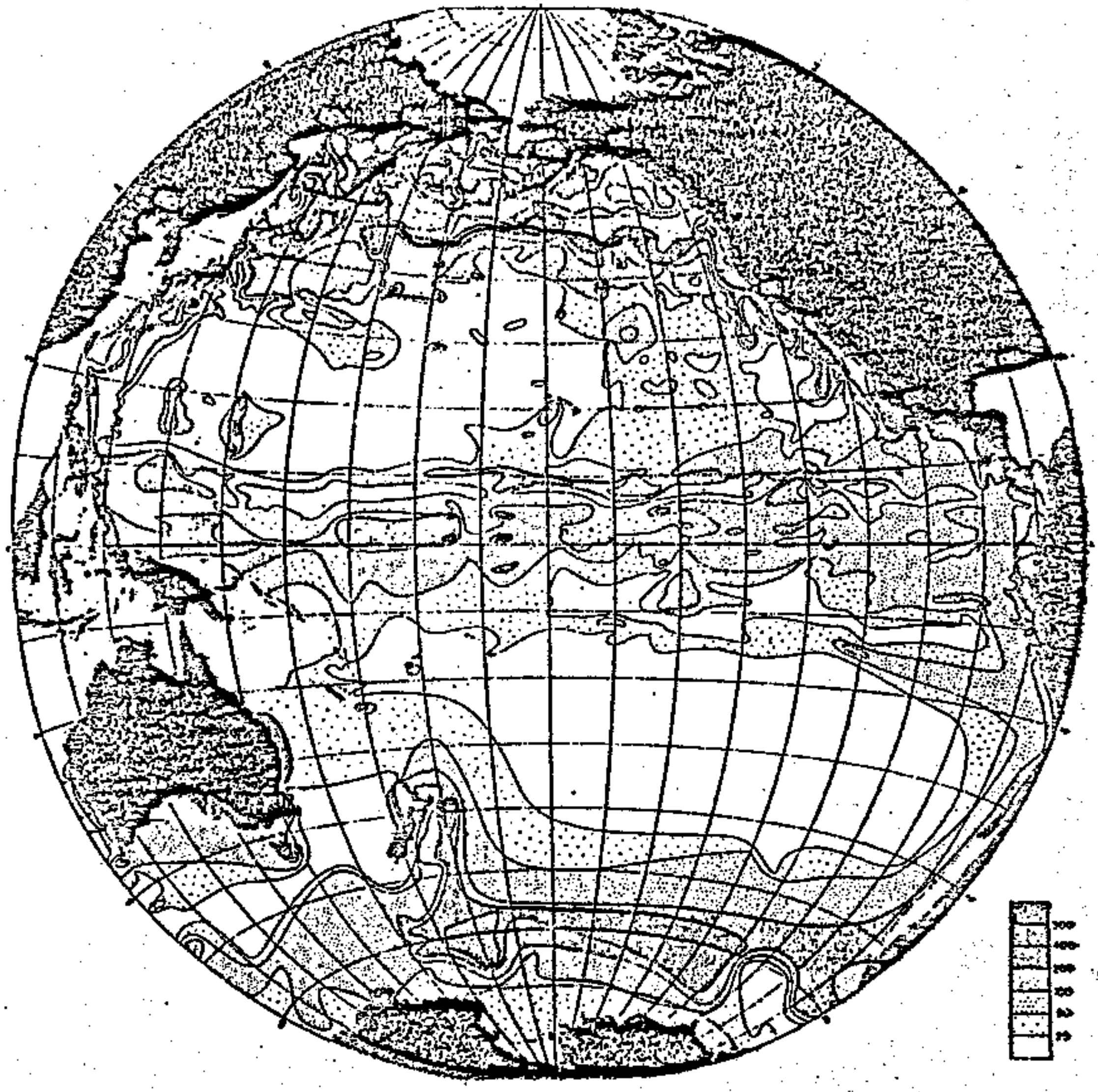


Figure 34.—Distribution of zooplankton volume (parts per 10^9 by volume) in approximately the upper 150 m of the Pacific Ocean, shaded by values (Reid, 1962).

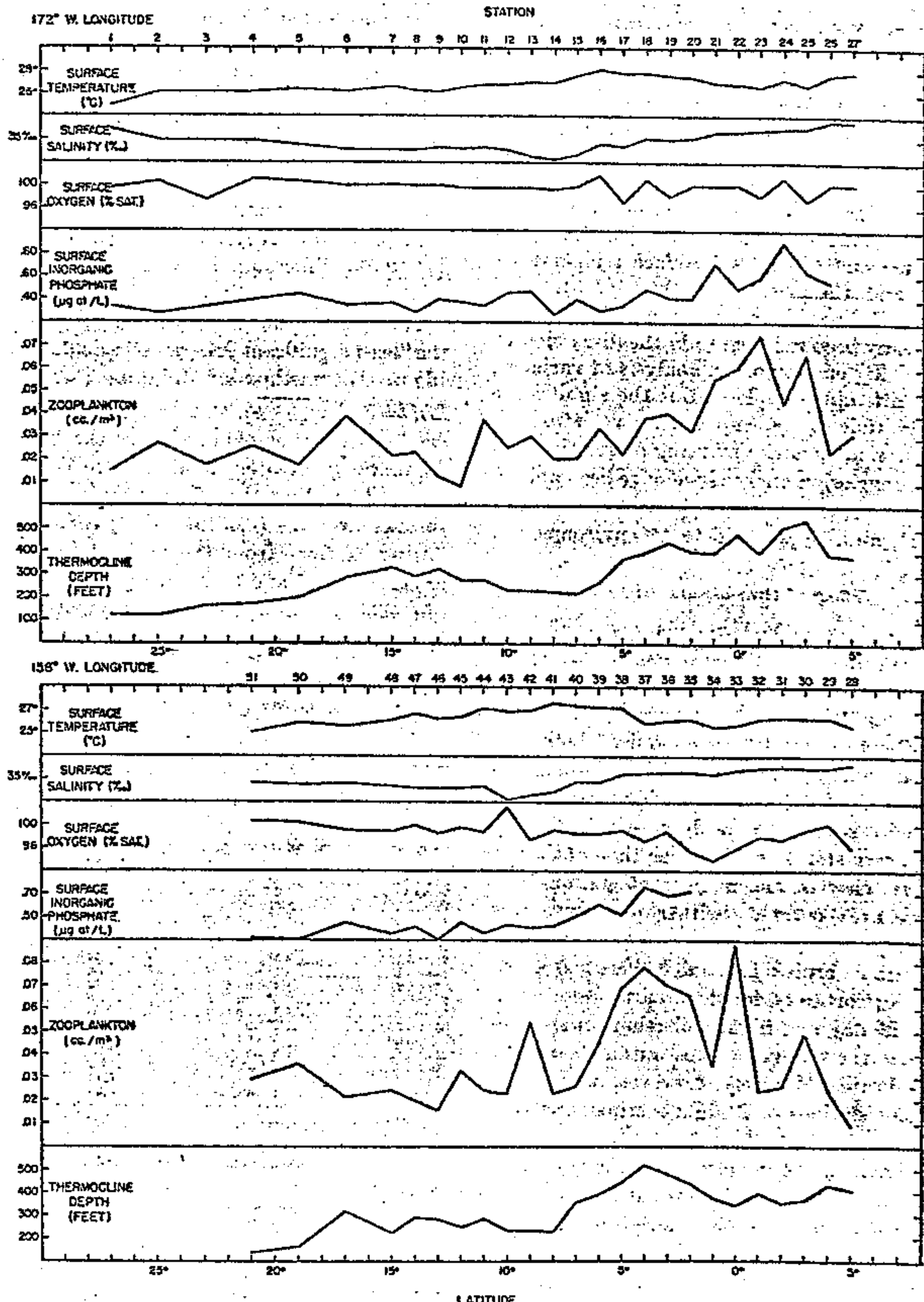


Figure 35.—Variations in temperature, salinity, oxygen, inorganic phosphate, thermocline depth, and zooplankton volume along long 158° and 172° W as found on cruise 5, Hugh M. Smith, June–August 1950 (King and Demond 1953).

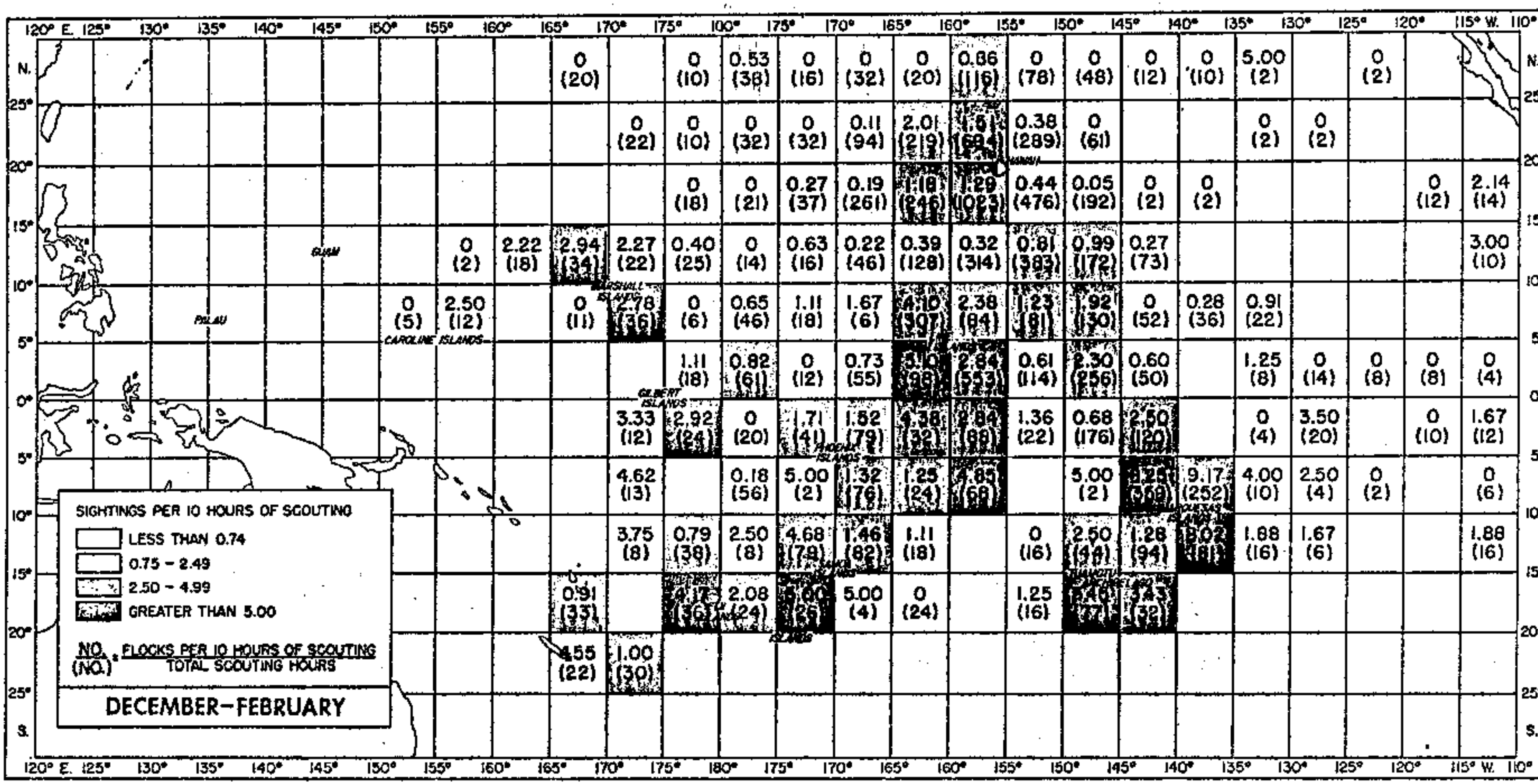


Figure 36a.—Bird flock sightings by National Marine Fisheries Service

res , D mbe bru 19 2 (ght)

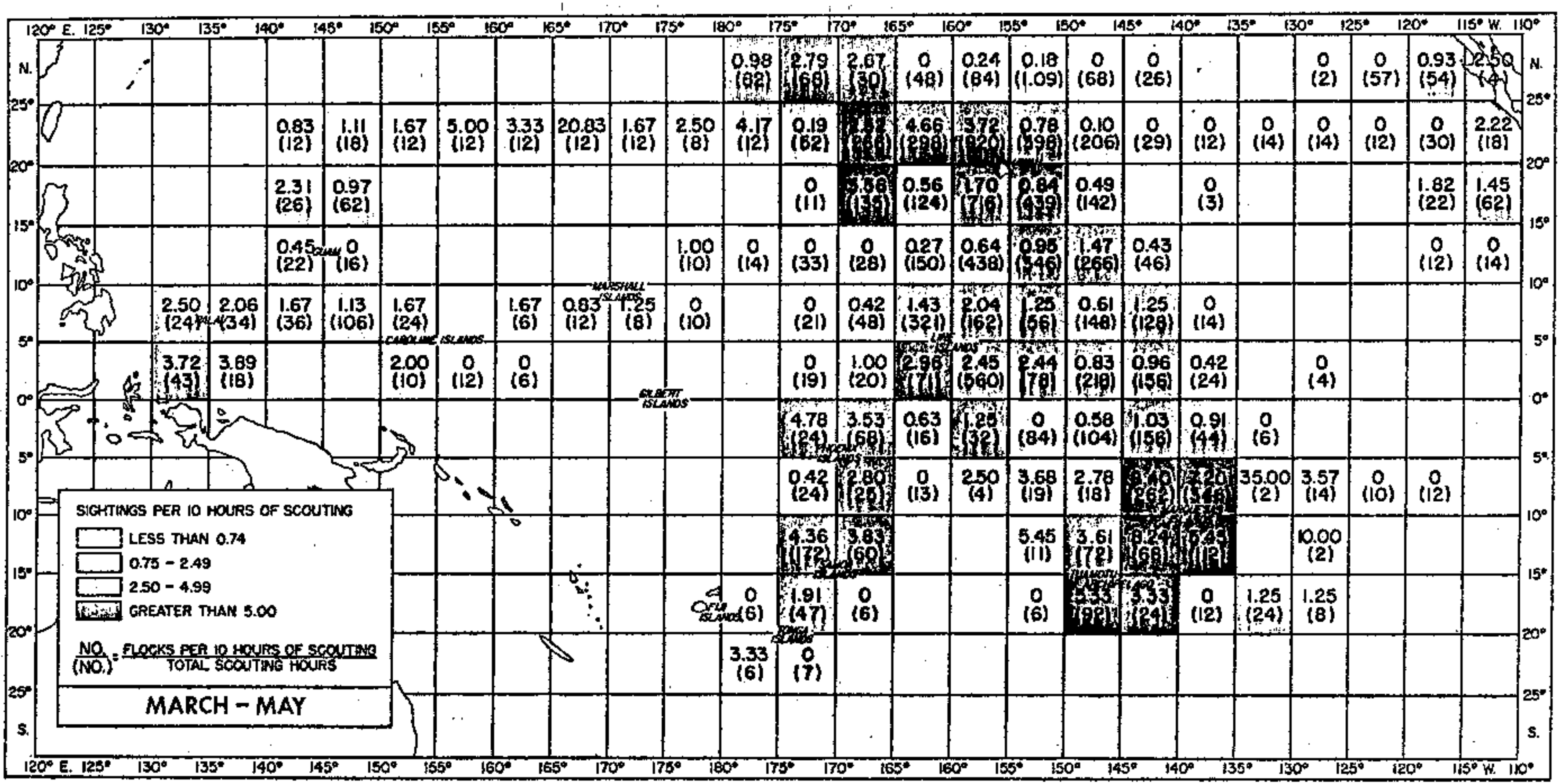


Figure 36b.--Bird flock sightings by National Marine Fisheries Service vessels, March-May 1950-72 (Naughton 3/).

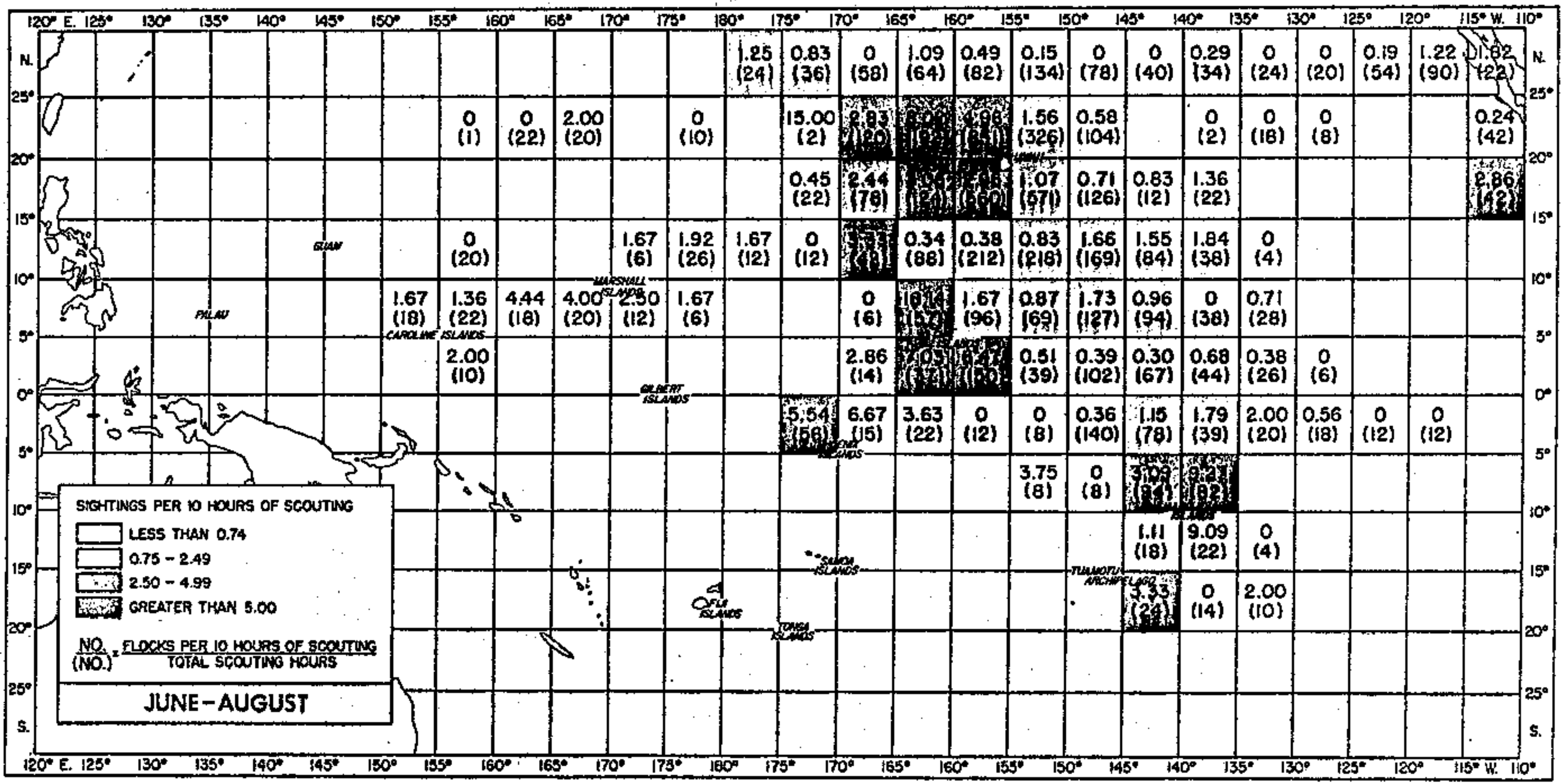


Figure 36c.--Bird flock sightings by National Marine Fisheries Service

sse Ju ugu 195((N nto).

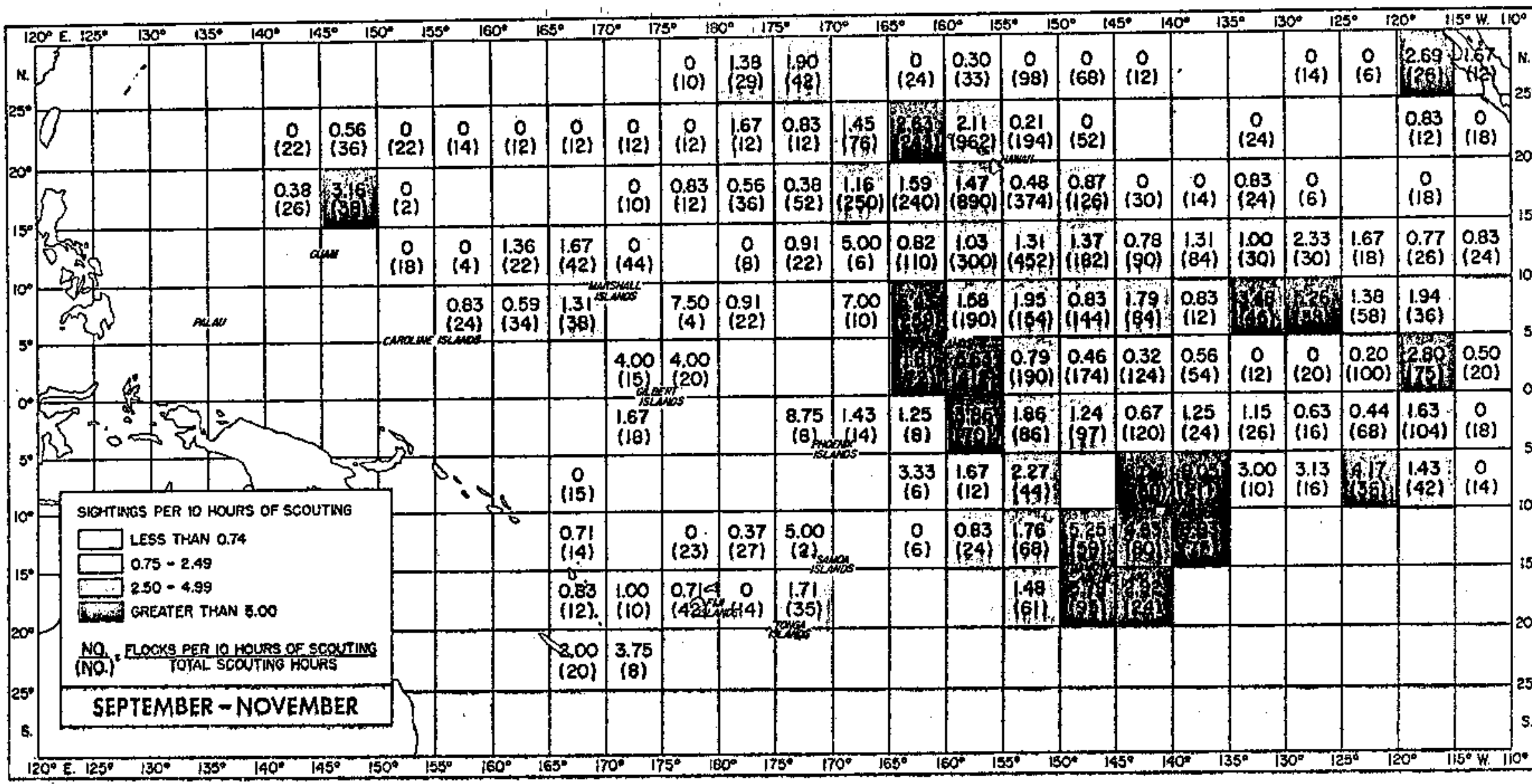


Figure 36d.—Bird flock sightings by National Marine Fisheries Service vessels, September-November 1950-72 (Naughton 3/).

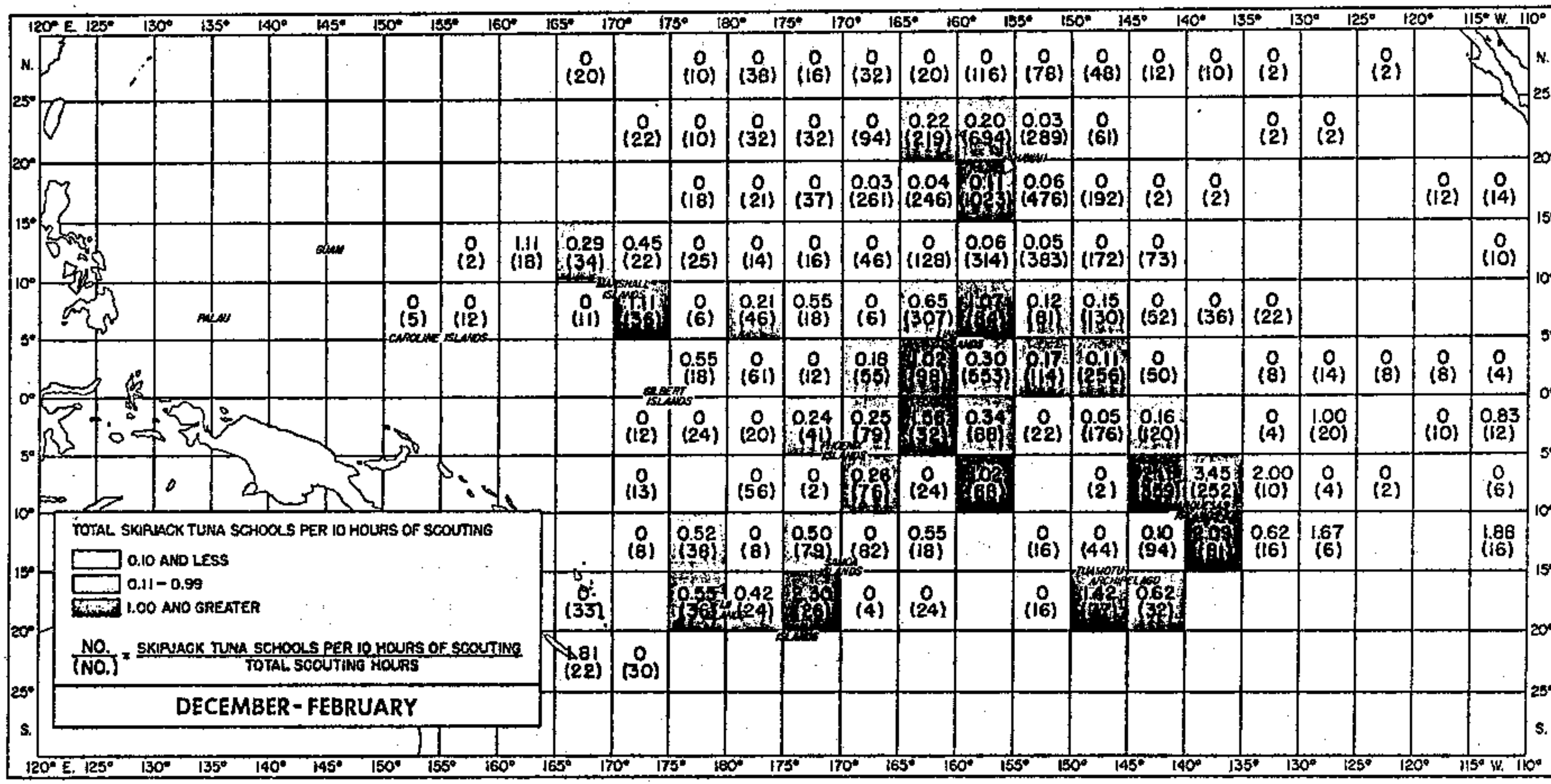


Figure 36e.--Skipjack tuna school sightings by National Marine Fisheries

S ice sel Dec r-F uar 150- Na on

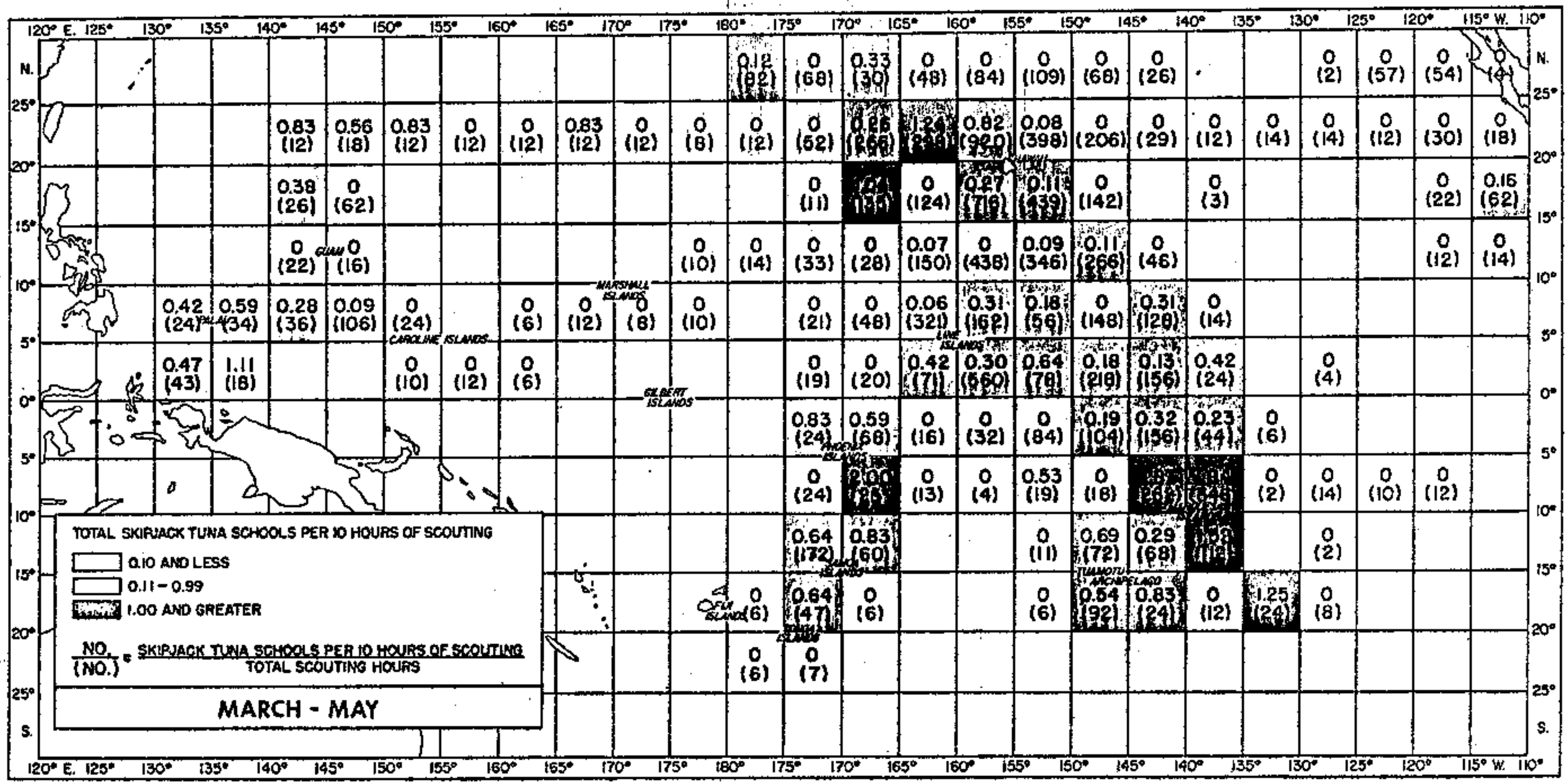


Figure 36f.--Skipjack tuna school sightings by National Marine Fisheries Service vessels, March-May 1950-72 (Naughton [3]).

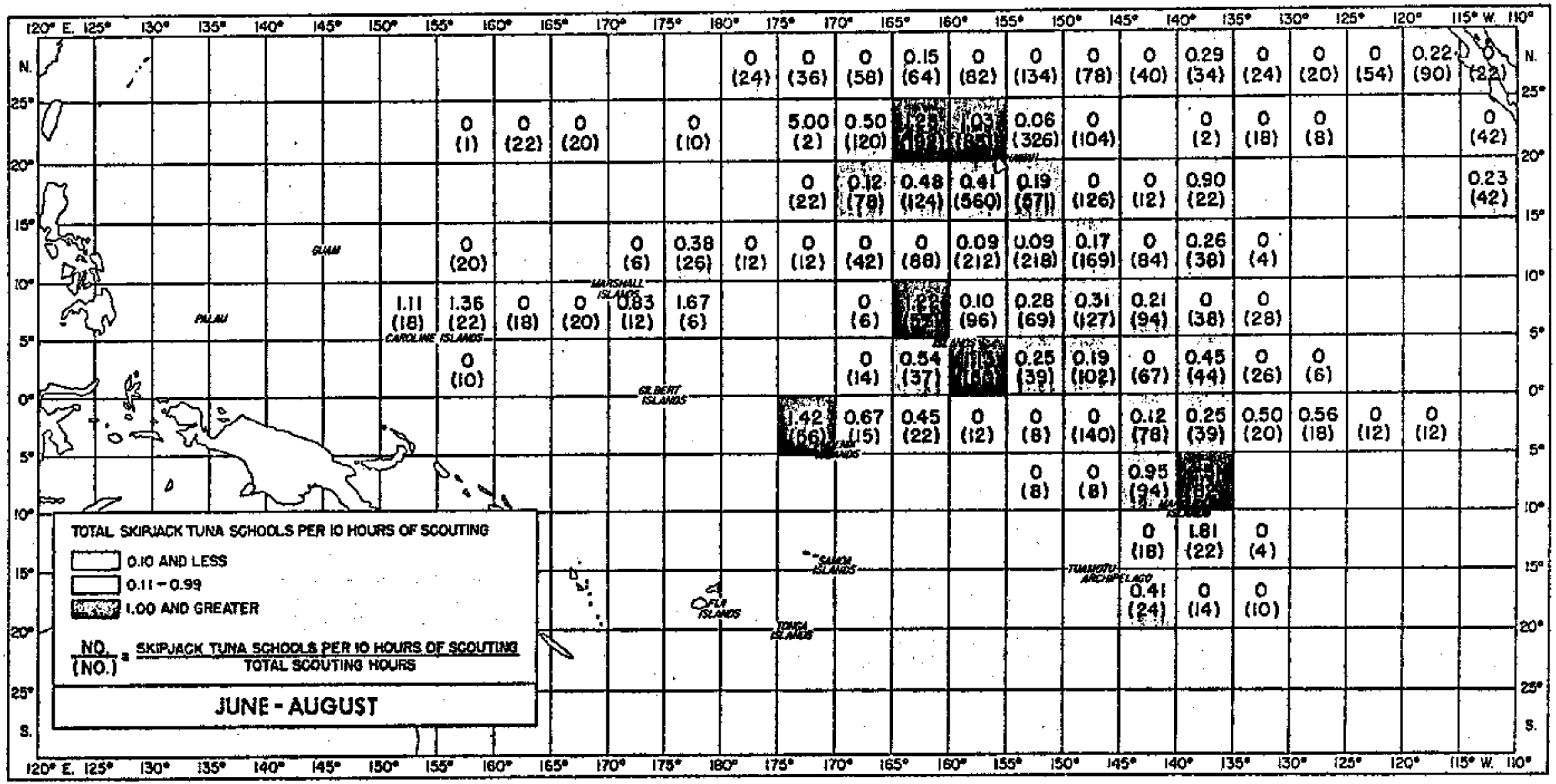


Figure 36g.—Skipjack tuna school sightings by National Marine Fisheries

rvi ves , J Aug 19 2 (ght 3/)

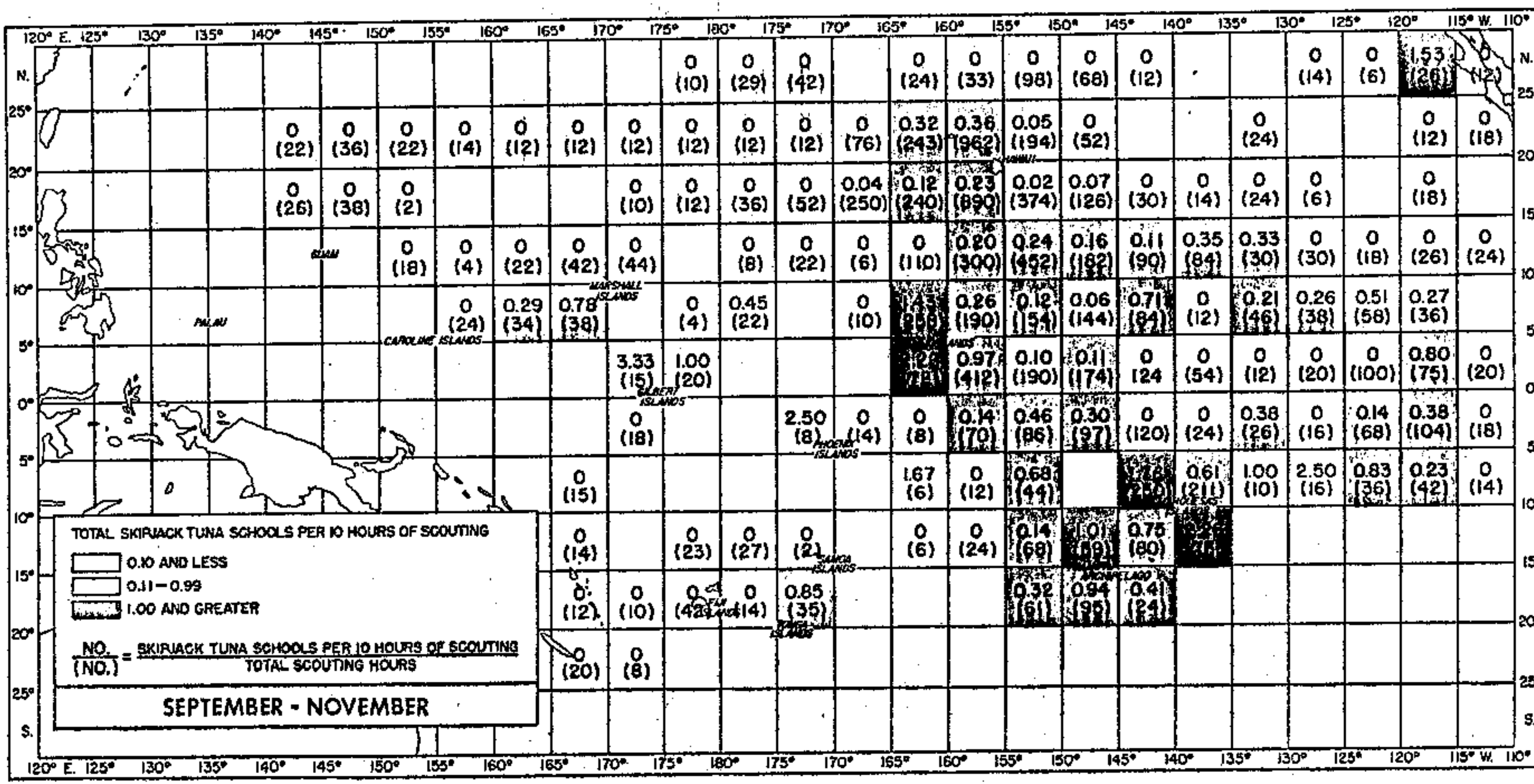


Figure 36h.—Skipjack tuna school sightings by National Marine Fisheries Service vessels, September-November 1950-72 (Naughton 3/).

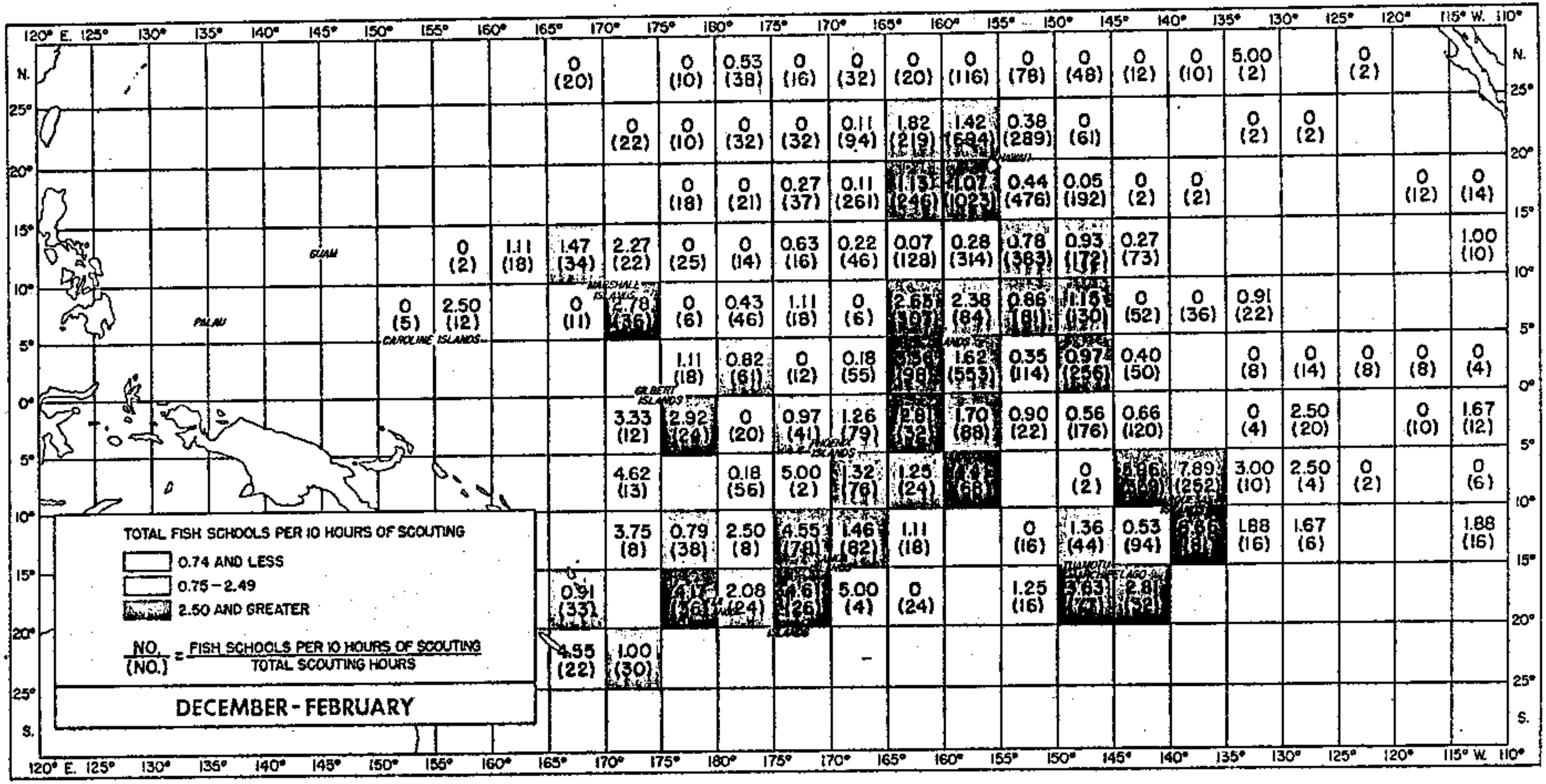


Figure 361.—Total school sightings by National Marine Fisheries
S... ce... sels ...ece... —F... ary 50-7 Nau... bu...

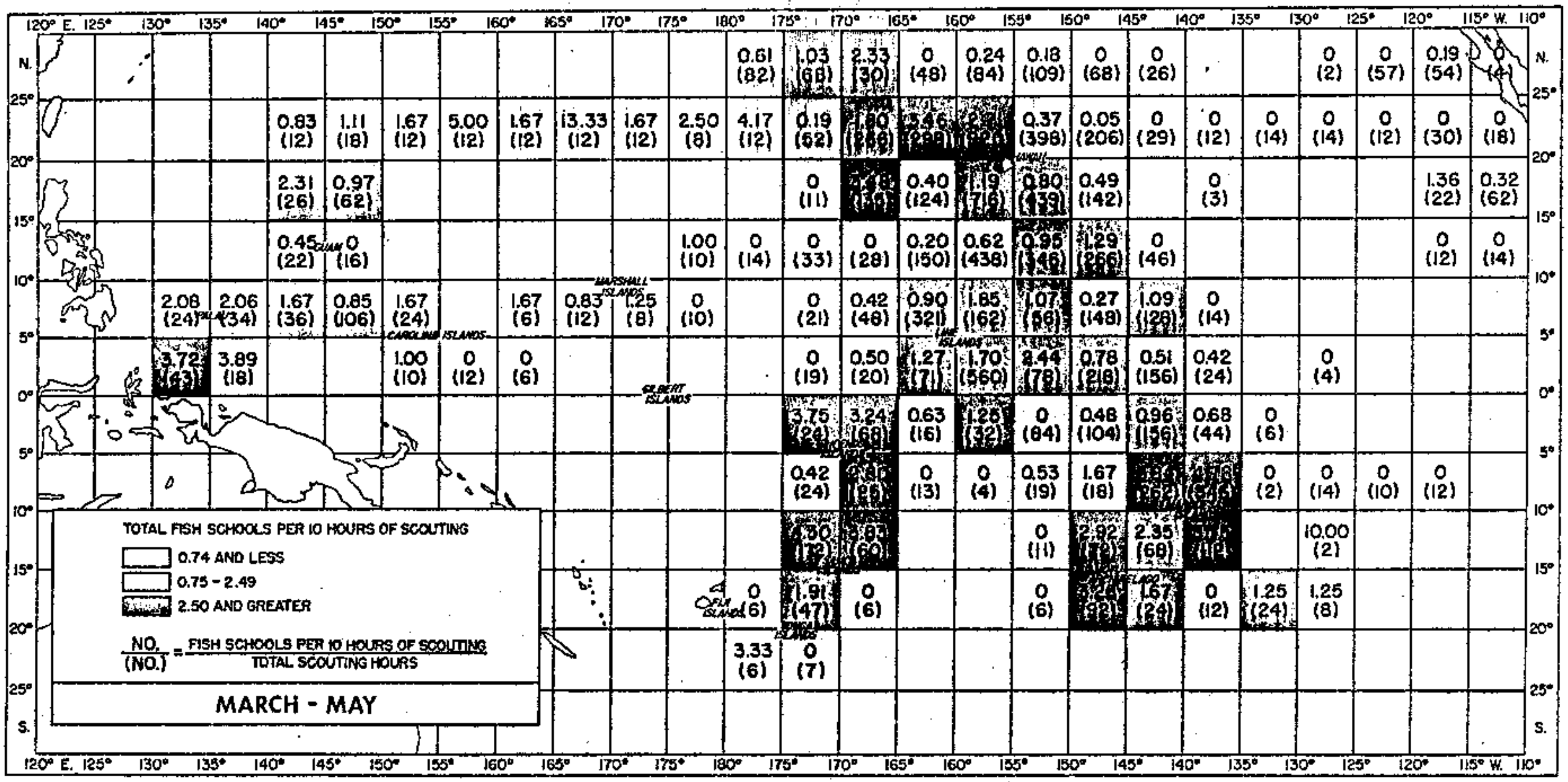


Figure 36j.—Total school sightings by National Marine Fisheries Service vessels, March-May 1950-72 (Naughton 5/).

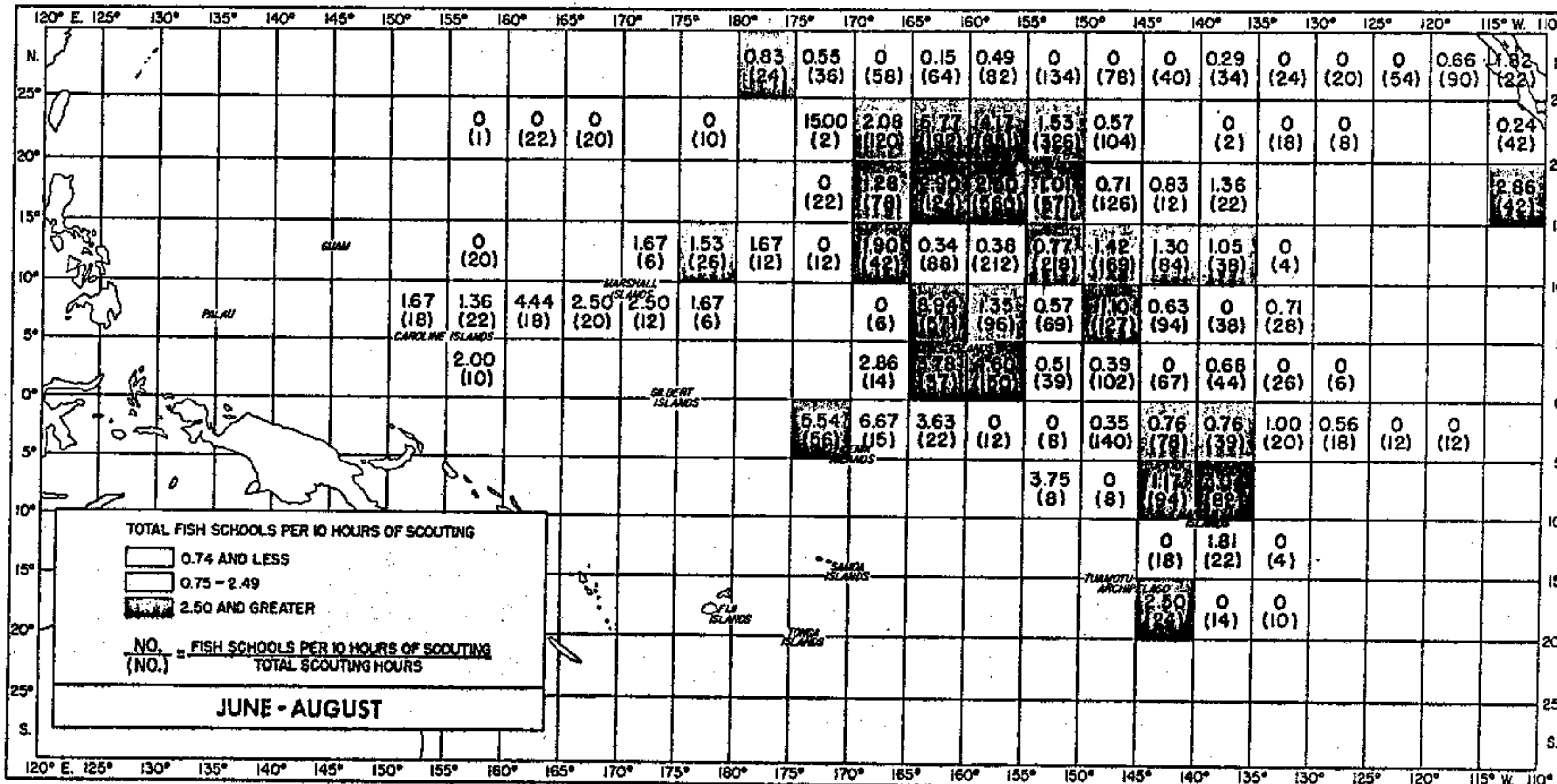


Figure 36kk--Total school sightings by National Marine Fisheries

Ser ve ls, he-d st -72 aug 3/

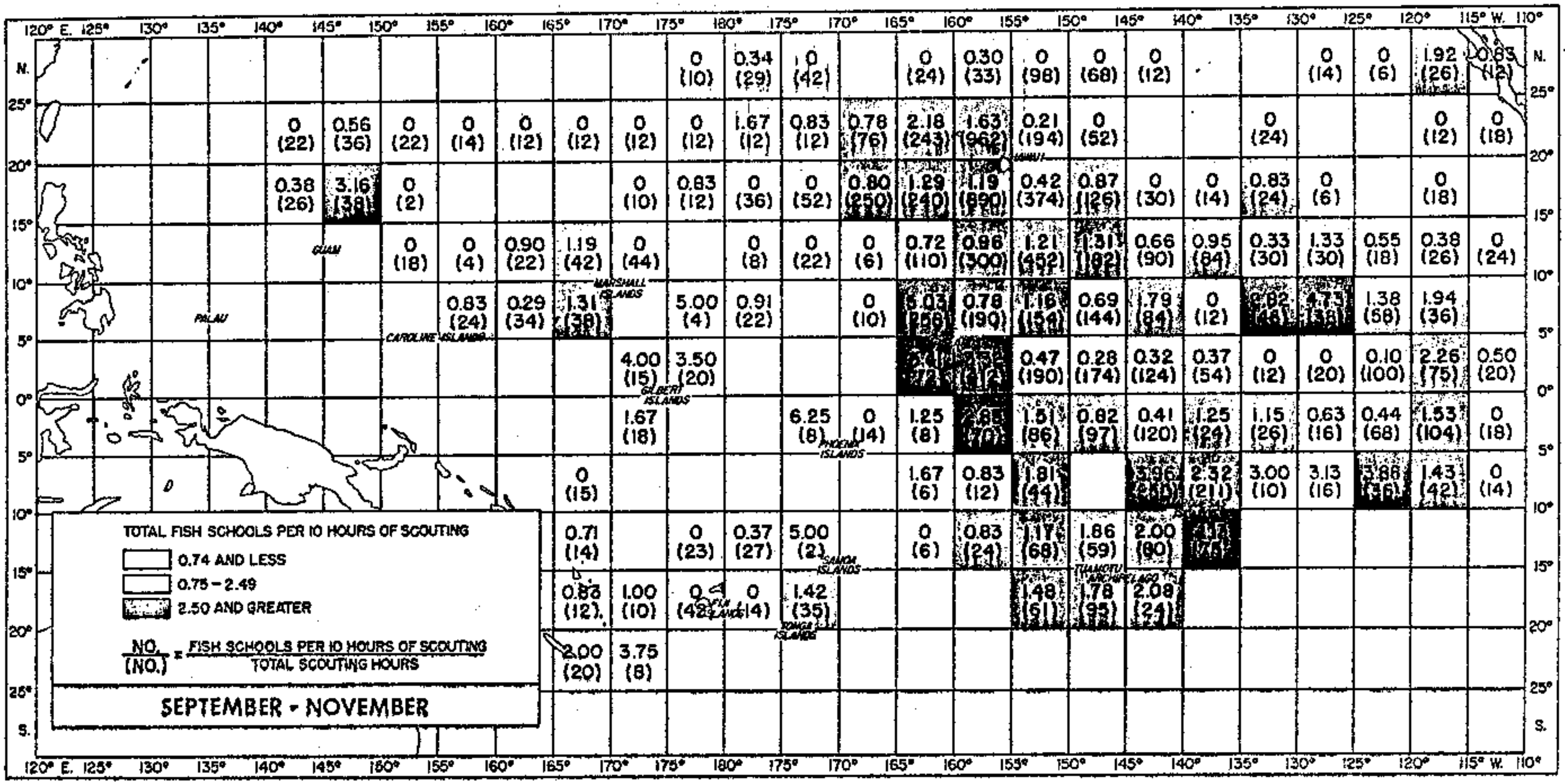
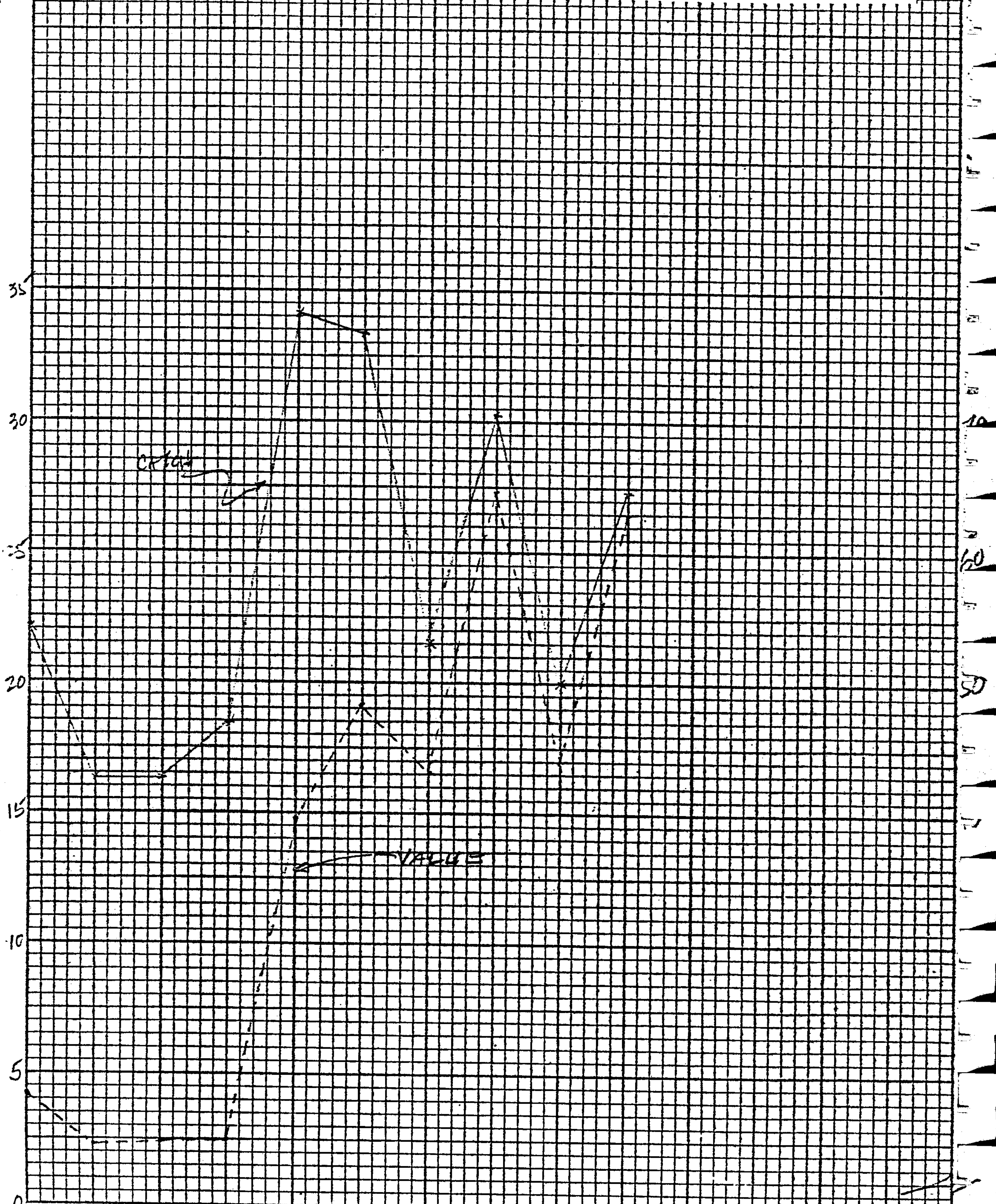


Figure 36L.—Total school sightings by National Marine Fisheries Service vessels, September-November 1950-72 (Naughton 3/).

Figure 37.--Annual catch and value of all species caught by handline fishing at Necker Island, 1966-75.



SHOMURA & UCHIDA 4/ MS

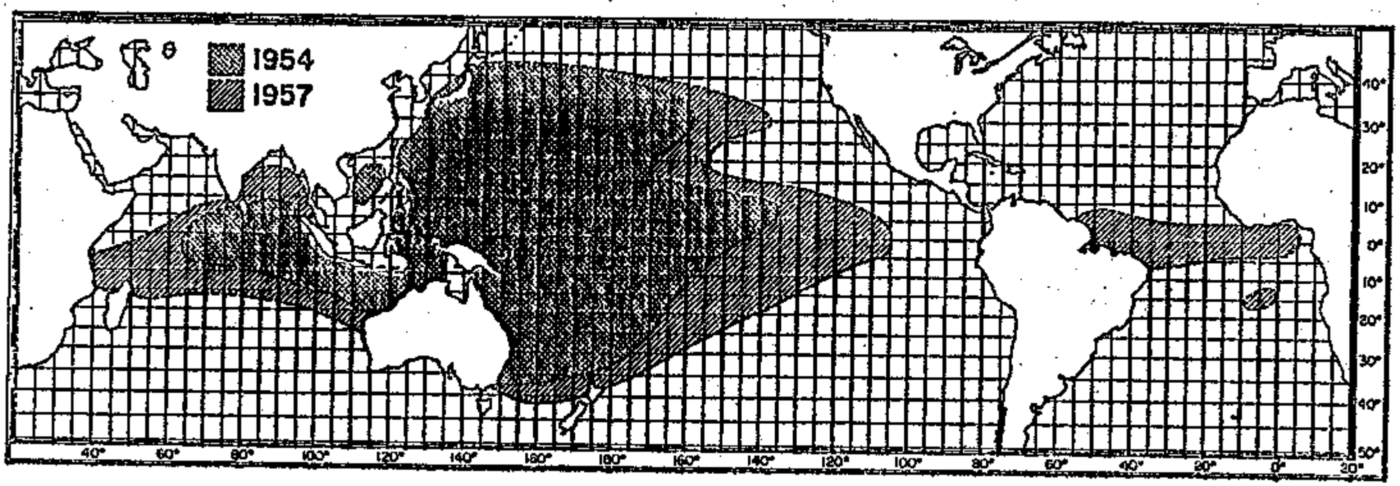


Figure 38.--Distribution of Japanese high-seas tuna fishing grounds, 1954 and 1957 (Shomura and Uchida 4/).

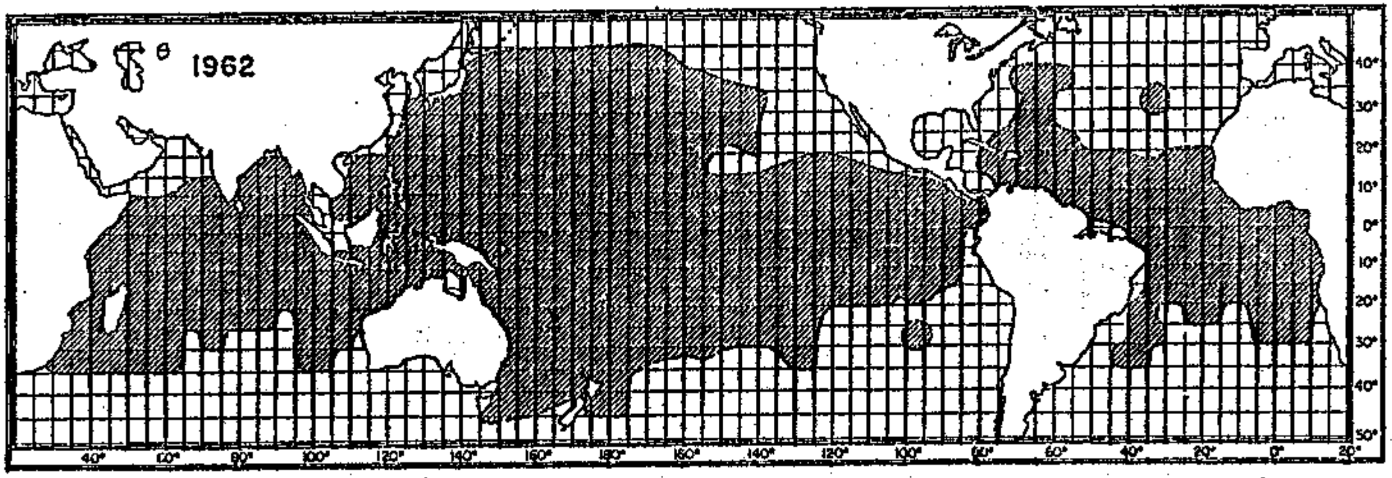


Figure 39.--Distribution of Japanese high-seas tuna fishing grounds, 1962 (Shomura and Uchida 4/).

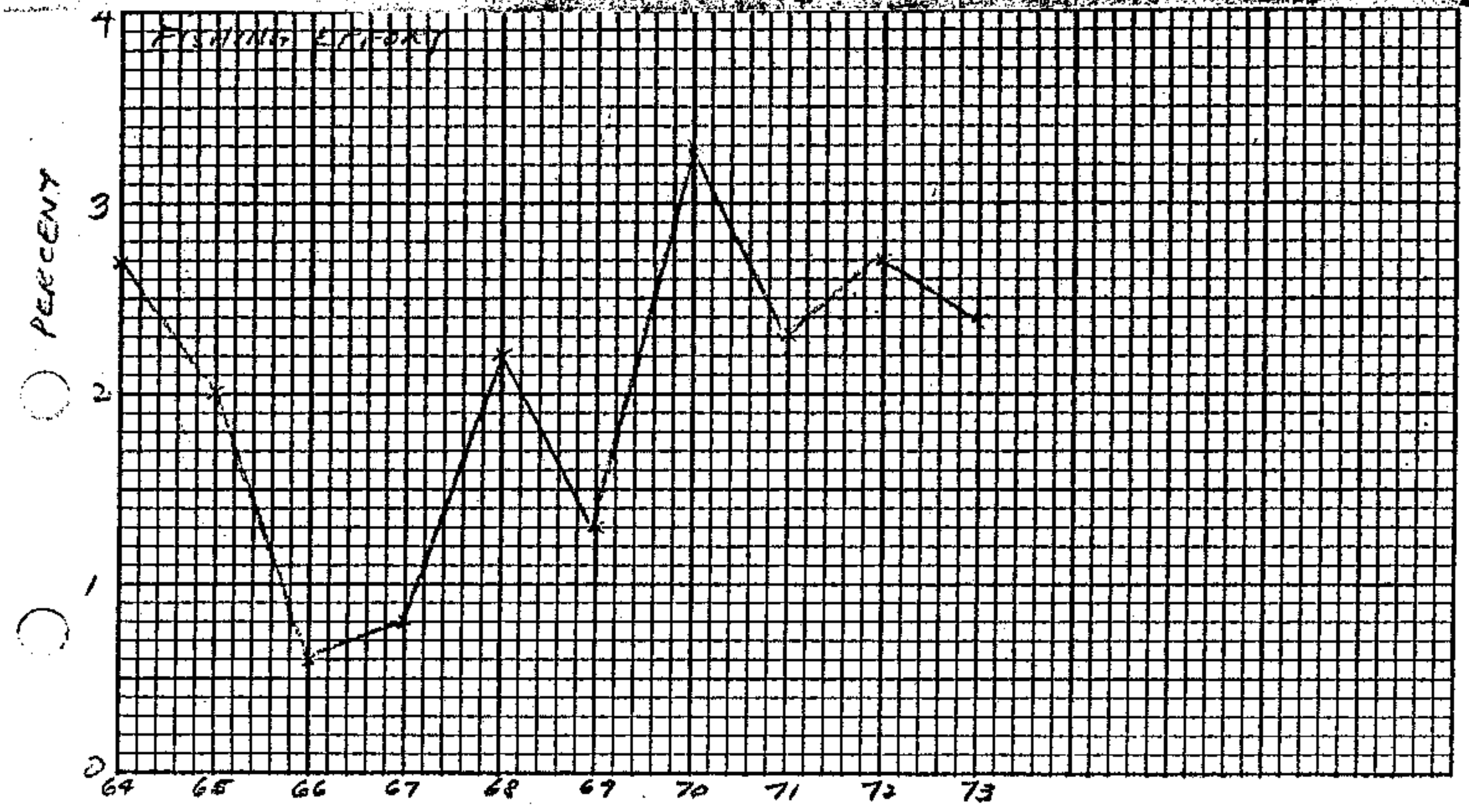
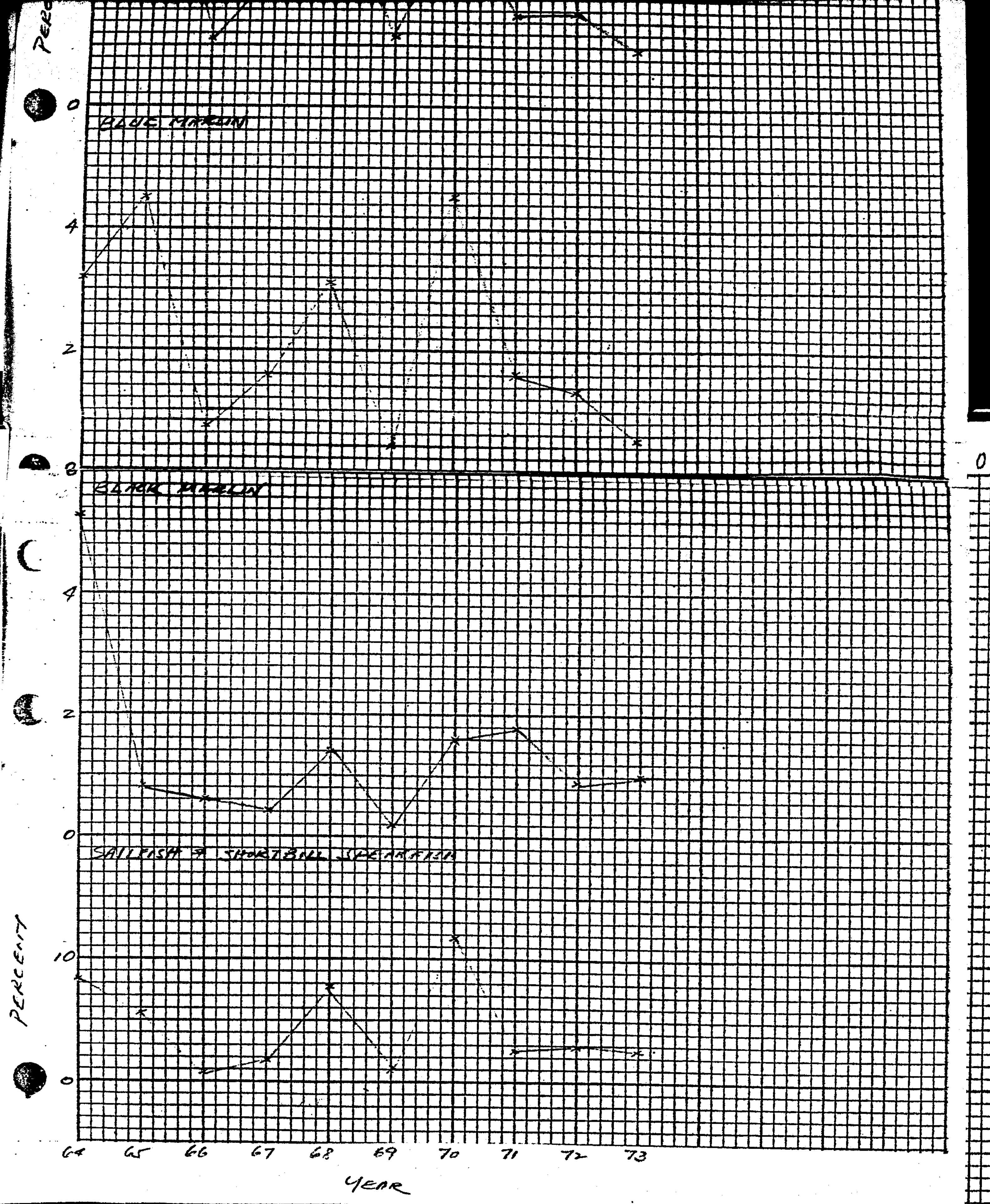
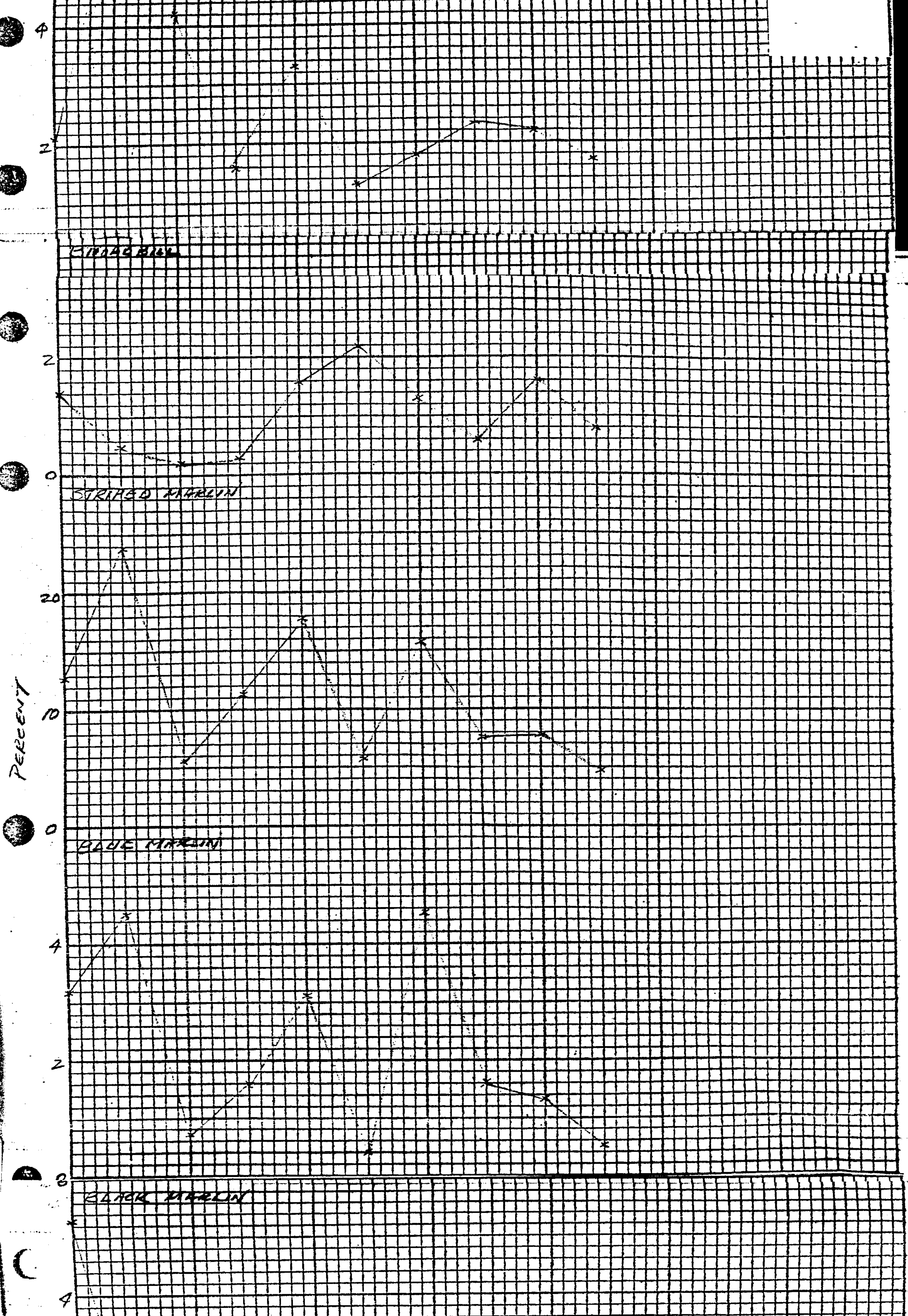


Figure 40.--Percentage of the North Pacific longline fishing effort of Japanese vessels expended in the NWHI region in 1964-73.

Fig. 40



BLUE MARLIN
BLACK MARLIN
SAILFISH & SHORTBILL SPEARFISH
PERCENT
YEAR
64
65
66
67
68
69
70
71
72
73
0
2
4
10


4
2
2
0
STRIPED MARLIN
20
10
PERCENT
0
BLUE MARLIN
4
2
0
BLACK MARLIN
4

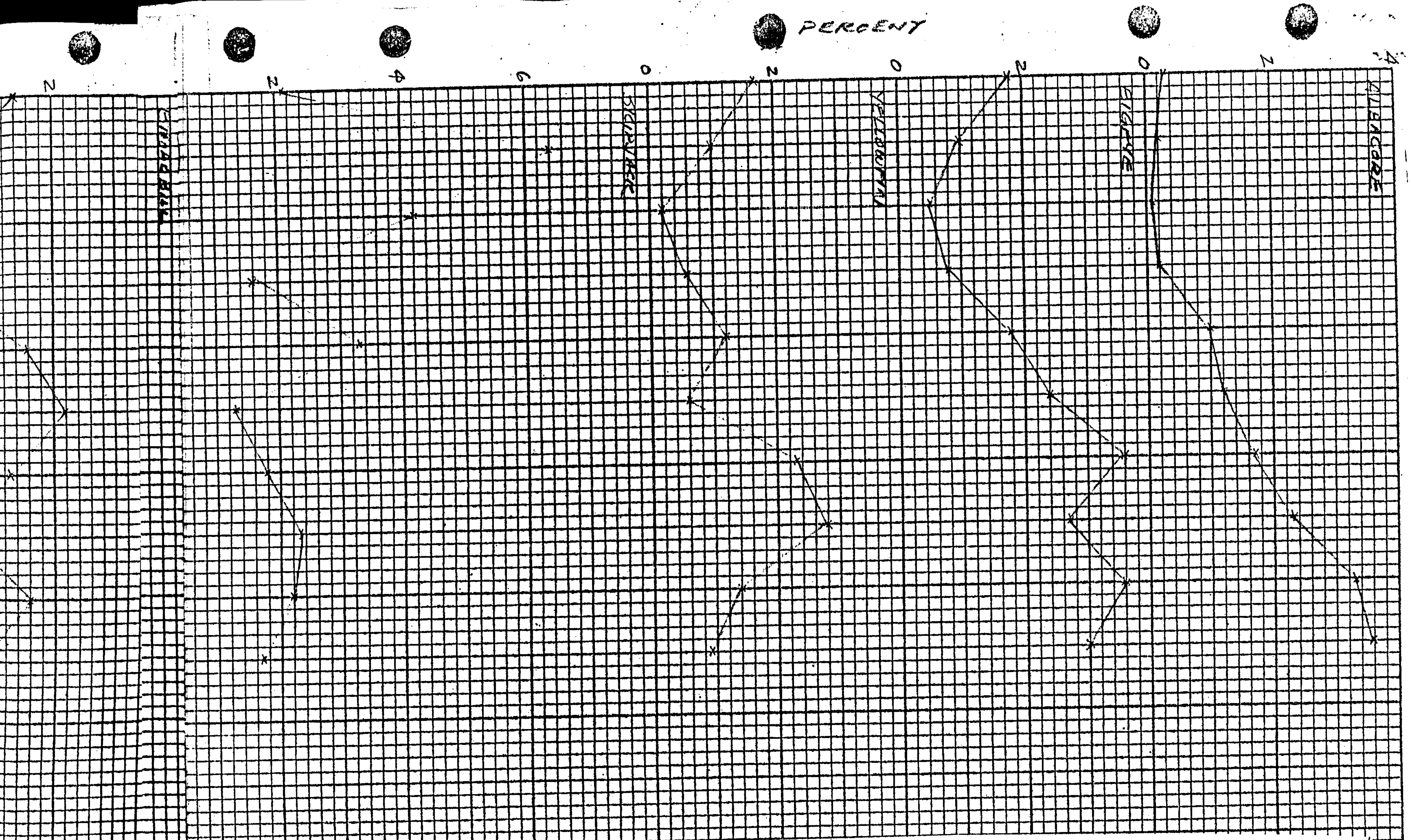


Figure 41.--Percentages of the North Pacific longline catches of tunas and billfishes of Japanese vessels made in the NWHI region, 1964-73.

Figure 42.--Percentage length frequency distribution of skipjack tuna and kawakawa caught during exploratory pole-and-line fishing in NWHI waters.

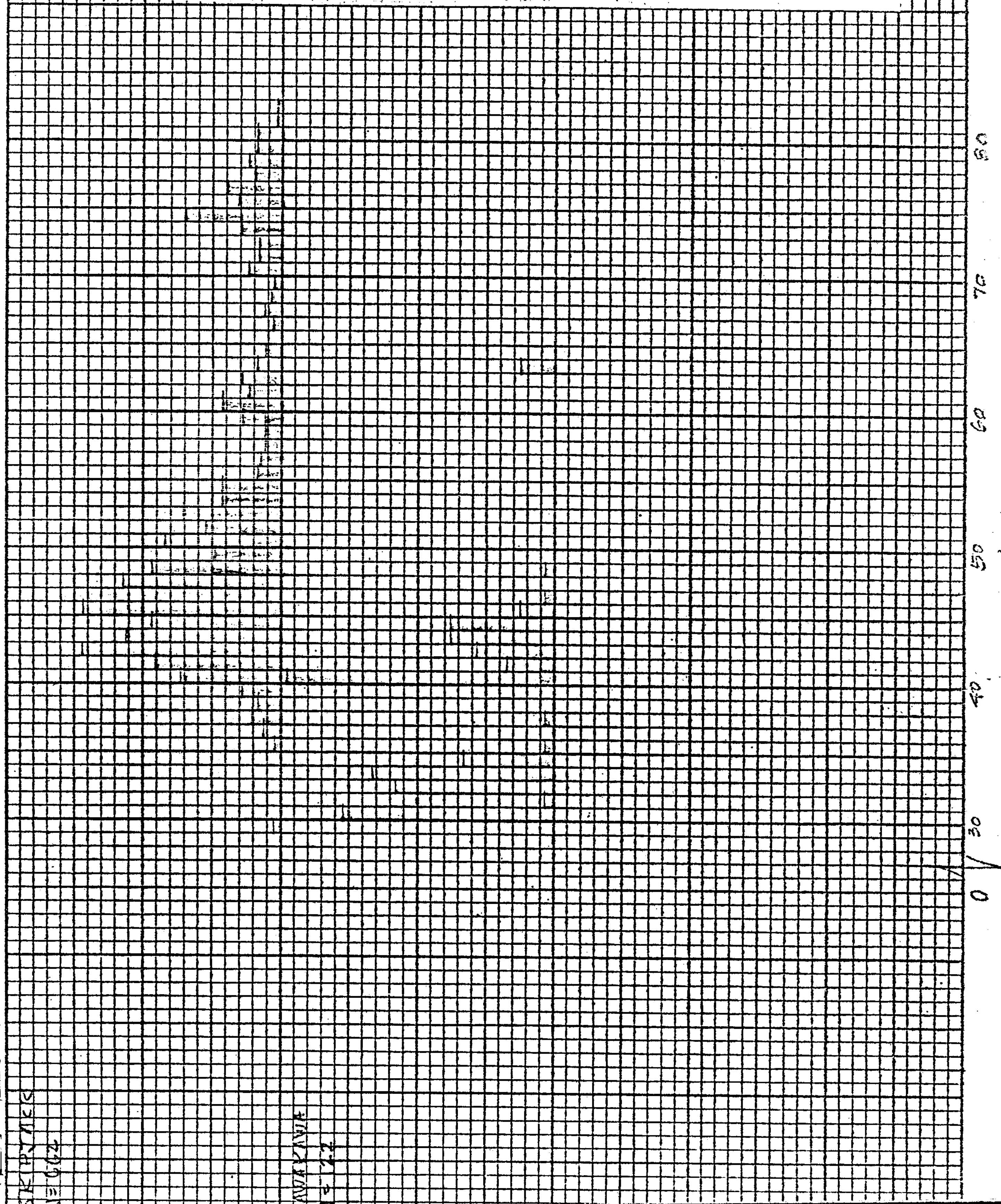


Figure 43.—Percentage weight frequency distribution of spiny lobsters caught during exploratory trap fishing in NWHI waters.