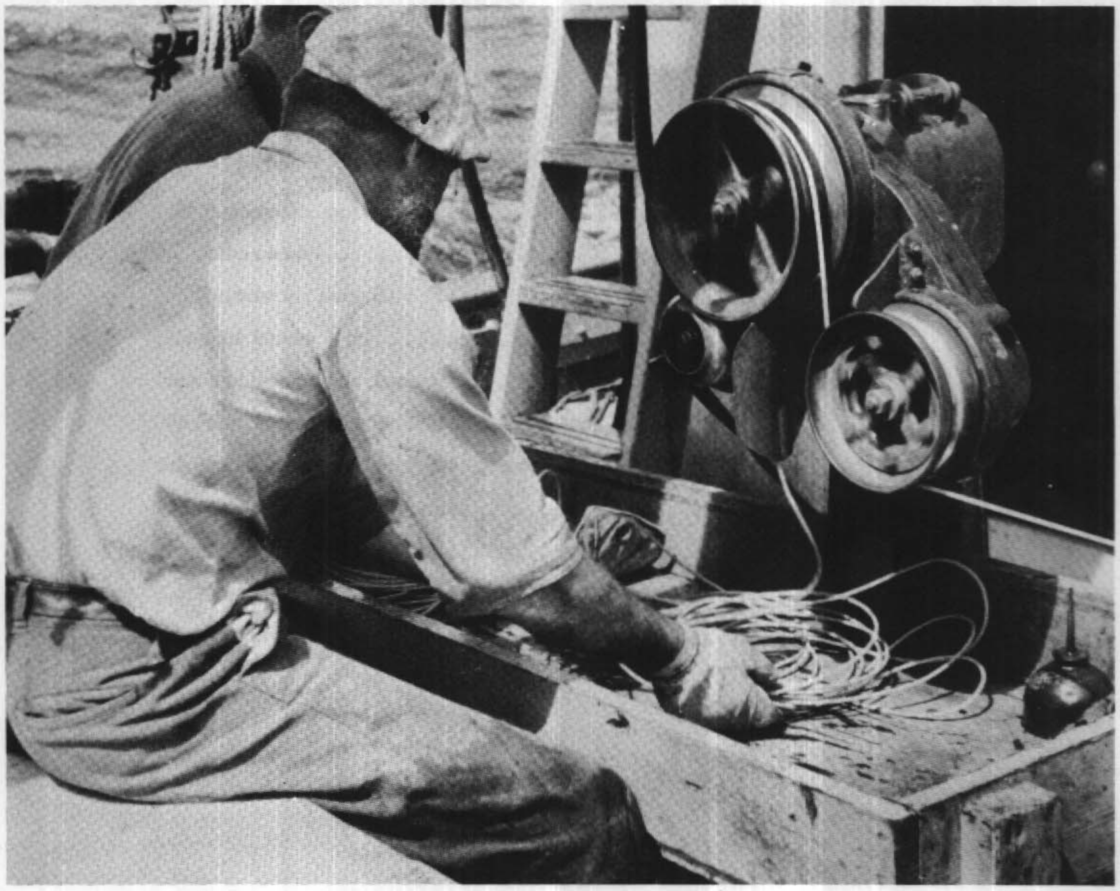
LONGLINE FISHING FOR DEEP-SWIMMING TUNAS IN THE CENTRAL PACIFIC, AUGUST-NOVEMBER 1952

SPECIAL SCIENTIFIC REPORT–FISHERIES No. 137

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

United States Department of the Interior, Douglas McKay, Secretary
Fish and Wildlife Service, John L. Farley, Director



LONGLINE FISHING FOR DEEP-SWIMMING TUNAS IN THE CENTRAL PACIFIC, AUGUST-NOVEMBER 1952

By

Garth I. Murphy

and

Richard S. Shomura
Fishery Research Biologists
Pacific Oceanic Fishery Investigations
Honolulu, T. H.

Special Scientific Report: Fisheries No. 137

WASHINGTON: FEBRUARY 1955

CONTENTS

LIST OF ILLUSTRATIONS

The Pacific Oceanic Fishery Investigations (POFI) is conducting a survey of the fishery resources of the central Pacific. Early in its program it became apparent that the various species of tuna in this area represented a potential source of raw material for the American canning industry. Further study showed that the deep-swimming tunas, particularly the yellowfin, which may be caught by longline, were the most immediately available, and furthermore, the resource appeared to be large enough to support a substantial fishery. Studies were then initiated to determine the magnitude of the resource, its geographical distribution throughout the year, and the environmental factors that control distribution and abundance. Included in this program was a series of longlining cruises which were to cross the equatorial region between 120°W. and 180° longitude.

Two previous reports (Murphy and Shomura 1953a, b) cover the results of longline fishing from July 1950 to June 1952. The present report includes the results of four cruises to equatorial waters during the period August to November 1952. The catches are examined in relation to the environment, and a summary is given of the geographical and vertical variation in the catch rates. In connection with geographical variation a summary is given of selected Japanese commercial fishing catches. There is included a résumé of the size distribution of longline-caught yellowfin and bigeye tuna across the equatorial Pacific, and an analysis of the sex ratios of the yellowfin tuna. Finally, certain topics of particular interest to commercial fishermen, such as gear design and shark damage are briefly discussed. The summarized field data from the four cruises appear in the appendix.

We use the common names of the fishes throughout this report. These, with their commonly accepted scientific names, are as follows:

White-tipped shark, *Carcharinus longimanus* (Poey)
Silky shark, *Carcharinus sp.* 1/
Great blue shark, *Prionace glauca* (Linnaeus)
Bonito shark, *Isurus glaucus* (Müller and Henle)
Marlin, *Makaira sp.*
Sailfish, *Istiophorus orientalis* (Schlegel)
Wahoo, *Acanthocybium solandri* (Cuvier and Valenciennes)
Dolphin, *Coryphaena hippurus* (Linnaeus)
Yellowfin tuna, *Neothunnus macropterus* (Temminck and Schlegel)
Bigeye tuna, *Parathunnus sibi* (Temminck and Schlegel)
Skipjack, *Katsuwonus pelamis* (Linnaeus)
Albacore, *Germo alalunga* (Bonnaterre)
Lancet fish, *Alepisaurus sp.*
Barracuda, *Sphyraena barracuda* (Walbaum)

Several persons were responsible for the execution of the fishing cruises. Included among the field parties were T. S. Hida, I. I. Ikehara, W. M. Matsumoto, D. L. McKernan, T. Otsu, T. J. Roseberry, and W. F. Royce. Considerable assistance in the planning of the cruises was rendered by O. E. Sette. The successful completion of the fishing was due in no small part to the cheerful cooperation of the officers and fishermen of the three vessels. T. S. Austin and the writers prepared the temperature profiles. Wilvan Van Campen translated the Japanese commercial catch data, and Jean Halling assisted in processing the catch records.

MATERIAL AND METHODS

The four cruises included in this report are (1) *John R. Manning* cruise 12, with lines of fishing stations across the Equator on 140°W. and 150°W. longitude; (2) *Cavalieri* cruise 1, a semicommercial fishing trip (McKernan 1953), with a line of stations fished south from 9°N. on 140°W. to the Equator followed by a series of stations north of the Equator between 140°W. and

---

1/ A species closely resembling *C. floridanus* Bigelow, Schroeder, and Springer, and *C. ahenea* (Stead).

150°W. longitude; (3) Hugh M. Smith cruise 18, with lines of fishing stations across the Equator along 120°W. and 130°W. longitude; and (4) John R. Manning cruise 13, with fishing sections across the Equator on 150°W. and 169°W. longitude.

The Cavalieri cruise warrants special mention because it represented an attempt at commercially harvesting the equatorial longline tuna resource. During this cruise considerably more gear was fished than during experimental surveys by POFI vessels. The design of the gear was identical to that used by POFI, and the daily fishing schedule was comparable except that more time was spent setting and hauling the greater number of baskets fished.

The gear used on the four cruises covered by this report was similar in construction to that used during previous POFI exploratory fishing, except that small amounts of specially designed gear were fished during some trips. Complete descriptions of the "standard" gear that formed the bulk of each set are furnished by Niska (1953) and Murphy and Shomura (1953a).

Briefly, each basket of the standard longline gear consisted of a main line 1,260 feet long suspended by 60-foot buoy lines and bearing six-hook droppers attached at 180-foot intervals. These droppers made of cotton line and steel leaders were about 88 feet in overall length. At each station the gear was set at dawn, and hauling commenced about noon. Setting took from 1 to 1.5 minutes per basket and hauling about 5 minutes per basket (tables 20-23). Thus, the operational aspect of these cruises was identical with past surveys except that different baits were used.

On earlier cruises the bait had been almost exclusively sardine. During these cruises other baits, such as herring and squid, and various methods for attaching the bait to the hook were tested. The results of these experiments are not reported herein except to note that the experimental baits and baiting methods did not appreciably alter the catch rates (Shomura MS), enabling us to disregard this factor in our evaluation of the abundance of tunas.

GEOGRAPHICAL VARIATION IN THE CATCH RATES

The four cruises during the period August-November 1952 (fig. 1) provide estimates of the abundance of deep-swimming tunas in the equatorial region over a wide range of longitudes (120°W. to 170°W.). Previous fishing during this general season in 1950 and 1951 indicated a concentration of yellowfin tuna between 1°N. and 6°N. latitude at 150°W. to 160°W. longitude (Murphy and Shomura 1953a). The results of the 1952 surveys provide a check on these earlier findings and also extend the geographical coverage during the period August to November.

By way of review of previous results and the general concepts utilized in their interpretation, it should first be pointed out that the prevailing winds in the mid-Pacific equatorial region during the period August to November are from the southeast quadrant (U. S. Pilot Charts). According to Cromwell (1953), these winds create divergence and upwelling at the Equator and tend to displace the upwelled water northward. This nutrient-rich upwelled water supports a larger population of zooplankton than the waters to the north and south (King and Demond 1953), and it was expected that this increase in the basic animal food would be reflected in the abundance of the larger fishes. Several fishing sections across the Equator indicated that the tuna, in particular the yellowfin, were indeed more abundant in the zone of enrichment (Murphy and Shomura 1953a, b).

The results of these four latest cruises will be considered in the light of previous findings, with attention focused on the yellowfin tuna catches, and the environmental circumstances associated with these catches followed by a brief discussion of the apparent distribution of albacore along the Equator. The catches of the other tunas are not singled out for special attention, but are included in tabular form in order to indicate the relative levels of abundance of the several species in the catch.

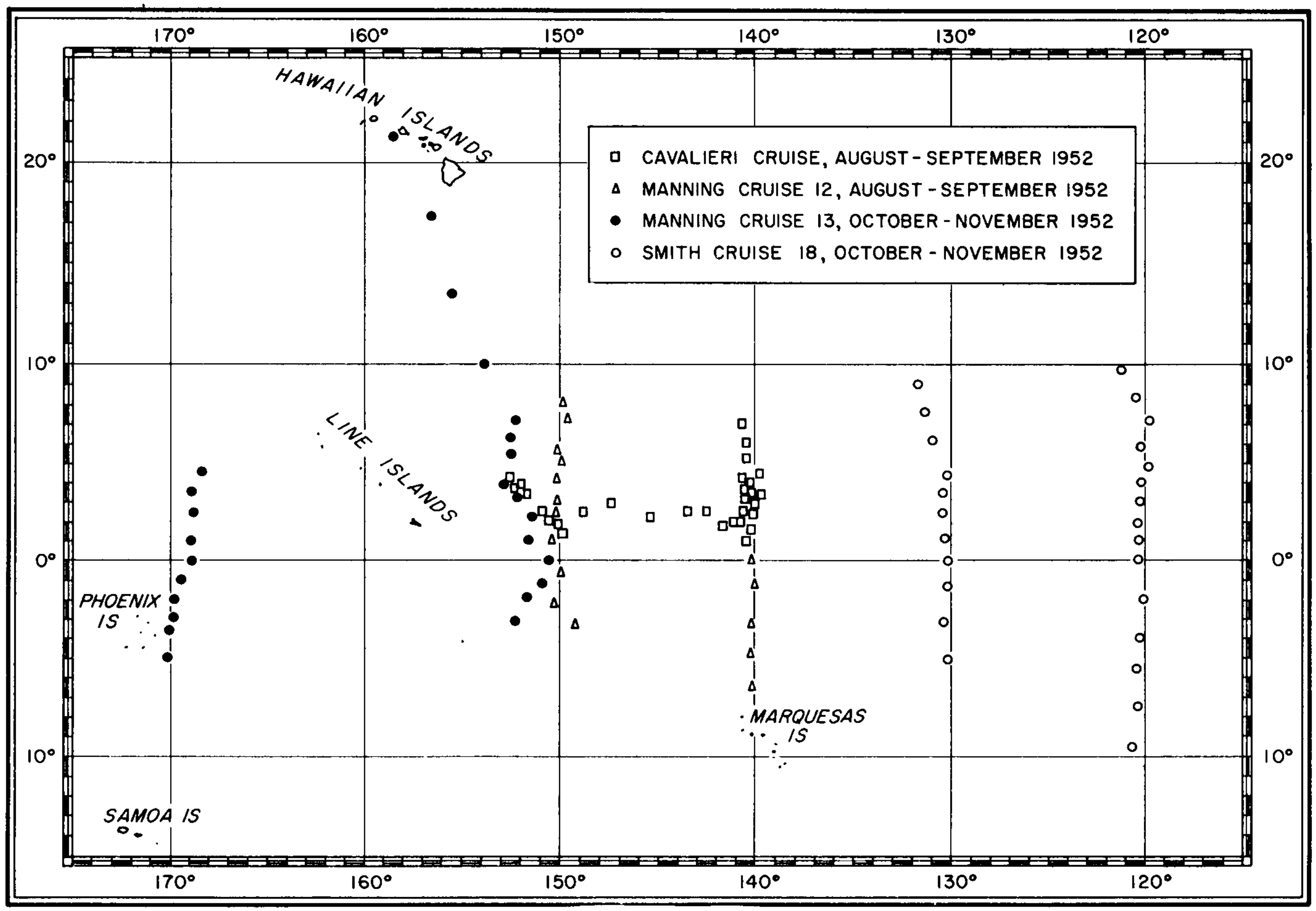


Figure 1.--Locations of fishing stations, Cavalieri cruise 1, Manning cruises 12 and 13, and Smith cruise 18.

Yellowfin Tuna

The yellowfin catches of these four cruises indicate a center of abundance in the region of 140°-150°W. longitude, just north of the Equator. East and west of this zone the abundance fell off markedly, particularly to the east. This agrees in general with earlier findings.

The section at 120°W. longitude (fig. 2, table 1) gives evidence of very intense upwelling of the type described by Cromwell (1953). This is indicated by the cooler surface water at the Equator. The general distribution of this cool water indicates that it is being moved northward, as would be expected under the prevailing winds. The yellowfin appear to have been virtually absent from this newly upwelled water, although they were taken to the north and south of it (fig. 2). This is understandable if it is hypothesized that the newly upwelled water had not been in the euphotic zone long enough to develop a population of tuna forage.

The section on 130°W. longitude (fig. 3, table 1) rather closely resembles the 120°W. section in respect to the distribution of isotherms and the distribution of yellowfin, except that on the former the surface temperatures were somewhat higher and the yellowfin more abundant in the region of upwelled water. The slightly higher surface temperatures along 130°W. might indicate that the upwelling had been less intense or from shallower depths, or it might mean that the water had been in the photosynthetic zone for a longer period of time. If the latter were true, tuna feed might have accumulated, leading to the somewhat denser population of yellowfin evidenced by our catch rates.

Table 1.--Summary of the tuna catch, Smith cruise 18 (more complete data will be found in the appendix)

Station	Date	Noon position		Catch per 100 hooks			
		Latitude	Longitude	Yellowfin	Bigeye	Albacore	Skipjack
1	10-18-52	9°39'N	121°13'W	-	-	-	-
3	10-19-52	8°21'N	120°20'W	2.1	2.1	-	-
4	10-21-52	7°12'N	119°52'W	0.4	5.0	-	-
5	10-22-52	5°52'N	120°11'W	-	0.4	-	-
6	10-23-52	4°53'N	119°49'W	-	1.3	-	-
7	10-24-52	4°02'N	120°12'W	-	0.4	-	-
8	10-25-52	3°03'N	120°15'W	-	3.3	-	-
9	10-26-52	1°55'N	120°26'W	0.4	-	-	-
10	10-27-52	1°01'N	120°13'W	-	-	-	-
12	10-28-52	0°02'N	120°20'W	1.3	0.8	-	-
14	10-29-52	1°59'S	120°03'W	-	0.4	-	-
16	10-30-52	3°58'S	120°14'W	1.7	0.4	-	-
18	10-31-52	5°36'S	120°25'W	1.7	0.4	0.4	1.3
20	11-1-52	7°33'S	120°21'W	5.8	1.3	-	-
22	11-2-52	9°36'S	120°44'W	0.4	0.4	-	-
23	11-5-52	5°10'S	130°06'W	1.3	0.8	-	0.4
25	11-6-52	3°11'S	130°17'W	2.5	1.3	-	2.1
27	11-7-52	1°21'S	130°10'W	0.8	-	-	-
29	11-8-52	0°04'S	130°10'W	2.1	-	-	-
30	11-9-52	1°11'N	130°15'W	-	0.8	-	-
31	11-10-52	2°23'N	130°25'W	1.3	-	-	-
32	11-11-52	3°23'N	130°29'W	0.4	-	-	-
33	11-12-52	4°18'N	130°11'W	1.7	-	-	-
35	11-13-52	6°13'N	131°00'W	0.4	0.8	-	-
36	11-14-52	7°39'N	131°20'W	0.4	1.3	-	2.1
37	11-15-52	9°05'N	131°41'W	-	-	-	-

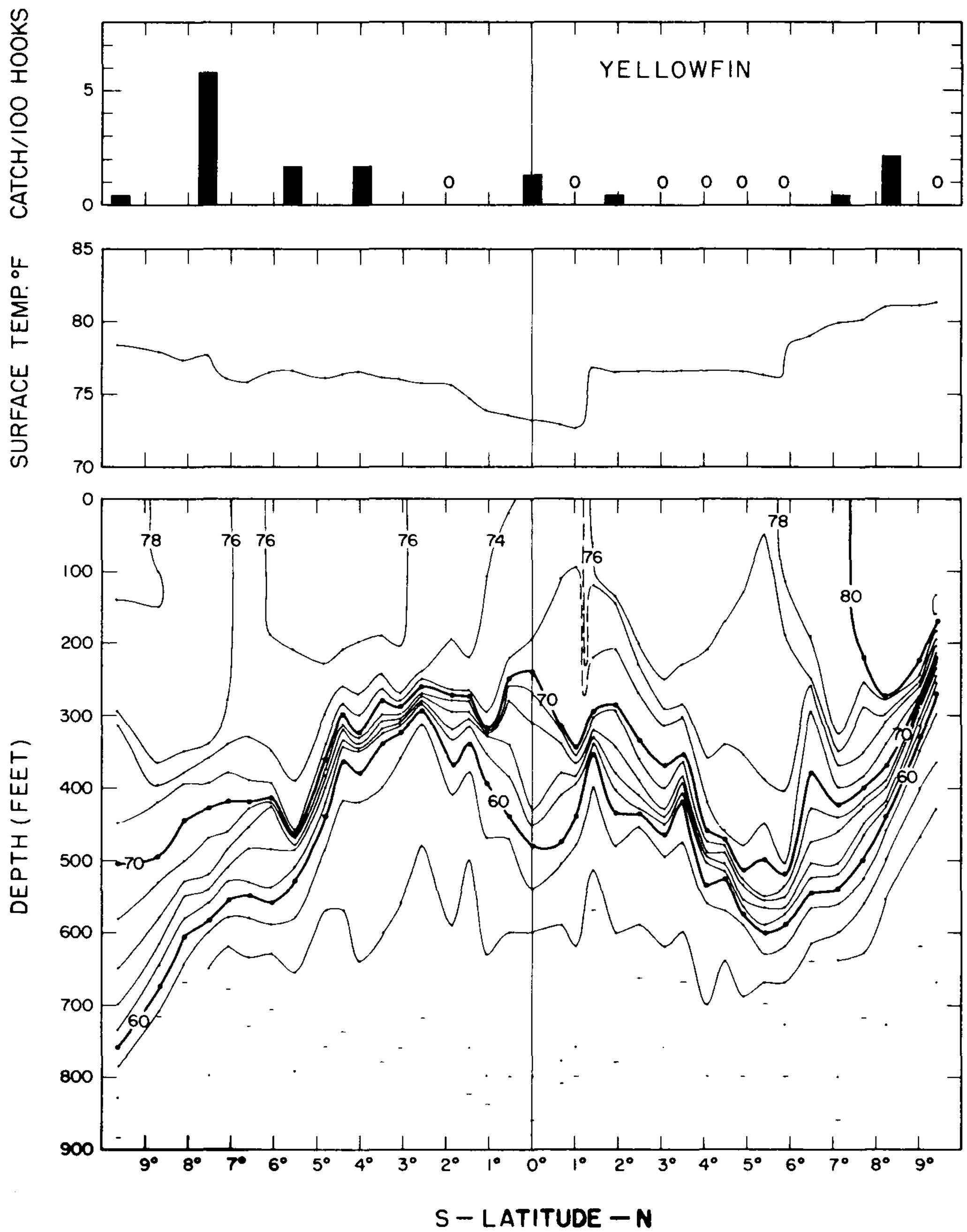


Figure 2.--Temperature section and yellowfin tuna catch along 120°W. longitude, October-November 1952. If no yellowfin were taken, a zero is shown in the upper panel.

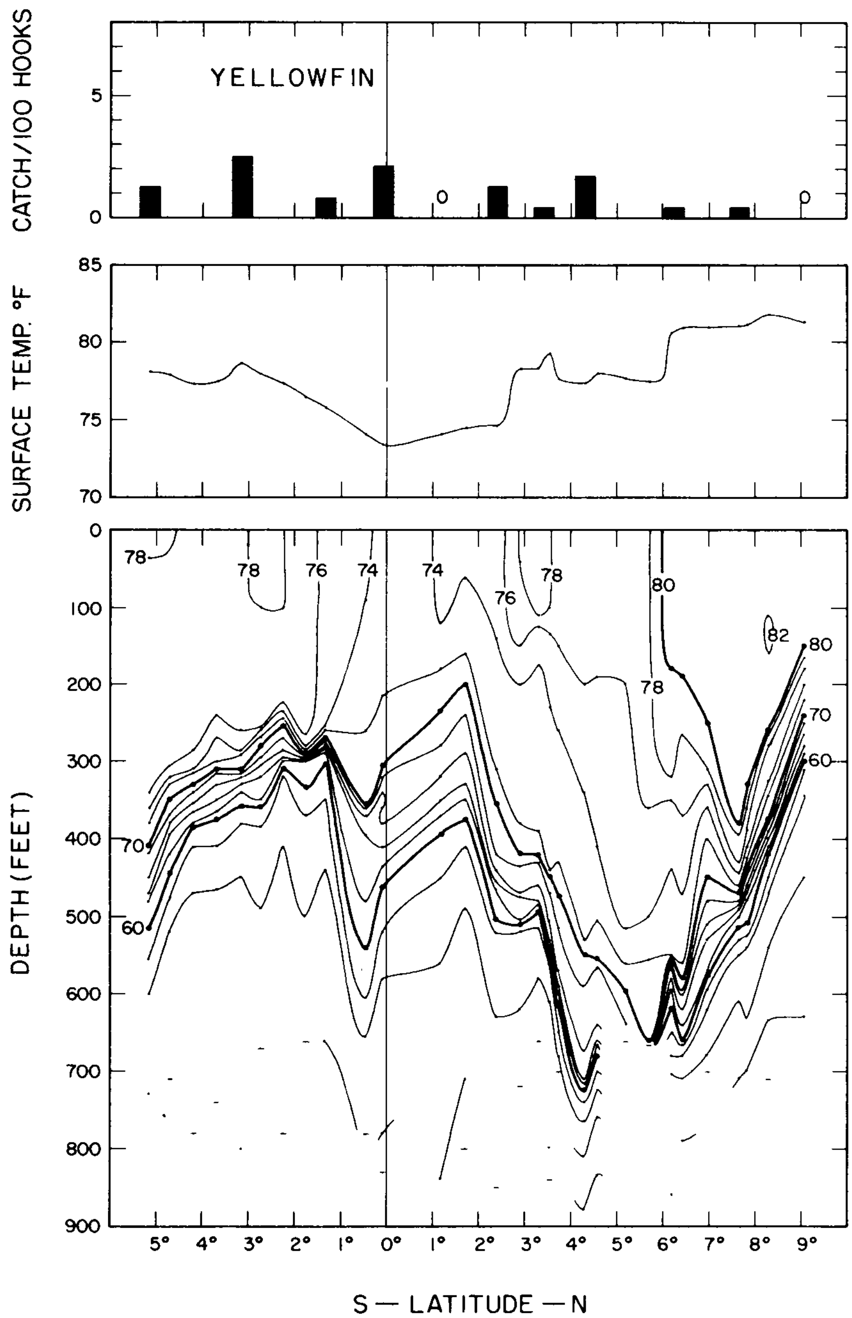


Figure 3.--Temperature section and yellowfin tuna catch along 130°W. longitude, November 1952. If no yellowfin were taken, a zero is shown in the upper panel.

The section on 140°W. (fig. 4, tables 2 and 3) gives the familiar picture of upwelling at the Equator, although less intense than on 120°W. and 130°W., and indicates clearly a concentration of yellowfin in the South Equatorial Current north of the Equator. This section is not, however, strictly comparable to the other sections included in this report as it is made up of stations from the *Cavalieri* cruise (1° to 7°N.) and from *Manning* cruise 12 (0° to 7°S.). The *Cavalieri* stations were fished from August 21 to September 6 and the *Manning* stations from August 31 to September 4, probably an inconsequential difference in time.

There were two sections along 150°W. longitude (figs. 5 and 6, tables 3 and 4). One was fished during the course of *Manning* cruise 12 in August 1952 and the second during *Manning* cruise 13 in October-November 1952. Both sections provide evidence of moderate upwelling and a moderate concentration of yellowfin north of the Equator. Falling between these sections in time were the stations fished by the *Cavalieri* in September of 1952 along 150°W. longitude. It is of interest to note that her catches (table 2) average considerably higher than those experienced a month earlier and a month later by the *Manning*. These catches of the *Cavalieri* were lower, however, than those obtained along 150°W. longitude in September 1951 (Murphy and Shomura 1953a).

Table 2.--Summary of the tuna catch, *Cavalieri* cruise 1 (more complete data will be found in the appendix)

Station	Date	Noon position		Catch per 100 hooks		
		Latitude	Longitude	Yellowfin	Bigeye	Skipjack
1	8-21-52	7°02'N	140°40'W	0.7	0.3	-
2	8-22-52	6°02'N	140°26'W	1.3	0.3	-
3	8-23-52	5°16'N	140°28'W	4.2	1.1	-
4	8-24-52	4°26'N	139°43'W	5.0	-	1.1
5	8-25-52	3°26'N	140°08'W	9.2	1.9	0.6
6	8-26-52	2°24'N	140°07'W	9.0	-	-
7	8-27-52	1°33'N	140°13'W	11.8	-	0.2
8	8-28-52	1°00'N	140°22'W	2.9	-	0.2
9	8-29-52	2°00'N	140°40'W	5.7	-	0.2
10	8-30-52	3°37'N	140°27'W	6.0	0.2	0.2
11	8-31-52	3°45'N	140°10'W	7.5	-	-
12	9-1-52	3°31'N	140°28'W	3.1	-	0.2
13	9-2-52	3°05'N	140°02'W	4.0	-	0.8
14	9-3-52	4°04'N	140°09'W	1.7	-	-
15	9-4-52	3°20'N	140°10'W	3.3	0.3	-
16	9-5-52	2°25'N	140°32'W	4.9	0.9	0.4
17	9-6-52	2°06'N	140°56'W	4.9	0.6	0.2
18	9-7-52	1°42'N	141°24'W	3.8	0.6	-
19	9-8-52	2°30'N	142°24'W	4.8	0.8	-
20	9-9-52	2°33'N	143°22'W	4.4	0.2	-
21	9-10-52	2°08'N	145°21'W	3.1	0.2	1.0
22	9-11-52	2°57'N	147°22'W	4.2	-	-
23	9-12-52	2°25'N	148°47'W	1.9	0.8	-
24	9-13-52	1°22'N	149°54'W	5.6	0.8	0.2
25	9-14-52	1°48'N	150°05'W	5.6	0.4	0.4
26	9-15-52	2°05'N	150°23'W	5.0	0.4	-
27	9-16-52	2°28'N	150°38'W	2.9	0.4	-
28	9-17-52	3°26'N	151°40'W	6.9	0.6	-
29	9-18-52	3°39'N	151°54'W	12.7	1.2	0.6
30	9-19-52	3°41'N	152°10'W	9.0	1.2	-
31	9-20-52	4°11'N	152°27'W	7.9	1.0	-

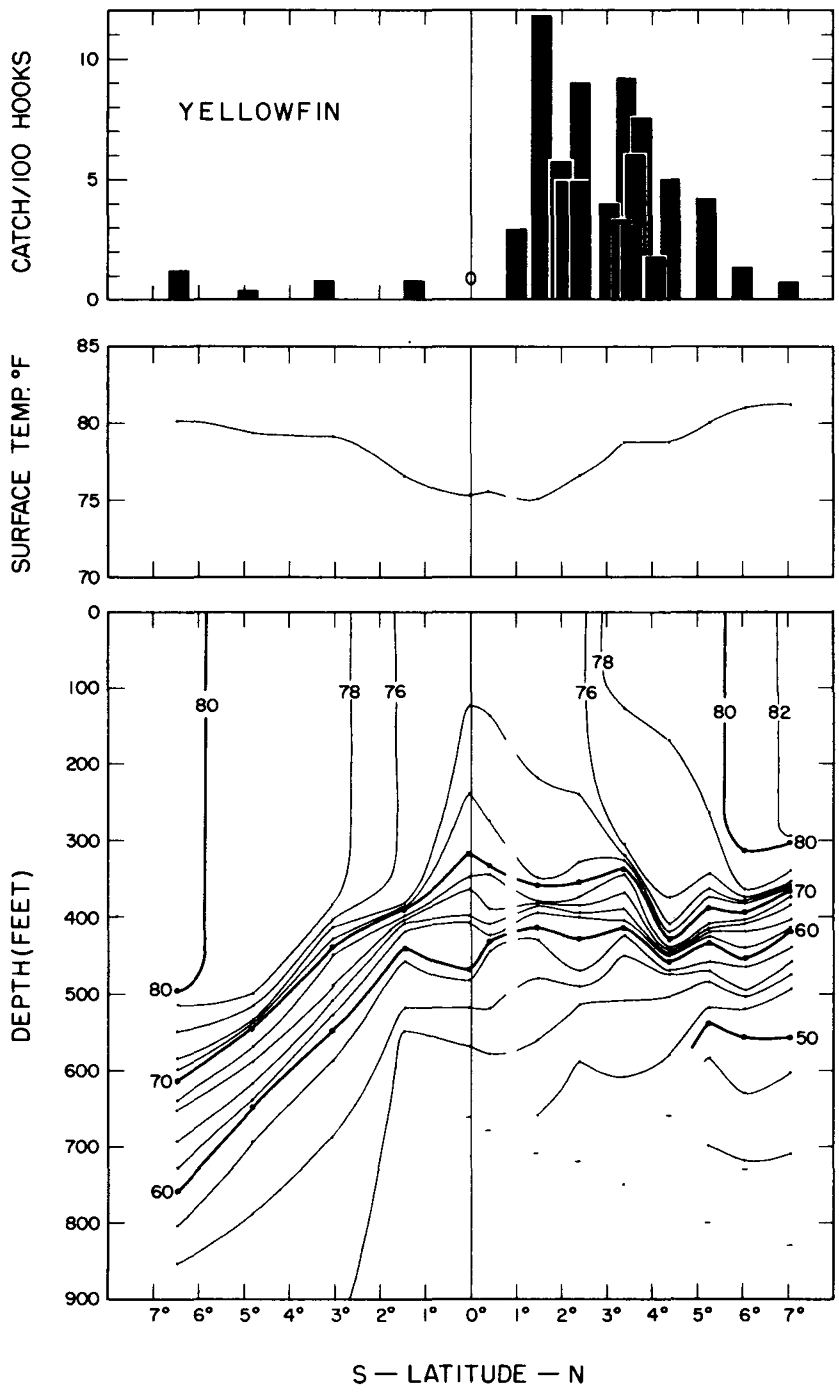


Figure 4.--Temperature section and yellowfin tuna catch along 140°W. longitude, August-September 1952. If no yellowfin were taken, a zero is shown in the upper panel. The break in the isotherms represents a 17-day interval between adjacent observations.

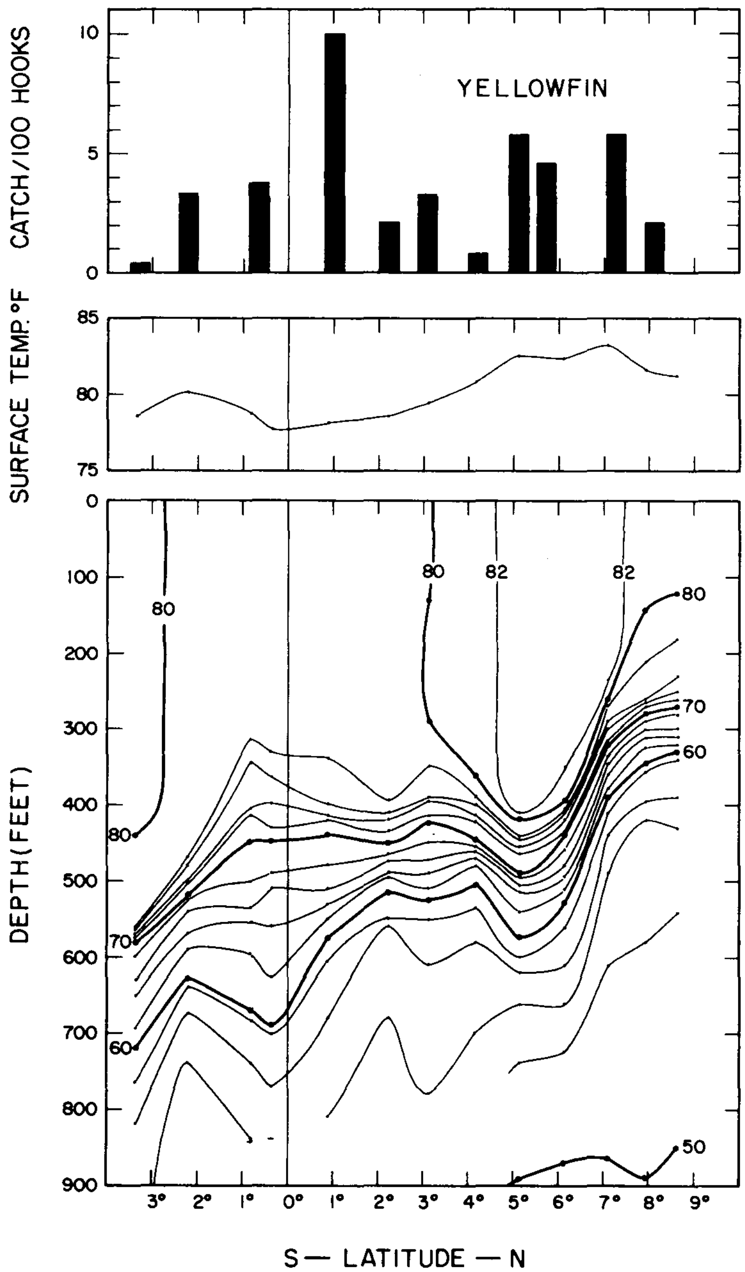


Figure 5.--Temperature section and yellowfin tuna catch along 150°W. longitude, August 1952.

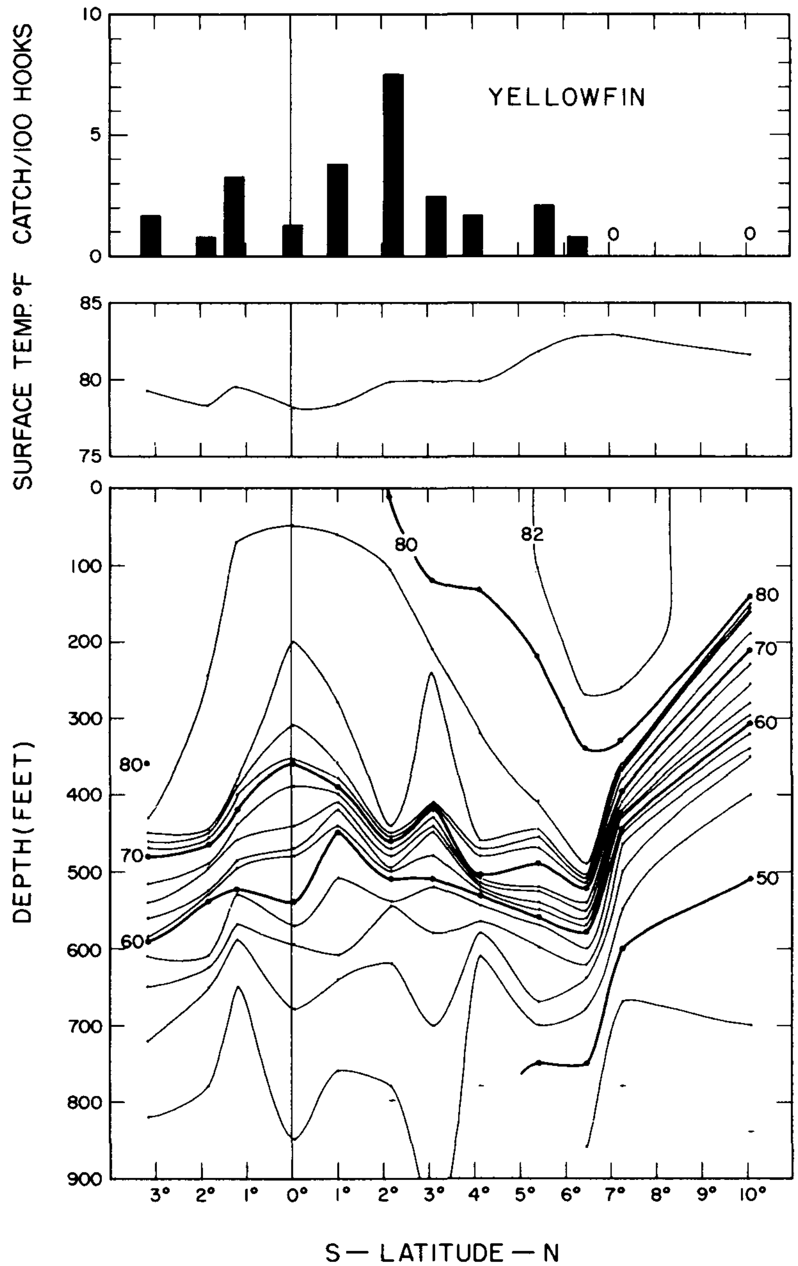


Figure 6.--Temperature section and yellowfin tuna catch along 150°W. longitude, October-November 1952. If no yellowfin were taken, a zero is shown in the upper panel.

Table 3.--Summary of the tuna catch, Manning cruise 12. (This tabulation includes only the catches at stations where 40 standard baskets (240 hooks) were fished in a manner designed to furnish an index of abundance. Other stations and experimental gear are considered elsewhere. More complete data will be found in the appendix.)

Station	Date	Noon position		Catch per 100 hooks			
		Latitude	Longitude	Yellowfin	Bigeye	Albacore	Skipjack
1	8-11-52	8°07'N	149°51'W	2.1	-	-	-
2	8-12-52	7°15'N	149°36'W	5.8	0.8	-	-
3	8-13-52	5°43'N	150°06'W	4.6	0.8	-	-
4	8-14-52	5°07'N	149°55'W	5.8	1.2	-	-
5	8-15-52	4°09'N	150°12'W	0.8	0.4	-	0.4
6	8-16-52	3°06'N	150°12'W	3.3	-	-	-
8	8-18-52	2°14'N	150°17'W	2.1	0.8	-	-
9	8-19-52	1°02'N	150°25'W	10.0	-	-	-
10	8-20-52	0°39'S	149°56'W	3.8	-	-	-
11	8-21-52	2°12'S	150°20'W	3.3	-	0.4	0.4
12	8-22-52	3°14'S	149°10'W	0.4	-	-	0.4
15	8-31-52	6°27'S	140°03'W	1.2	1.7	0.4	0.4
16	9-1-52	4°51'S	140°09'W	0.4	0.4	-	0.4
17	9-2-52	3°14'S	140°06'W	0.8	1.7	-	-
18	9-3-52	1°14'S	140°02'W	0.8	0.8	-	0.4
19	9-4-52	0°01'N	140°08'W	-	-	-	-

The section along 169°W. longitude in November 1952 (fig. 7, table 4) shows somewhat less evidence of upwelling in the vicinity of the Equator than do the sections to the east. Coincident with this, there was little indication of a yellowfin concentration to the north of the Equator. In general, the fish seem to have been more evenly spread over the entire section, with only a slight tendency to aggregate in the vicinity of the Equator.

In summary, the distribution of yellowfin tuna along the Equator in the central Pacific as revealed by the results of these four cruises is consistent with the distributions obtained during 1950 and 1951 in the late summer and fall. There is evidence, however, that the abundance was somewhat less during the early fall of 1952 than during the same period of 1951. During the earlier period a series of 10 stations over a rather wide area west of 150°W. longitude at approximately 2°N. latitude produced catches of yellowfin averaging over 12 fish per hundred hooks. During the fall of 1952 a larger number of stations in the same general locality resulted in only two catches near 12 per hundred hooks, and the average was about 6 yellowfin per hundred hooks. As yet there is no adequate explanation for this variation in the level of abundance.

Albacore

The cruises undertaken in the equatorial region provide only limited information on the distribution of albacore. This species is so important to the American tuna industry, however, that there is some justification for a preliminary statement of our findings. In general our surveys indicate that albacore are more abundant south than north of the Equator. This is shown by catches made along 169°W. longitude at about 5°S. in November 1952 (table 4), and by the good catches made at 5°-8°S. latitude along 169°W. and 180°W. longitude in February 1952 (Murphy and Shomura 1953b). Albacore appear to be more abundant to the west, as evidenced by the almost negative results along 120°W. and 130°W. (table 1), moderate results along 140°W. and 150°W. (tables 2 and 3), and relatively high catches along 169°W. and 180°W. (table 4 and Murphy and Shomura 1953b). The best catch was made during February 1952, when 6 albacore per 100 hooks

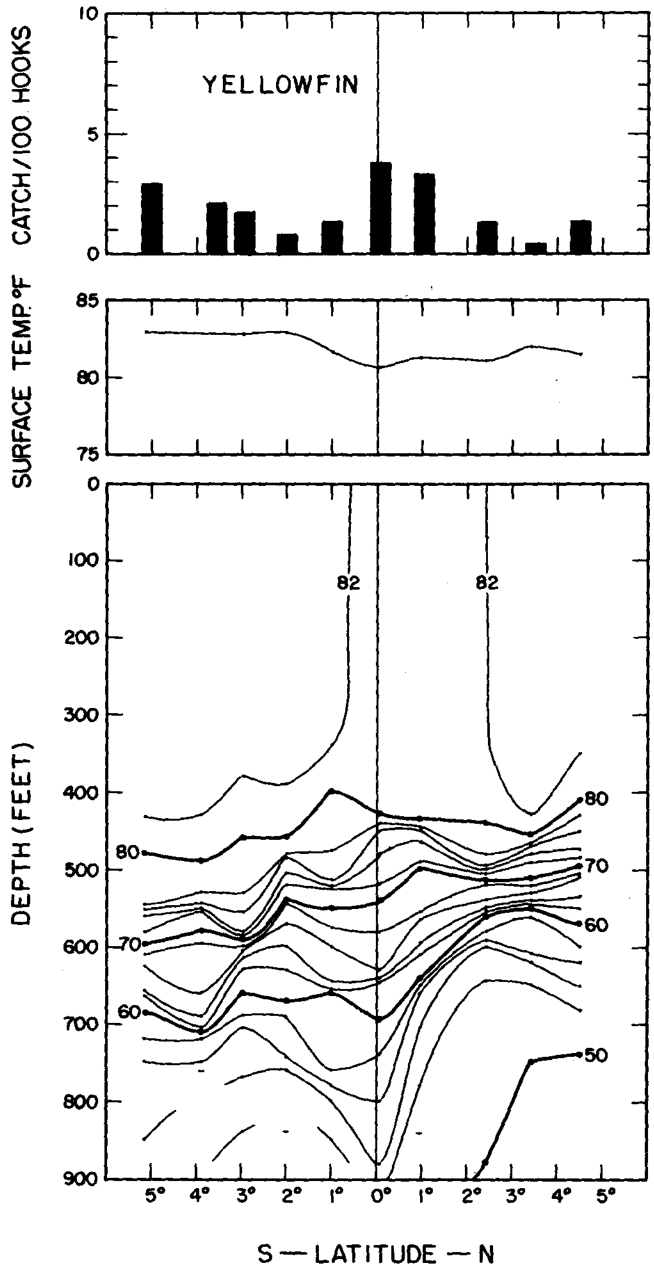


Figure 7.--Temperature section and yellowfin tuna catch along 169° W. longitude, November 1952.

Table 4.--Summary of the tuna catch, Manning cruise 13. (This tabulation includes only the catches at stations where 40 standard baskets (240 hooks) were fished in a manner designed to furnish an index of abundance. Other stations and experimental gear are considered elsewhere.)

Station	Date	Noon position		Catch per 100 hooks			
		Latitude	Longitude	Yellowfin	Bigeye	Albacore	Skipjack
1	10-17-52	21°11'N	158°25'W	-	-	1.7	-
2	10-19-52	17°16'N	156°32'W	-	0.8	-	-
3	10-21-52	13°30'N	155°24'W	-	1.7	-	0.4
4	10-23-52	10°03'N	153°35'W	-	0.4	-	0.4
6	10-25-52	7°06'N	152°11'W	-	1.7	-	-
7	10-26-52	6°17'N	152°28'W	0.8	0.4	-	-
8	10-27-52	5°34'N	152°26'W	2.1	-	-	-
9	10-28-52	4°00'N	152°20'W	1.7	0.4	-	-
10	10-29-52	3°13'N	152°05'W	2.5	1.3	-	-
11	10-30-52	2°15'N	151°19'W	7.5	-	-	-
14	11-3-52	1°00'N	151°26'W	3.8	0.4	-	0.8
15	11-4-52	0°03'N	150°39'W	1.3	-	-	0.4
16	11-5-52	1°14'S	150°51'W	3.3	-	-	3.8
17	11-6-52	1°52'S	151°46'W	0.8	-	-	-
18	11-7-52	3°06'S	152°15'W	1.7	-	0.4	-
19	11-19-52	5°00'S	170°08'W	2.9	0.8	2.9	-
20	11-20-52	3°36'S	170°02'W	2.1	-	1.3	-
21	11-21-52	2°57'S	169°49'W	1.7	-	-	0.4
22	11-22-52	1°59'S	169°44'W	0.8	0.4	0.8	0.8
23	11-23-52	1°00'S	169°27'W	1.3	-	-	0.4
24	11-24-52	0°04'N	168°48'W	3.8	-	-	0.4
25	11-25-52	1°03'N	168°52'W	3.3	-	-	1.3
26	11-26-52	2°24'N	168°44'W	1.3	-	-	-
27	11-27-52	3°30'N	168°49'W	0.4	-	-	0.4
28	11-28-52	4°30'N	168°17'W	1.3	-	-	-

were taken at 5°S. latitude, 180°E. longitude. The absolute size of the catch obtained on these surveys cannot, however, be regarded as indicative of the potential of the population as the gear was designed for yellowfin fishing and probably was not operated in a manner conducive to the most efficient capture of albacore.

Japanese Longline Fishing

There was a renewal of Japanese commercial fishing in the western part of the central Pacific during the latter half of 1952. Some of their catches during the period covered by this report (August-November 1952) in the western portion of the area under consideration are given in tables 5 and 6. In general they show the same abundance of tunas as our experimental fishing, with bigeye dominating north and yellowfin south of 5°N. latitude. Further, it is evident that the relatively low catch rates experienced by us at 169°W. longitude were representative as far west as 180° longitude.

Certain portions of the data in table 6 are of special interest because they afford an opportunity for a direct comparison of our catch rates with commercial fishing results. Figure 8 shows the catches of the Manning along 169°W. longitude in comparison with Japanese catches (averaged by degrees of latitude) made between 168°W. and 175°W. longitude at almost the same

Table 5.--Summary of Japanese longline fishing in the central Pacific in 1952 (adapted from Kanagawa Prefecture Fishery Experiment Station, Monthly Report Nos. 3-6)

Month	Latitude	Longitude	Number of hooks	Catch per 100 hooks					
				Yellow-fin	Big-eye	Alba-core	Skip-jack	Spear-fishes	Sharks
July	6°-12°N	164°-178°W	189,770	0.23	2.29	0.04	0.32	1.41	0.64
August	0°- 6°N	160°-177°W	81,750	1.71	0.91	0.04	0.08	1.14	0.59
	8°-20°N	161°-180°W	237,190	0.17	2.47	0.07	0.13	1.37	1.13
September	3°- 4°N	171°-178°W	33,120	2.77	0.29	0.02	0.06	0.79	0.66
	7°-12°N	158°-179°W	124,000	0.22	1.83	0.04	0.14	1.01	0.81
October	7°-11°N	173°-180°W	154,340	0.35	1.80	0.09	0.03	0.77	0.78
	3°- 6°N	167°-179°W	107,090	2.79	0.68	0.02	0.31	1.01	0.73
November	7°-11°N	169°-179°W	101,954	0.27	2.22	0.01	0.08	0.65	0.97
	0°- 5°N	160°-179°W	111,780	1.83	0.78	0.06	-	0.80	0.98

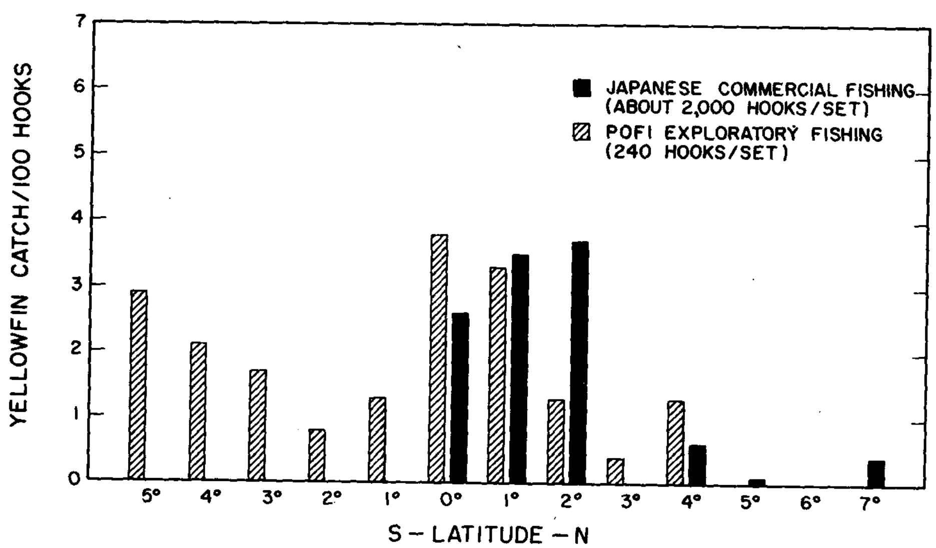


Figure 8.--Comparison between the catch rates of Japanese commercial sets and POFI exploratory sets. The bars representing Japanese fishing are based on data in table 6. The bars representing POFI fishing are based on results of fishing along 169°W. longitude during _Manning_ cruise 13 (table 4).

Table 6.--Records of individual commercial longline sets by two Japanese vessels in the central Pacific in 1952 (unpublished data furnished by Mr. Toshizō Nomura of the Kanagawa Prefecture Fisheries Experiment Station)

Date	Latitude	Longitude	Number of hooks	Catch per 100 hooks			
				Yellowfin	Bigeye	Albacore	Skipjack
Vessel A							
27 Oct.	5°20'N	175°10'W	1,560	0.12	0.57	-	-
28 "	4°29'N	175°15'W	1,560	0.57	0.45	-	-
3 Nov.	6°38'N	173°08'W	1,560	0.12	1.28	-	-
4 "	6°50'N	171°40'W	1,560	0.77	2.76	-	-
5 "	6°38'N	169°20'W	1,560	0.51	3.46	-	-
6 "	7°20'N	165°01'W	1,560	0.38	1.92	-	-
7 "	6°30'N	166°00'W	1,560	0.64	2.12	0.26	-
8 "	6°54'N	166°38'W	1,560	1.28	1.67	-	-
9 "	2°28'N	166°20'W	1,950	2.00	0.10	-	-
10 "	1°40'N	168°30'W	1,950	5.13	0.62	-	-
11 "	1°48'N	168°30'W	1,950	3.95	0.41	-	-
13 "	0°53'N	169°35'W	1,950	5.23	0.15	-	-
14 "	0°56'N	170°30'W	1,950	1.74	0.62	-	-
15 "	0°17'N	169°20'W	1,950	0.26	0.15	0.10	-
17 "	0°24'N	169°55'W	1,950	4.10	0.31	-	-
18 "	0°57'N	170°07'W	1,950	3.18	0.41	-	-
19 "	0°35'N	169°55'W	1,950	2.51	0.21	0.05	-
20 "	0°11'N	170°30'W	1,950	3.54	0.21	0.10	-
21 "	0°35'N	170°10'W	1,950	3.90	0.41	0.10	-
22 "	0°36'N	170°07'W	1,950	4.67	0.31	0.05	-
23 "	0°37'N	170°03'W	1,950	3.49	0.21	0.15	-
Vessel B							
29 Oct.	6°55'N	178°18'E	1,830	0.49	1.80	-	0.11
30 "	7°15'N	179°16'E	1,830	0.44	1.42	-	0.44
31 "	7°00'N	178°53'E	1,830	0.11	2.13	-	0.55
2 Nov.	10°27'N	179°10'E	1,830	0.16	0.71	-	0.11
4 "	6°51'N	178°58'W	1,830	0.11	2.19	-	0.11
5 "	6°58'N	178°33'W	1,830	0.22	2.68	-	0.05
6 "	6°52'N	178°21'W	1,830	0.27	1.91	-	0.16
7 "	7°00'N	178°36'W	1,830	0.27	2.51	-	0.16
8 "	7°07'N	178°33'W	1,830	0.05	2.79	-	0.16
9 "	6°59'N	178°39'W	1,830	0.27	3.06	-	0.16
10 "	6°55'N	178°45'W	1,830	0.16	2.51	-	0.27
11 "	6°57'N	178°47'W	1,830	0.05	1.09	-	-
12 "	7°03'N	178°39'W	1,830	0.27	1.75	-	-
13 "	6°58'N	178°35'W	1,830	0.38	1.75	-	0.16
14 "	7°00'N	178°44'W	1,464	0.14	0.89	-	0.27
15 "	7°15'N	178°55'W	1,400	0.07	3.43	-	0.36
16 "	7°40'N	179°07'W	1,120	0.80	0.71	-	0.27

time. The Japanese catches are of the same general magnitude as ours but are less variable. The variability of our catches can probably be attributed to the small amount of fishing effort represented. From these data it can be concluded that the catch rates obtained by small experimental sets of gear are representative of what might be expected from a large commercial set.

SIZE OF TUNAS

Length frequencies of the yellowfin tuna taken on the nine sections (table 7) suggest a tendency for the catches to be composed of larger fish toward the eastern end of the survey area, although the difference is not as pronounced as indicated in earlier surveys (Murphy and Shomura 1953b). A recapitulation of data for yellowfin is given in table 7 and in figure 9, based on data in Murphy and Otsu (1954), Murphy and Shomura (1953a, b), and table 7. This clearly shows that longline yellowfin increase in size from west to east. The simplest explanation of this size differential is that the growth rate of the yellowfin changes across the Pacific. This is most likely a reflection of the relative availability of food in the several areas.

Table 7.--Length frequencies of yellowfin tuna taken by longline fishing gear

Length	Smith cruise 18		Manning cruise 12		Cavalieri cruise 1			Manning cruise 13	
	120°W.	130°W.	140°W.	150°W.	140°W.1/	145°W.2/	150°W.3/	150°W.	169°W.
cm									
42	1	-	-	-	-	-	-	-	-
47	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	-
57	-	-	-	-	-	-	-	-	-
62	-	-	-	-	-	-	-	-	-
112	-	-	-	-	3	-	-	1	-
117	-	1	-	-	-	-	1	1	1
122	1	1	1	2	2	-	1	-	3
127	2	2	1	3	2	1	1	1	2
132	1	2	1	9	12	3	11	4	8
137	6	3	1	17	23	13	40	11	18
142	3	1	1	33	47	12	40	17	5
147	5	2	-	13	40	13	37	16	7
152	4	1	-	11	51	18	30	4	3
157	5	2	-	5	62	21	13	2	-
162	3	1	1	3	39	12	3	1	-
167	2	5	-	1	21	4	1	-	-
172	-	2	-	-	6	-	-	1	-
177	-	-	-	-	-	1	-	-	-

1/ Stations 1-19
2/ Stations 20-22
3/ Stations 23-31

This proposal is compatible with our estimates of the amount of upwelling in the three areas figured. In the westernmost area (140°E. to 170°E. longitude) there is no evidence that upwelling takes place along the Equator (Murphy and Otsu 1954). In the central area (180° to 150°W. longitude) moderate to strong upwelling is a persistent feature of the hydrography along the Equator (Austin 1954, Cromwell 1953, Murphy and Shomura 1953a, b, and figs. 5-7 of this report). In the easternmost area (145°W. to 120°W. longitude) upwelling appears to be very intense, at least at times (figs. 2-3).

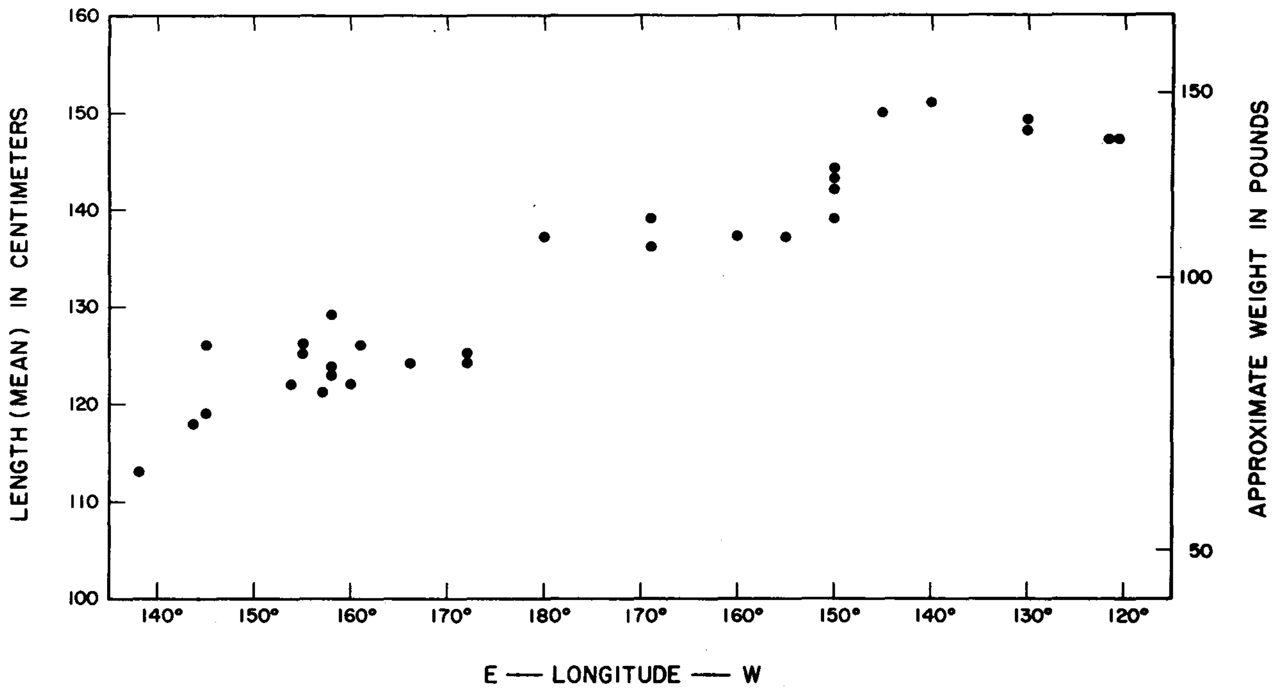


Figure 9.--Mean lengths of samples of longline-caught yellowfin plotted against longitude of capture.

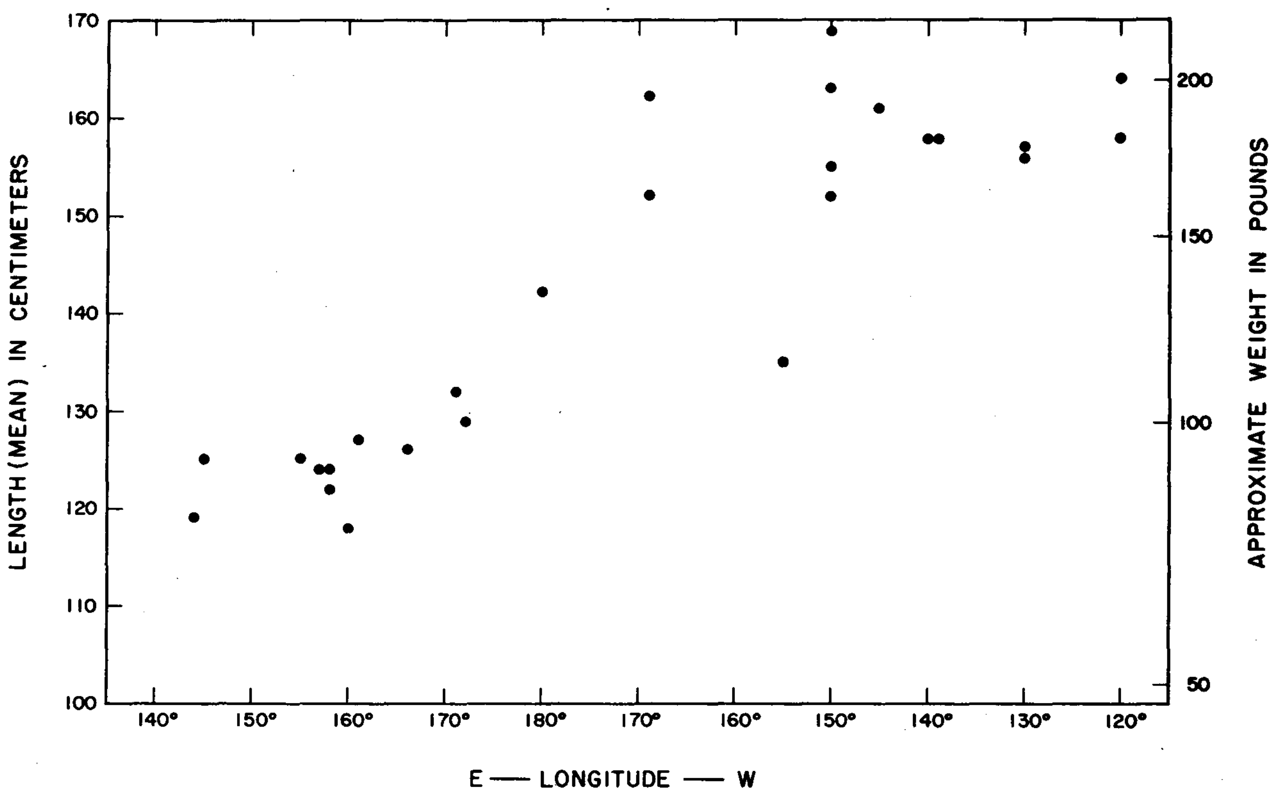


Figure 10.--Mean lengths of samples of longline-caught bigeye tuna plotted against the longitude of capture.

The length frequencies of bigeye tuna show the same marked increase in size from west to east as do the yellowfin (fig. 10--this figure is based on the same sources as fig. 9, and includes the measurements from the cruises noted in table 8). There is a suggestion of two size levels in figure 10, with fish west of 180° considerably smaller than those to the east but considering the relatively small number of fish in each sample, the steep gradient centering at 180° may be an artifact.

Table 8.--Length frequencies of bigeye tuna taken by longline fishing gear

Length	Smith cruise 18		Manning cruise 12		Cavalieri cruise 1			Manning cruise 13	
	120°W.	130°W.	140°W.	150°W.	140°W.1/	145°W.2/	150°W.3/	150°W.	169°W.
cm									
57	-	-	-	-	-	-	-	1	-
87	-	-	-	-	-	-	1	-	-
92	-	-	-	-	-	-	-	1	-
97	-	-	-	-	-	-	-	-	-
102	-	1	-	-	-	-	-	1	-
122	1	-	-	-	-	-	-	-	-
127	1	-	-	-	1	-	-	-	-
132	-	-	1	1	1	-	-	2	-
137	1	-	-	-	2	-	-	1	-
142	1	-	-	-	1	-	1	1	-
147	6	3	1	1	-	-	1	2	-
152	1	1	1	1	2	3	1	2	-
157	4	1	3	3	3	3	2	3	-
162	10	1	2	2	3	2	3	1	1
167	4	1	1	1	3	1	4	2	1
172	2	1	2	2	1	1	2	4	1
177	-	2	-	-	-	1	6	1	-
182	2	-	-	-	2	-	1	1	-
187	1	1	-	-	1	-	-	1	-
192	-	-	-	-	-	-	-	1	-
197	-	-	-	-	-	-	-	-	-

1/ Stations 1-19
2/ Stations 20-22
3/ Stations 23-31

The samples of albacore and skipjack are inadequate for the type of analysis performed on the yellowfin and bigeye. They are, however, useful in another respect, because they indicate that the longline will take relatively small fish (table 9). The capture of albacore and skipjack is good evidence that the absence of appreciable numbers of small yellowfin and bigeye from the longline catches is due to their absence from the habitat fished on our cruises to the Equator rather than to gear selection.

SEX RATIOS OF THE TUNAS

Puzzling discrepancies appear in the sex ratios of tuna taken on the longline. In previous reports we have noted the fact that males predominate in the catches of bigeye and yellowfin (Murphy and Shomura 1953a, b). With respect to yellowfin, Nakamura (1949) noted that catches made in the East Philippine Sea had equal representation of the sexes up to 122 cm.

(about 77 pounds), and that there were more males among the larger fish. The present longline samples (table 10) also contain more male yellowfin and bigeye.

Sufficient material is now on hand for a preliminary analysis of the sex discrepancy of the yellowfin tuna. We have used samples from the Japanese mothership operations of 1950 and 1951 (Murphy and Otsu 1954), POFI longline cruises (Murphy and Shomura 1953a, b), POFI livebait fishing and trolling in the central Pacific, and the cruises covered in this report (table 10).

Table 9.--Length frequencies of albacore and skipjack tuna taken by longline fishing gear

Length	Albacore		Skipjack			
	Manning 12	Manning 13	Manning 12	Cavalieri 1	Manning 13	Smith 18
cm						
35	-	-	-	1	-	-
58	-	-	-	-	1	-
64	-	-	-	-	-	1
66	-	-	-	-	-	-
67	-	-	-	1	-	1
68	-	-	-	-	-	3
69	-	-	-	-	-	-
70	-	-	-	1	-	-
71	-	-	-	-	-	-
72	-	-	-	-	-	-
73	-	-	-	-	1	1
74	-	-	-	2	-	-
75	-	-	1	2	2	-
76	-	-	-	1	2	2
77	-	-	-	3	3	-
78	-	-	-	2	3	1
79	-	-	2	4	6	2
80	-	-	2	4	7	1
81	-	-	3	2	2	1
82	-	-	-	2	1	1
89	-	1	-	-	-	-
90	-	-	-	-	-	-
91	-	1	-	-	-	-
92	1	-	-	-	-	-
93	-	2	-	-	-	-
94	-	1	-	-	-	-
95	-	2	-	-	-	-
96	-	3	-	-	-	-
97	-	-	-	-	-	-
98	-	1	-	-	-	-
99	-	2	-	-	-	-
100	-	-	-	-	-	-
101	-	1	-	-	-	-
102	-	-	-	-	-	-
103	-	1	-	-	-	-
104	-	1	-	-	-	-
105	-	1	-	-	-	-
106	-	1	-	-	-	-

Table 10.--Summary of frequency of males and females in three species of tuna

Cruise	Species	Number of males	Number of females	Ratio of males:females
Smith cruise 18	Yellowfin	33	19	1:0.6
	Bigeye	30	13	1:0.4
	Skipjack	5	2	1:0.4
	Albacore	-	1	- -
Cavalieri cruise 1	Yellowfin	439	167	1:0.4
	Bigeye	42	15	1:0.4
	Skipjack	12	13	1:1.1
Manning cruise 12	Yellowfin	65	45	1:0.7
	Bigeye	15	7	1:0.5
Manning cruise 13	Yellowfin	77	43	1:0.6
	Bigeye	19	9	1:0.5
	Albacore	7	11	1:1.6
	Skipjack	15	12	1:0.8

In analyzing the length frequencies of the yellowfin, the samples were combined into three groups corresponding to the samples from the western, central, and eastern equatorial Pacific. These combined samples (fig. 11) indicate essentially the same type of sex ratio discrepancy noted by Nakamura, namely equal representation up to a certain size, followed by a preponderance of males in the larger categories. It is interesting to note that as the average size of the fish within each sample increases, the length at which males begin to predominate also increases (fig. 11).

In the "western region" (fig. 11), males begin to predominate at about 122 centimeters, which is approximately the size noted by Nakamura (1949) for fish taken at the western end of the zone. In the "central region" males do not predominate until a size of 137 cm. is reached. In the "eastern region" the difference in the ratio appears at about 147 cm., although the sample is inadequate for clear delineation.

It is interesting to speculate on the cause of the discrepancy in the sex ratio of the larger fish. One possibility is differential growth, but if this were responsible, there should be a preponderance of females in some of the smaller size categories. Another possibility is that females do not feed while spawning and are therefore removed from the fishable population for an unknown period of time. However, it appears that if females ceased feeding for a long enough period to produce the discrepancies in figure 11, they would have a slower growth rate than the males, and as already pointed out, differential growth appears untenable. A third hypothesis is that females during a portion of their life occupy a different geographical range from the males. This seems unlikely in the absence of samples showing a preponderance of females. The final and most credible hypothesis is that there is differential mortality between the sexes after a certain size (age) is attained.

VERTICAL DISTRIBUTION OF TUNAS

In earlier reports we pointed out that yellowfin, bigeye, and albacore tuna were usually caught at a greater rate on the deeper fishing hooks of a set of longline gear (Murphy and Shomura 1953a, b). This was in general agreement with the findings of various Japanese workers,

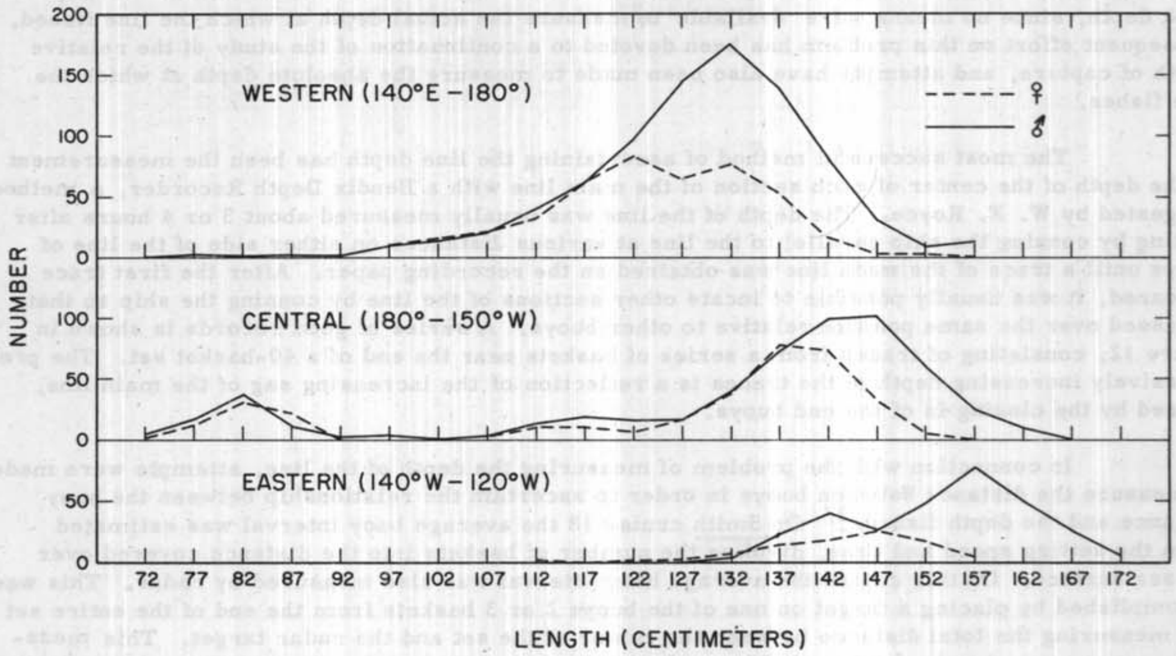


Figure 11. --Length frequencies of male and female yellowfin tuna from three regions of the equatorial Pacific.

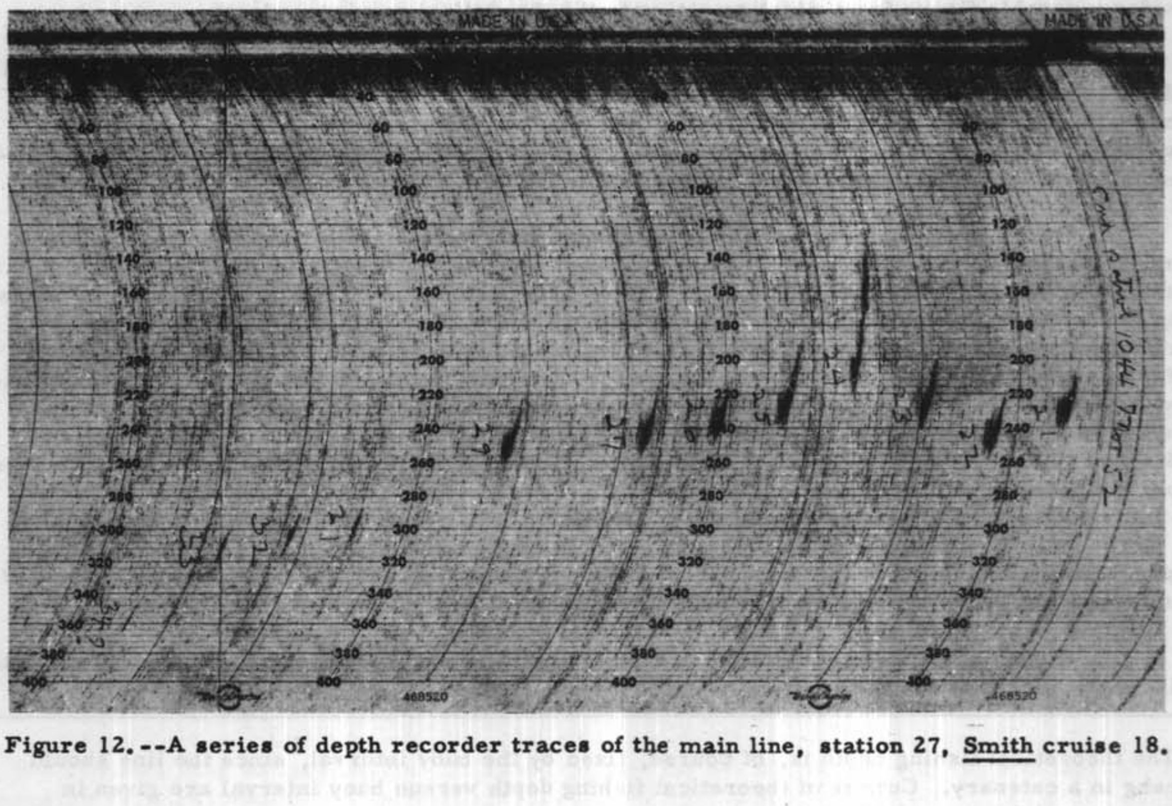


Figure 12. --A series of depth recorder traces of the main line, station 27, <u>Smith</u> cruise 18.

e.g. Nakamura (1949). These conclusions were necessarily based on a consideration of relative hook depth, since no means were available to measure the actual depth at which the line fished. Subsequent effort on this problem has been devoted to a continuation of the study of the relative depth of capture, and attempts have also been made to measure the absolute depth at which the line fishes.

The most successful method of ascertaining the line depth has been the measurement of the depth of the center of each section of the main line with a Bendix Depth Recorder, a method suggested by W. F. Royce. The depth of the line was usually measured about 3 or 4 hours after setting by conning the ship parallel to the line at various distances on either side of the line of buoys until a trace of the main line was obtained on the recording paper. After the first trace appeared, it was usually possible to locate other sections of the line by conning the ship so that it passed over the same position relative to other buoys. A series of good records is shown in figure 12, consisting of traces from a series of baskets near the end of a 40-basket set. The progressively increasing depth of the traces is a reflection of the increasing sag of the main line, caused by the closing in of the end buoys.

In connection with the problem of measuring the depth of the line, attempts were made to measure the distance between buoys in order to ascertain the relationship between the buoy distance and the depth fished.[2/] On Smith cruise 18 the average buoy interval was estimated from the setting speed and time, dividing the number of baskets into the distance covered over the sea surface. On this cruise the average buoy interval was also measured by radar. This was accomplished by placing a target on one of the buoys 2 or 3 baskets from the end of the entire set and measuring the total distance between the center of the set and the radar target. This measurement appeared to be fairly reliable as the line was usually quite straight. The measurements by radar taken some 4 hours after the gear was set were in close agreement with the distance between buoys as estimated from the setting speed and time (table 11). Thus, the latter method furnishes a good estimate of the average buoy interval during the course of the fishing day and provides a useable figure from which to estimate the theoretical maximum depth.

It is quite evident from comparison of the theoretical depths and the measured depths (tables 11 and 12) that on these two cruises there was considerable streaming of the line, which probably was caused by a current differential between the surface water and the thermocline. This was also evident in the field, as the center of the sag of the main line was nearly always located at a considerable distance from a straight line between any two buoys.

The correlation between the theoretical depth as determined from the average buoy interval and the actual depth measured with the depth recorder is not particularly close ($r = 0.315$ for the combined data of tables 11 and 12). Part of this can be laid to a lack of precision in measuring the two variables (line depth and buoy interval), and part can be laid to changing conditions with respect to the speed of the surface current from station to station, i.e., failure to control the factors other than buoy distance that determine the actual depth the line fished. Another difficulty, which may in part be responsible for the low correlation between buoy distance and depth, is indicated by the suggestion of a negative relation between the number of successful depth recorder traces and the average depth at each station (table 11). This suggests that as the line goes deeper the chances of obtaining a legible record on the depth recorder are lessened. This was also indicated in the field by the progressive faintness of the traces as the apparent depth of the line increased. That there is a real relation between buoy distance and line depth is indicated by the progressive deepening of the traces in figure 12. These traces were obtained near the end of a set, where the buoys supporting successive baskets were progressively closer together.

It has not yet been possible to establish any relationship between the catch and the data on line depth, nor between the relative depth of the greatest catch and either the depth of the

2/ The theoretical fishing depth is, of course, fixed by the buoy interval, since the line should hang in a catenary. Curves of theoretical fishing depth versus buoy interval are given in Murphy and Shomura (1953a).

thermocline or the measured depth of the line. However, summaries of the catches of the four cruises by station and relative hook depth indicate that on three cruises (Manning cruises 12 and 13 and Smith cruise 18; tables 13, 15, and 16) there were no significant differences in the catch of yellowfin among the three hook levels, although the shallower hooks caught fewer fish. On two of these cruises Bendix depth recorder records (tables 11 and 12) indicate there was considerable current-induced streaming of the line. This would, of course, reduce the depth differential between shallow and deep hooks, and less difference in catch should be expected. On the Cavalieri cruise (table 14) yellowfin were taken in significantly greater numbers on the deep hooks, but there are no records of the depths fished by the line.

On all four cruises more bigeye were taken on the deeper hooks, but the differences were statistically significant on only two (Cavalieri and Manning cruise 13). The only cruise on which albacore were taken in any number (Manning cruise 13, table 15) indicated a much greater catch on the deepest hooks.

Table 11.--Measurements of buoy interval and line depth, Smith cruise 18

Station	Buoy interval (feet)		Echo sounder measurements of line depth (feet)				Theoretical mean[1/]
	Setting distance	Radar measurement	Number of observations	Minimum	Maximum	Mean	
1	950	943	2	316	332	324	430
3	950	960	5	224	336	285	430
4	950	820	1	-	-	280	430
5	955	950	7	168	232	186	430
6	930	-	1	-	-	176	440
7	965	-	-	-	-	-	420
8	535	560	1	-	-	204	590
9	850	860	10	172	196	178	480
10	995	1105	12	172	212	191	410
12	987	960	8	212	224	220	410
14	990	950	3	220	248	233	410
16	1040	1055	-	-	-	-	380
18	1035	1025	-	-	-	-	380
20	1030	1030	1	-	-	248	390
22	935	960	1	-	-	260	440
23	1020	-	2	288	292	290	390
25	1045	1008	8	248	368	322	370
27	1080	1045	18	192	352	250	350
29	1070	1035	-	132	176	162	360
30	1105	1140	8	160	240	191	330
31	1120	1150	7	124	136	131	320
32	1120	1120	3	128	132	131	320
33	1120	1030	8	132	268	212	320
35	1190	-	7	160	192	176	250
36	1185	-	1	-	-	240	250
37	1200	-	6	120	180	147	240

1/ Based on the mean setting buoy distance as estimated from the setting speed and time.

Table 12.--Measurements of buoy interval and line depth, *Manning* cruise 12

Station	Setting distance in feet	Echo soundings of line depth in feet				Theoretical mean 1/
		Number of observations	Minimum	Maximum	Mean	
1	1135	-	-	-	-	300
2	1095	-	-	-	-	340
3	1095	11	164	246	220	340
4	1055	7	210	254	232	370
5	1095	-	-	-	-	340
6	1055	-	-	-	-	370
8	1100	8	236	272	247	330
9	1125	4	88	132	112	310
10	1090	8	126	172	153	340
11	992	7	126	216	162	410
12	1200	1	-	-	-	230
15	1100	6	238	292	274	330
16	900	5	336	372	357	460
17	1040	5	270	294	286	380
18	820	-	-	-	-	490
19	1025	6	132	140	137	390

1/ Based on the mean buoy distance as estimated from the setting speed and time.

Table 13.--Yellowfin and bigeye tuna catch by relative hook depth, *Manning* cruise 12

Species	Station 1/	Shallow	Intermediate	Deep	χ^2
Yellowfin	1-2	9	4	6	2.001
	3-4	9	13	3	6.082*
	5-6, 8	3	7	5	1.600
	9	6	10	7	1.130
	10-11	6	6	5	0.118
	12, 15-18, 21-22	6	10	8	1.000
	Total	39	50	34	11.931 Total χ^2 (d.f. 12) 3.268 Pooled χ^2 (d.f. 2) 8.663 Interaction χ^2 (d.f. 10)
Bigeye	All stations	5	9	11	2.241 Pooled χ^2 (d.f. 2)

1/ Stations combined to give minimum expected catches of five.
* Significant at the 0.05 level.

Table 14.--Yellowfin and bigeye tuna catch by relative hook depth, Cavalieri cruise 1

Species	Station[1/]	Shallow	Intermediate	Deep	χ^2
Yellowfin	1-3	4	10	7	2.571
	4	8	5	5	1.000
	5	8	11	14	1.636
	6	8	13	12	1.273
	7	5	25	19	12.901**
	8-9	15	10	11	1.167
	10	4	11	10	3.441
	11	9	15	10	1.824
	12-13	6	12	13	2.775
	14-15	6	7	7	0.100
	16	5	8	9	1.182
	17	7	11	5	2.435
	18	2	9	6	4.350
	19	8	9	6	0.608
	20	7	6	8	0.286
	21	3	3	9	4.800
	22	3	9	8	3.098
	23-24	9	13	14	1.167
	25	5	9	13	3.556
	26	5	11	8	2.250
	27	5	6	4	0.400
	29	12	19	30	8.100*
	31	8	14	16	2.736
	Total	152	246	244	63.655 Total χ^2 (d.f. 46) 26.954** Pooled χ^2 (d.f. 2) 36.701 Interaction χ^2 (d.f. 44)
Bigeye	1-15	1	6	8	5.200
	16-20	4	6	5	0.400
	21-31	1	12	13	10.227**
	Total	6	24	26	15.827* Total χ^2 (d.f. 6) 12.997** Pooled χ^2 (d.f. 2) 2.829 Interaction χ^2 (d.f. 4)

1/ Stations combined to give minimum expected catches of 5.
* Significant at the 0.05 level.
** Significant at the 0.01 level.

To further elucidate the depth distribution of tunas, some gear with 30-fathom float lines and some with 2-fathom float lines was fished along with the regular gear having 10-fathom float lines (table 17). There was little difference in the yellowfin catch among the three types of gear, however, during this cruise there was also no significant difference in the catch of yellowfin with relative depth within the regular gear. On the other hand, during each experiment the deepest fishing gear caught more bigeye (table 17), and during this cruise the bigeye were taken in greater numbers on the deeper hooks of the regular gear (table 13).

Table 15.--Yellowfin, bigeye, and albacore tuna catch by relative hook depth, Manning cruise 13

Species	Station[1/]	Shallow	Intermediate	Deep	χ^2
Yellowfin	1-9	8	5	2	3.600
	10-11	6	11	11	1.792
	12-14	7	8	10	0.560
	15-17	5	7	4	0.876
	18-20	7	6	11	1.750
	21-24	4	7	13	5.250
	25-28	3	8	5	2.376
	Total	40	52	56	16.204 Total χ^2 (d.f. 14) 2.811 Pooled χ^2 (d.f. 2) 13.393 Interaction χ^2 (d.f. 12)
Bigeye	1-28	7	5	15	6.222*
Albacore	1-28	0	6	16	17.826**

1/ Stations combined to give minimum expected catches of 5.
* Significant at the 0.05 level.
** Significant at the 0.01 level.

Table 16.--Analysis of yellowfin and bigeye tuna catch by relative hook depth, Smith cruise 18

Species	Station[1/]	Shallow	Intermediate	Deep	χ^2
Yellowfin	1-18	6	5	7	0.333
	20-22	4	5	6	0.400
	23-37	9	7	10	0.538
	Total	19	17	23	1.271 Total χ^2 (d.f. 6) 0.949 Pooled χ^2 (d.f. 2) 0.322 Interaction χ^2 (d.f. 4)
Bigeye	1-4	5	4	7	0.876
	5-12	2	4	9	5.200
	14-37	9	3	7	2.949
	Total	16	11	23	9.025 Total χ^2 (d.f. 6) 4.359 Pooled χ^2 (d.f. 2) 4.666 Interaction χ^2 (d.f. 4)

1/ Stations combined to give minimum expected catches of 5.

Accumulated data on the relative vertical distribution of yellowfin, bigeye, and albacore (see data in Murphy and Shomura 1953a, b) indicate that yellowfin are usually but not consistently more abundant at the deeper levels in the equatorial Pacific, the best bigeye catches are more regularly associated with the deeper fishing levels, and albacore are clearly caught in greatest abundance on the deepest fishing hooks. This may be a reflection of the general horizontal distribution of these three species. Yellowfin appear to be a tropical species; bigeye are also tropical in occurrence but are abundant considerably farther north than the yellowfin (Nakamura 1949); surface albacore are abundant in northern waters not inhabited by the yellowfin nor the bigeye. It seems probable that temperature is one of the chief controlling factors in the latitudinal distribution of these species, and very likely it is also responsible, at least in part, for a difference in vertical distribution in the equatorial region, with the species whose distribution extends farther north apparently occupying deeper, colder waters in the tropics.

Table 17.--Catches of yellowfin on 10 baskets of special gear compared with the catches of the adjacent 10 baskets of standard gear, Manning cruise 12

Station	Yellowfin		Bigeye	
	Standard	30-fathom float lines 1/	Standard	30-fathom float lines 1/
2	2	1	-	1
4	6	9	-	1
6	1	1	-	1
9	3	5	-	-
11	3	-	-	-
Total	11	16	0	3
Station	Standard	2-fathom float lines 2/	Standard	2-fathom float lines 2/
3	3	-	1	-
5	1	5	1	-
8	1	1	-	-
10	3	-	-	-
12	-	-	-	-
Total	8	6	2	0

1/ Identical with standard gear, except that the 10-fathom float lines were replaced with 30-fathom lines.

2/ Gear made up with 2-fathom float lines and with droppers consisting of a 1-foot cotton section, a 4-fathom sekiyama section, and a fathom of wire leader.

IMPROVEMENT OF LONGLINE GEAR

The first longlines designed by POFI were essentially modifications of the gear used commercially by Hawaiian and Japanese fishermen. One of the components of this gear is the "sekiyama", a 22-foot section constructed of 12 strands of No. 8 Irish linen whipped with No. 6 cotton located between the cotton line and the wire leader of each dropper. The sekiyama is used to provide a good gripping surface on the part of the line most often handled in fighting fish, and also perhaps to resist abrasion of the line on the hull when fish go under the boat. Because it is one of the more expensive components of the longline gear (about $2.25 each), an experiment was conducted to ascertain whether the 261-thread cotton line used in the balance of the gear could be substituted for it.

On Manning cruise 13, 10 baskets of longline gear in which 261-thread cotton line was substituted for the sekiyama were fished in addition to 40 baskets of standard gear. A comparison of the catch on this gear with the catch of the 10 adjacent baskets of standard gear is given in table 18. The capture of 56 fish on each type of gear is a good indication that the efficiency was not changed by the elimination of the sekiyama. Insofar as durability is concerned, five droppers were broken on each of the two types of gear. During the cruise both scientists and fishermen were in agreement that the absence of the sekiyama did not cause undue difficulty in handling fish.

Table 18.--Analysis of catch of experimental baskets with 10 adjacent standard baskets, *Manning* cruise 13

Station	With sekiyama	Without sekiyama	Total catch[1/]
1-3	5	8	13
4-8	4	8	12
9-11	8	8	16
14, 15	7	5	12
16, 17	6	5	11
18, 19	8	4	12
20, 21	4	9	13
22-24	7	4	11
25-28	7	5	12
Total	56	56	112

1/ Catch includes all species except sharks.

SHARK DAMAGE TO THE CATCH

Varying fractions of the catch were damaged by sharks. This damage usually takes the form of one or more bites from the body of the tuna while it is being hauled in. The problem is of considerable importance to a commercial fishery because severely bitten fish are unsuitable for canning. In considering the data it should be borne in mind that: (1) our records of shark-bitten fish did not include estimates of the severity of the damage to each fish (about one-half of the fish recorded as bitten are probably unsuitable for the cannery); and (2) no particular effort has been made during the course of POFI experimental fishing to reduce shark damage. For these reasons our estimates of the severity of the problem can be considered as maximal.

During the course of six cruises 21 percent of all yellowfin landed were damaged by sharks (table 19). If half of these were unsuitable for canning, the net loss would be about 10 percent of the catch. It is of interest to note that the percent of loss to sharks appears to be related to the size of the fish. For instance, bigeye, the largest species in the catch, sustained the highest rate of shark damage; and skipjack, the smallest species, sustained the lowest rate.

This may in part be related to the relative inconspicuousness of the smaller fish, but more likely is related to the speed of handling. Most shark damage occurs at the surface while a hooked fish is being hauled in, and small fish like skipjack are landed with considerably more celerity than large fish such as bigeye. This indicates that shark damage can be considerably lessened by reducing the "playing time" in bringing fish aboard.

Table 19.--Summary of shark-bitten tuna (by species), _Manning_ cruises 11, 12, and 13, _Gilbert_ cruise 1, _Cavalieri_ cruise 1, _Smith_ cruise 18

Cruise	Yellowfin		Bigeye		Skipjack		Albacore		Total	
	Catch	Percent shark bitten	Catch	Percent shark bitten	Catch	Percent shark bitten	Catch	Percent shark bitten	Catch	Percent shark bitten
Manning 11	211	18.5	30	36.7	17	11.8	64	15.6	322	19.2
Manning 12	146	23.3	28	35.7	9	0.0	2	50.0	185	24.3
Cavalieri 1	720	19.9	65	21.5	29	6.9	-	-	814	19.5
Smith 18	59	15.3	51	27.4	14	0.0	1	0.0	125	18.4
Manning 13	148	29.1	28	17.9	34	14.7	21	23.8	231	25.1
Gilbert 1	72	25.0	43	11.6	1	0.0	-	-	116	19.8
Total	1356	21.1	245	24.1	104	8.7	88	18.2	1793	20.6

SUMMARY

1. During the period August to November 1952 there were four longline fishing cruises to the equatorial Pacific between 120°W. and 170°W. longitude.

2. Upwelling was very intense at the Equator on 120°W. longitude. Yellowfin catches were low in this upwelled water, suggesting that the water had not been in the photosynthetic zone long enough to have developed a favorable food supply.

3. Along 130°W. longitude upwelling was somewhat less intense than on 120°W., and in the zone of upwelled water moderate quantities of yellowfin were taken.

4. Two sections along 150°W. longitude and one along 140°W. gave evidence of moderate upwelling. Along these sections there was a marked concentration of yellowfin tuna to the north of the Equator.

5. Compared with the results of other cruises, there was only moderately good fishing along 150°W. longitude in August and October, although good fishing was experienced during the intervening month (September). This may be an indication of the magnitude of the short-term fluctuations to be expected in that region.

6. Albacore were relatively abundant a few degrees south of the Equator on the western section (169°W. longitude).

7. Japanese commercial fishing in the region of 170°W. - 180° longitude showed bigeye relatively abundant north of 5°N. latitude, and yellowfin relatively abundant south of that latitude. Catch rates of the Japanese vessels were almost identical with catch rates of POFI experimental fishing.

8. The size of the longline-caught yellowfin and bigeye increases from west to east. The differences in size are compatible with apparent differences in the amount of upwelling, suggesting that there are fundamental differences in the growth rates of yellowfin and bigeye among the western, central, and eastern Pacific, related to the relative productivity of the three areas.

9. The preponderance of males in longline catches of yellowfin may be a reflection of a higher mortality of females after a certain age.

10. A method of using the echo sounder to ascertain the depth fished by the longline was devised, and preliminary results of its application are given. In most instances considerable streaming of the line prevented it from reaching its maximum possible depth.

11. In general yellowfin catches were higher on the deep and intermediate hooks, and less on the shallow hooks. Bigeye and albacore were taken most frequently on the deep hooks.

12. Experimental fishing indicated that the expensive sekiyama sections of the branch lines can be eliminated.

13. An estimated 10 percent of the catch was unsuitable for delivery to the cannery because of mutilation by sharks. This figure can probably be reduced in commercial operations.

LITERATURE CITED

Austin, Thomas S.

1954. Mid-Pacific oceanography III, transequatorial waters, August-October 1951. U. S. Fish and Wildlife Service, Spec. Sci. Rep.: Fish. No. 131, June 1954, 17 pp., 13 figs., stations 29-50.

Cromwell, Townsend

1953. Circulation in a meridional plane in the central equatorial Pacific. Jour. of Mar. Res., Vol. 12, No. 2, pp. 196-213.

Kanagawa Prefecture Fishery Experiment Station

1952. Monthly Report No. 3, August; No. 4, September; No. 5, October; No. 6, December.

King, Joseph E. and J. Demond

1953. Zooplankton abundance in the central Pacific. U. S. Fish and Wildlife Service, Fish. Bull., Vol. 54, No. 82, pp. 111-144.

McKernan, Donald L.

1953. Pioneer longlining for tuna along the Equator. Pacific Fisherman, Vol. 51, No. 8, July 1953, pp. 19, 21, 23.

Murphy, Garth I. and T. Otsu

1954. Analysis of the catches of nine Japanese tuna longline expeditions to the western Pacific Ocean. U. S. Fish and Wildlife Service, Spec. Sci. Rep.: Fish. No. 128, Dec. 1954, 46 pp.

Murphy, Garth I. and R. S. Shomura

1953a. Longline fishing for deep-swimming tunas in the central Pacific, 1950-1951. U. S. Fish and Wildlife Service, Spec. Sci. Rep.: Fish. No. 98, May 1953, 47 pp.

1953b. Longline fishing for deep-swimming tunas in the central Pacific, January-June 1952. U. S. Fish and Wildlife Service, Spec. Sci. Rep.: Fish. No. 108, August 1953, 32 pp.

Nakamura, Hiroshi

1949. The tunas and their fisheries. Takeuchi Shobo, Tokyo, 118 pp. U. S. Fish and Wildlife Service, Spec. Sci. Rep.: Fish. No. 82, The tunas and their fisheries. August 1952, 115 pp.

Niska, Edwin L.

1953. Construction details of tuna longline gear used by Pacific Oceanic Fishery Investigations. U. S. Fish and Wildlife Service, Comm. Fish. Rev., Vol. 15, No. 6, June 1953, pp. 1-6.

Shomura, Richard S.

MS. A comparative study of longline baits.

APPENDIX

Summarized Field Data

Table 20.--Time taken for setting and hauling the longline gear, *Manning* cruise 12

Station[1]	Set			Haul					Fish handling break[4] (min.)
					Regular gear		Experimental gear[3]		
	Total baskets set	Time started to set	Time taken for setting (min.)	Time started to haul	Number of baskets	Time taken[2] for hauling (min.)	Number of baskets	Time taken for hauling (min.)	
1	40	0633	64	1226	40	201	-	-	68
2	50	0557	73	1200	40	219	10	62	43
3	50	0600	78	1222	40	207	10	65	53
4	50	0600	72	1215	40	176	10	57	25
5	50	0600	75	1208	40	166	10	65	26
6	50	0554	66	1205	40	220	10	44	21
8	50	0605	70	1220	40	252	10	38	51
9	50	0610	70	1222	40	182	10	57	53
10	50	0602	68	1215	40	164	10	41	32
11	50	0610	62	1226	40	175	10	42	35
12	50	0605	75	1212	40	171	10	47	28
15	40	0605	55	1230	40	190	-	-	37
16	40	0608	45	1240	40	177	-	-	33
17	40	0610	52	1228	40	182	-	-	30
18	40	0612	36	1251	40	195	-	-	39
19	40	0605	45	1235	40	138	-	-	21
Average			1.36 min. per basket			4.71 min. per basket	Deep gear 5.24 min. per basket Shallow gear 5.12 min. per basket		

1/ Fishing stations 21 and 22 were special stations for diurnal study and are therefore omitted.
2/ Does not include the fish handling break.
3/ Stations 2, 4, 6, 9, and 11, with deep fishing gear; stations 3, 5, 8, 10, and 12, with shallow fishing gear.
4/ Break came midway during hauling of the regular baskets.

Table 21.--Time taken for setting and hauling the longline gear, Cavalieri cruise 1

Station	Number of baskets	Set: Time started to set	Set: Time taken for setting (min.)	Haul: Time started to haul	Haul: Time taken for hauling (min.)
1	50	0509	64	1200	395
2	50	0509	61	1159	261
3	60	0508	87	1201	319
4	60	0507	84	1256	297
5	60	0512	86	1149	290
6	61	0505	89	1208	257
7	70	0458	106	1138	378
8	70	0513	94	1155	283
9	70	0453	94	1200	314
10	70	0458	110	1150	304
11	76	0507	114	1213	347
12	70	0500	117	1149	301
13	79	0457	98	1145	375
14	79	0504	105	1150	336
15	60	0457	86	1235	253
16	75	0458	107	1213	319
17	79	0506	115	1231	316
18	80	0504	118	1218	375
19	80	0504	103	1228	347
20	81	0500	110	1219	331
21	80	0459	104	1220	334
22	80	0506	107	1234	332
23	80	0505	109	1213	364
24	80	0428	110	1143	362
25	81	0441	108	1148	370
26	80	0428	121	1226	327
27	85	0427	124	1149	356
28	80	0428	124	1150	550
29	80	0443	116	1155	493
30	80	0437	112	1133	367
31	80	0433	113	1135	327
Average			1.41 min. per basket		4.67 min. per basket

Table 22.--Time taken for setting and hauling the longline gear[1/], Smith cruise 18

Station	Set		Haul		Fish handling break (min.)
	Time started to set	Time taken for setting (min.)	Time started to haul	Time taken for hauling[2/] (min.)	
1	0600	48	1234	274	55
3	0550	48	1211	218	47
4	0547	47	1213	220	44
5	0540	47	1220	192	52
6	0543	47	1214	232	76
7	0541	49	1211	159	76
8	0540	27	1217	195	51
9	0553	43	1219	155	63
10	0539	49	1218	153	57
12	0548	47	1212	172	48
14	0536	47	1210	153	65
16	0619	41	1231	152	42
18	0603	47	1212	150	54
20	0635	47	1212	163	49
22	0537	43	1214	159	54
23	0604	45	1248	155	50
25	0610	44	1255	163	47
27	0611	45	1250	152	48
29	0608	44	1251	153	70
30	0609	45	1247	156	47
31	0607	47	1303	161	40
32	0618	64	1256	157	47
33	0618	47	1247	150	56
35	0621	47	1252	148	51
36	0627	49	1252	146	68
37	0630	50	1301	135	48
Average		1.16 min. per basket		4.25 min. per basket	

1/ 40 baskets of gear used on each station.
2/ Does not include the fish handling break.

Table 23.--Time taken for setting and hauling the longline gear[1/], *Manning* cruise 13

Station[2/]	Set		Haul			Fish handling break (min.)
	Time started to set	Time taken for setting (min.)	Time started to haul	Time taken for hauling (min.)		
				Regular gear	Experimental gear	
1	0614	48	1007	212	53	45
2	0559	61	1244	156	43	46
3	0600	55	1214	189	54	58
4	0555	53	1215	199	58	15
6	0607	48	1213	168	41	43
7	0600	50	1150	156	44	29
8	0600	49	1205	193	57	40
9	0600	55	1214	143	41	36
10	0600	50	1216	148	50	32
11	0603	47	1155	150	41	37
14	0600	55	1202	127	39	28
15	0558	47	1201	137	37	34
16	0553	43	1216	161	43	27
17	0552	48	1202	133	36	24
18	0558	46	1154	142	45	22
19	0602	50	1215	235	66	37
20	0605	50	1200	214	71	22
21	0602	56	1150	150	61	35
22	0557	48	1149	190	39	29
23	0606	52	1157	178	44	30
24	0605	50	1153	169	45	39
25	0604	56	1205	203	43	21
26	0600	55	1212	180	44	24
27	0600	59	1219	156	57	20
28	0605	55	1207	172	43	25
Average		1.03 min. per basket		4.26 min. per basket	4.78 min. per basket	

1/ 50 baskets of gear set at each station--40 regular and 10 experimental.
2/ Stations 12 and 13 were special stations for diurnal study and are therefore omitted.

Table 24.--Complete catch records Manning cruise 12 (40 baskets - 240 hooks)

Station	Yellowfin	Bigeye	Skipjack	Albacore	Marlin	Dolphin	Sharks			Others
							White-tipped	Silky	Great blue	
1	5	-	-	-	4	-	3	-	2	12 1/
2	14	2	-	-	1	-	2	-	-	1 2/
3	11	2	-	-	1	-	-	-	1	-
4	14	3	-	-	-	-	4	-	-	3 3/
5	2	1	1	-	-	-	2	-	-	1 2/
6	8	-	-	-	1	1	1	-	-	2 2/
8	5	2	-	-	1	-	2	-	-	-
9	23	-	-	-	-	-	2	-	1	1 2/
10	9	-	-	-	-	-	4	-	1	-
11	8	-	1	1	1	-	4	-	1	-
12	1	-	1	-	-	-	6	-	-	3 4/
15	3	4	1	1	-	-	6	1	-	3 5/
16	1	1	1	-	-	-	2	-	-	1 2/
17	2	4	-	-	-	-	2	-	-	-
18	2	2	1	-	1	-	2	-	5	-
19	-	-	-	-	-	-	4	1	1	-

1/ 2 unidentified sharks, 8 thresher sharks, 2 lancet fish
2/ unidentified sharks
3/ 2 unidentified sharks, 1 wahoo
4/ 2 wahoo, 1 lancet fish
5/ 3 wahoo

Table 25.--Complete catch records Manning cruise 12, special baskets (10 baskets - 60 hooks). Stations 2, 4, 6, 9, and 11 with 30 f. instead of 10 f. float lines; balance with 2 f. float lines

Station	Yellowfin	Bigeye	Skipjack	Albacore	Marlin	Dolphin	Sharks			Others
							White-tipped	Silky	Great blue	
2	1	1	-	-	-	-	-	-	-	1 1/
3	-	-	-	-	-	-	1	-	-	-
4	9	1	-	-	-	-	-	-	-	-
5	5	-	-	-	-	-	-	-	-	1 2/
6	1	1	-	-	-	-	-	-	1	1 3/
8	-	-	-	-	-	-	1	-	-	-
9	5	-	-	-	-	-	1	-	-	1 2/
10	-	-	-	-	-	-	3	-	-	-
11	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-

1/ wahoo
2/ unidentified shark
3/ lancet fish

Table 26.--Complete catch records of special stations, *Manning* cruise 12 (10 baskets per group - 60 hooks)

Station	Group	Yellowfin	Bigeye	Skipjack	Albacore	Marlin	Dolphin	Sharks: White-tipped	Sharks: Silky	Sharks: Great blue	Others
21 1/	I	1	-	-	-	-	-	-	-	-	-
2°01'N,	II	2	-	-	-	-	-	1	-	-	1 3/
141°21'W	III	2	-	1	-	-	-	-	-	-	-
	IV	-	1	-	-	-	-	-	1	-	-
	V	-	3	-	-	1	-	-	-	-	1 3/
	VI	-	-	-	-	-	-	1	-	-	-
22 2/	I	1	-	-	-	-	-	-	1	-	-
1°56'N,	II	1	-	1	-	-	-	1	-	-	-
142°23'W	III	2	-	-	-	-	-	1	-	-	-
	IV	6	-	-	-	-	-	3	1	-	-

1/ Group I set 0618, hauled 0912; group II set 0955, hauled 1253; group III set 1337, hauled 1703; group IV set 1756, hauled 1809; group V set 2142, hauled 2200; group VI set 0206, hauled 0512.

2/ All four groups set consecutively starting at 0606, hauling times: group I - 0903, group II - 1042, group III - 1500, group IV - 1726.

3/ Unidentified shark

Table 27.--Complete catch records, Cavalieri cruise

Station	Hooks	Yellowfin	Bigeye	Skipjack	Albacore	Marlin	Dolphin	Sharks: White-tipped	Sharks: Silky	Sharks: Great blue	Others 1/
1	300	2	1	-	-	2	1	-	-	-	2
2	300	4	1	-	-	2	-	2	-	2	8
3	360	15	4	-	-	-	-	1	-	-	8 2/
4	360	18	-	4	-	-	1	-	-	-	3
5	360	34	7	2	-	-	-	2	-	-	7 3/
6	366	32	-	-	-	-	-	1	-	-	4
7	414	49	-	1	-	-	-	4	-	2	8 4/
8	420	12	-	1	-	1	-	-	-	2	5 2/
9	420	24	-	1	-	-	-	2	-	3	2 5/
10	420	25	1	1	-	1	-	3	-	2	2
11	456	34	-	-	-	1	-	2	-	8	3 5/
12	420	13	-	1	-	-	-	3	-	1	2
13	474	19	-	4	-	-	-	-	-	2	3
14	474	8	-	-	-	-	-	2	-	8	6 6/
15	360	12	1	-	-	-	-	-	-	2	1 7/
16	450	21	4	2	-	-	1	-	-	-	-
17	474	23	3	1	-	-	-	3	-	1	2
18	480	17	3	-	-	1	-	2	-	2	2 8/
19	480	23	4	-	-	-	-	1	1	1	3 2/
20	480	21	1	-	-	-	-	1	1	2	4 5/
21	480	15	1	5	-	-	-	1	-	-	1
22	480	20	-	-	-	1	-	2	-	2	2 9/
23	480	9	4	-	-	1	-	6	-	2	3 3/
24	480	27	4	1	-	2	-	6	-	-	2
25	486	27	2	2	-	-	-	7	-	-	2 7/
26	480	24	2	-	-	2	-	-	1	-	2 10/
27	510	15	2	-	-	2	-	-	-	-	2 5/
28	480	33	3	-	-	1	-	-	-	-	2 5/
29	480	61	6	3	-	1	-	5	-	-	4 3/
30	480	43	6	-	-	-	-	-	-	-	4
31	480	38	5	-	-	-	-	9	-	-	3 11/

1/ "Others" are all unidentified sharks except as otherwise noted.
2/ 1 wahoo
3/ 1 broadbill swordfish
4/ 1 thresher shark, 1 lancet fish
5/ 1 lancet fish
6/ 2 lancet fish
7/ 1 hammerhead shark
8/ 1 thresher shark
9/ 1 thresher shark, 1 wahoo
10/ 1 bonito shark
11/ 2 bonito sharks

Table 28.--Complete catch records of special stations, Manning cruise 13 (10 baskets per group - 60 hooks)

Station	Group	Yellowfin	Bigeye	Skipjack	Albacore	Marlin	Dolphin	Sharks			Others
								White-tipped	Silky	Great blue	
12[1/]	I	-	-	-	-	-	-	-	-	-	-
2°15'N,	II	4	-	1	-	-	-	7	-	-	-
151°16'W	III	2	-	-	-	-	-	5	-	-	-
	IV	-	-	-	-	-	-	9	-	-	-
	V	-	-	-	-	-	-	11	1	-	1[3/]
	VI	-	-	-	-	-	-	3	-	-	-
13[2/]	I	-	-	1	-	-	-	-	1	-	-
2°07'N,	II	2	-	2	-	-	-	-	-	-	-
151°37'W	III	2	-	-	-	-	-	1	-	-	-
	IV	3	-	1	-	-	-	1	-	-	-

1/ Group I set 0555, hauled 0901; group II set 0935, hauled 1306; group III set 1401, hauled 1703; group IV set 1738, hauled 2106; group V set 2153, hauled 0102; group VI set 0155, hauled 0505.

2/ All four groups set consecutively starting at 0555. Hauling times: group I - 0900, group II - 1157, group III - 1518, group IV - 1754.

3/ Broadbill swordfish

Table 29.--Complete catch records, Manning cruise 13 (40 regular baskets - 240 hooks)

Station	Yellowfin	Bigeye	Skipjack	Albacore	Marlin	Dolphin	Sharks			Others
							White-tipped	Silky	Great blue	
1	-	-	-	4	-	2	-	-	-	2[1/]
2	-	2	-	-	-	2	1	-	1	3[2/]
3	-	4	1	-	1	-	1	-	-	2[1/]
4	-	1	1	-	-	-	1	-	1	5[3/]
6	-	4	-	-	-	-	2	1	1	-
7	2	1	-	-	2	-	4	1	3	-
8	5	-	-	-	1	-	1	1	-	1[1/]
9	4	1	-	-	2	-	3	-	-	1[1/]
10	6	3	-	-	-	-	8	1	-	2[1/]
11	18	-	2	-	2	-	11	-	-	-
14	9	1	1	-	1	-	4	-	1	-
15	3	-	9	-	-	-	9	-	-	2[4/]
16	8	-	-	-	-	-	8	-	-	-
17	2	-	-	-	1	-	2	1	2	1[5/]
18	4	-	-	1	-	-	7	-	-	2[1/]
19	7	2	-	7	-	-	-	-	1	-
20	5	-	-	3	-	-	1	-	3	-
21	4	-	1	-	1	-	3	-	-	1[6/]
22	2	1	2	2	1	-	2	-	-	-
23	3	-	1	-	-	-	2	-	-	-
24	9	-	1	-	-	-	1	1	2	1[7/]
25	8	-	3	-	-	-	-	1	1	-
26	3	-	-	-	-	-	-	1	-	-
27	1	-	1	-	1	-	2	5	1	1[1/]
28	3	-	-	-	-	-	1	1	-	1[8/]

1/ lancet fish
2/ 2 lancet fish, unidentified shark
3/ 4 lancet fish, 1 unidentified shark
4/ 1 lancet fish, 1 sunfish
5/ wahoo
6/ shortnosed spearfish
7/ unidentified shark
8/ sunfish

Table 30. --Complete catch records, Manning cruise 13
(10 baskets without sekiyama - 60 hooks)

Station	Yellowfin	Bigeye	Skipjack	Albacore	Marlin	Dolphin	Sharks			Others
							White-tipped	Silky	Great blue	
1	-	-	-	2	-	-	-	-	-	1 1/
2	-	2	-	-	-	-	-	-	-	-
3	-	3	-	-	-	-	-	-	-	1 1/
4	-	-	-	-	-	-	1	-	2	-
6	-	-	-	-	1	-	-	-	-	1 2/
7	1	-	-	-	1	-	1	-	-	-
8	3	1	-	-	-	-	2	1	-	-
9	-	2	-	-	1	-	2	-	-	-
10	1	-	-	-	-	-	2	-	-	-
11	3	-	-	-	1	-	1	-	-	-
14	3	-	1	-	-	-	-	-	-	-
15	-	-	1	-	-	-	4	1	-	-
16	1	-	-	-	1	-	1	-	-	1 3/
17	2	-	-	-	-	-	1	-	-	-
18	1	-	-	-	-	-	3	-	-	-
19	2	-	-	1	-	-	-	-	-	-
20	5	-	-	1	-	-	-	-	-	-
21	3	-	-	-	-	-	-	-	1	-
22	-	-	-	-	-	-	-	-	-	-
23	1	-	1	-	-	-	-	-	-	-
24	2	-	-	-	-	-	-	-	-	-
25	1	-	2	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	1	-	1	1	-	-
28	-	-	-	-	-	-	1	-	-	-

1/ lancet fish
2/ sailfish
3/ sunfish

Table 31.--Complete catch records, Smith cruise 18
(40 baskets - 240 hooks)

Station	Yellowfin	Bigeye	Skipjack	Albacore	Marlin	Dolphin	Sharks			Others
							White-tipped	Silky	Great blue	
1	-	-	-	-	-	-	6	-	-	-
3	5	5	-	-	2	-	-	-	-	8 1/
4	1	11	-	-	-	-	6	-	1	3 2/
5	-	1	-	-	1	-	-	-	-	8 1/
6	-	3	-	-	-	3	3	1	1	13 3/
7	-	1	-	-	1	-	2	11	6	7 1/
8	-	8	-	-	-	-	3	1	3	-
9	1	-	-	-	-	-	1	-	-	1 1/
10	-	-	-	-	2	-	1	-	5	-
12	3	2	-	-	-	-	1	-	1	1 4/
14	-	1	-	-	3	-	6	-	1	1 5/
16	4	1	-	-	1	-	4	-	2	-
18	4	1	3	1	-	-	2	-	-	-
20	14	3	-	-	-	-	-	-	-	-
22	1	1	-	-	-	-	-	-	-	1 1/
23	3	2	1	-	-	-	5	-	1	1 5/
25	6	3	5	-	1	-	5	1	-	1 5/
27	2	-	-	-	-	-	6	-	1	-
29	5	-	-	-	-	-	5	-	1	-
30	-	2	-	-	1	-	6	-	12	-
31	3	-	-	-	1	-	9	-	6	-
32	1	-	-	-	4	-	4	-	4	2 6/
33	4	-	-	-	-	-	2	3	4	1 2/
35	1	2	-	-	2	-	3	7	6	-
36	1	3	5	-	-	-	3	2	3	3 7/
37	-	-	-	-	2	1	-	2	1	1 8/

1/ unidentified sharks
2/ lancet fish
3/ 11 unidentified sharks, 2 lancet fish
4/ hammerhead shark
5/ wahoo
6/ lancet fish, bonito shark
7/ lancet fish, wahoo, sailfish
8/ sailfish

Table 32. --Wind direction and force on stations during Manning cruises 12 and 13, Smith cruise 18, and Cavalieri cruise

Station	Manning 12		Manning 13		Smith 18		Cavalieri	
	Prevailing wind	Beaufort force	Prevailing wind	Beaufort force	Prevailing wind	Beaufort force	Prevailing wind	Beaufort force
1	SE	3	W	2	E	3	SE	4
2	SE	3	NE	4			ESE	5
3	E	2	NE	5	SSE	3	ESE	4
4	ESE	5	E	6	S	4	ESE	5
5	SE	4	Night-light 1/		SSE	3	SE	3
6	ESE	3	ESE	3	SSE	4	ESE	4
7	Night-light 1/		SE	4	SSE	4	E	4
8	SE	4	SE	4	S	4	E	3
9	SE	3	ESE	4	SSE	4	E	3
10	E	3	SE	4	ESE	4	ESE	3
11	ENE	3	SE	4			ESE	3
12	ENE	4	SE	5	ESE	4	E	3
13	Night-light 1/		ESE	3			ESE	3
14	Night-light 1/		SE	4	E	4	SE	3
15	SE	5	ESE	4			ESE	3
16	E	4	ESE	3	E	4	ESE	3
17	ESE	4	NE	3			E	2
18	E	2	NE	4	E	4	E	2
19	SE	3	NNE	4			SE	2
20	Night-light 1/		NNE	2	E	4	SE	2
21	ESE	3	SE	4			SE	2
22	SE	3	E	4	E	4	SE	2
23			ENE	5	ENE	4	SE	2
24			E	5			SE	3
25			ESE	5	ENE	4	SE	2
26			E	6			SE	2
27			E	5	E	4	SE	3
28			E	5			SE	3
29					E	4	SE	3
30					SE	4	SE	3
31					SE	2	SE	3
32					SE	3		
33					SE	4		
34								
35					S	4		
36					S	4		
37					S	4		

1/ Night-light collecting stations, no tuna fishing done.