LONGLINE FISHING FOR DEEP-SWIMMING TUNAS IN THE CENTRAL PACIFIC, JANUARY-JUNE 1952

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 108

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

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Washington, D. C.
August, 1953

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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, JANUARY - JUNE 1952

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Special Scientific Report: Fisheries No. 108

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CONTENTS

ILLUSTRATIONS

INTRODUCTION

This is the second interim report on an investigation of the deep-swimming tuna resources of the central Pacific Ocean (fig. 1). This study is being conducted by the U. S. Fish and Wildlife Service through the Pacific Oceanic Fishery Investigations (POFI). The first report (Murphy and Shomura 1953) dealt with the results of fishing during the period from July 1950 to September 1951. The fishing on which this report is based took place from January to June 1952.

During Cruise 11 of the *John R. Manning* (fig. 2), January to March 1952, section lines were fished across the Equator at 180°, 169°, and 155° W. longitude. Cruise 1 of the *Charles H. Gilbert* (May and June 1952) included sections at 130° and 120° W. longitude. In this paper the results of fishing are discussed together with a preliminary evaluation of the relation of the tuna to the environment.

We use the vernacular names of the fishes throughout the 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)

ACKNOWLEDGEMENTS

Several persons contributed to the planning and organization of the two cruises, including O. E. Sette, D. L. McKernan, and W. F. Royce. Dr. Royce is also responsible for the provisional identifications of the sharks. The successful completion of the cruises was due in no small part to the enthusiastic performance of the officers and fishermen of the *John R. Manning* and the *Charles H. Gilbert*.

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

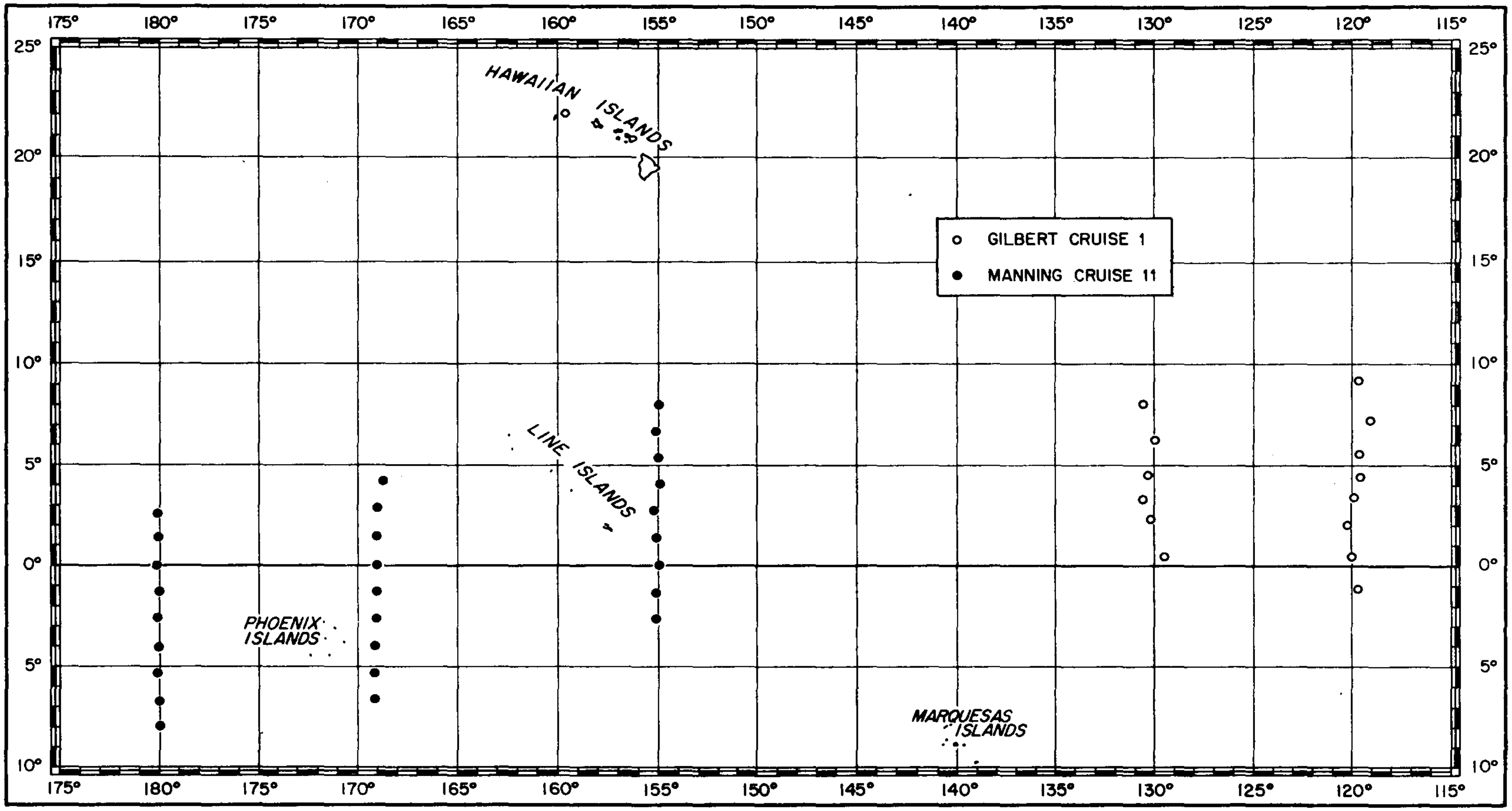

FIG. I. CENTRAL PACIFIC OCEAN, SHOWING LOCATION OF LONGLINE STATIONS

FIG. 2. THE JOHN R MANNING AT THE EQUATOR ON 180°. THE CREW HAS JUST FINISHED SETTING THE LONGLINE.

W. G. Van Campen translated the Japanese fishing data included in the report. Miss Jean Halling assisted in processing the catch records.

OPERATIONAL DATA

Longline fishing on the Manning and Gilbert was done in essentially the same manner as on the Hugh M. Smith (Murphy and Shomura 1953) with minor modifications. Forty baskets of standard POFI longline gear (Niska 1953) were used at each station during the cruises under consideration. Each of these baskets had a main line 1,260 feet long with six evenly spaced hook droppers. Each dropper was 88 feet in overall length. At certain stations on Cruise 11 of the Manning, 5 additional baskets of experimental gear were set. These will be discussed in a later section. Fresh frozen sardines, approximately four to the pound, were used as bait. Before use they were thawed and packed in rock salt for from 1 to 3 days. The baits were hooked through the eyes.

Setting of the gear began about dawn and usually took an hour. Retrieving the gear usually started at noon and finished about 4:00 P.M. Tables 1 and 2 give the exact working time for all stations. These tables indicate that the stations were in general comparable as regards the length of time the gear was fished and the daily scheduling of the fishing.

HORIZONTAL DISTRIBUTION OF YELLOWFIN TUNA

The results of the first longline cruises to the equatorial Pacific in the vicinity of 150°-160° W. longitude during the period from August to November indicated a marked concentration of deep-swimming yellowfin tuna in a zone north of the Equator (Murphy and Shomura 1953). These surveys were made during a period of predominant southeast trades, which cause upwelling near the Equator and tend to displace the upwelled water northward (Cromwell[2]). It was tentatively concluded that this enriched water, with its increased plankton and presumably increased tuna forage, was directly linked with the observed concentration of yellowfin.

Extrapolation of this theory to periods or areas characterized by winds other than southeast indicates that the location of the most productive zone should be somewhat different. Northeast winds should create a mirror image of the circulation created by southeast winds, with the zone of greatest productivity displaced to the south of the Equator. Easterly or variable winds should result in the zone of greatest productivity being symmetrically arranged about the Equator

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2/ Cromwell, Townsend. MS. Circulation in a meridional plane in the central equatorial Pacific.

Table 1.--Time taken for setting and hauling the longline, *John R. Manning* Cruise 11.

Station	Number of baskets	Time started to set	Time taken for setting (min.)	Time started to haul	Actual time taken for hauling (min.)	Fish-handling break[1] (min.)
1	40	0615	47	1213	237	65
2	"	0613	62	1206	240	64
3	"	0620	55	1222	212	61
4	"	0618	59	1205	211	62
5	"	0620	78	1220	179	59
6	"	0615	69	1217	173	65
7	"	0600	78	1211	194	63
8	"	0612	61	1209	201	60
9	"	0611	62	1210	167	58
10	45	0605	64	1218	190	59
11	"	0605	68	1205	207	65
12	"	0607	67	1206	216	65
13	"	0600	65	1215	184	67
14	"	0606	54	1210	240	58
15	"	0600	70	1217	213	65
16	"	0605	60	1222	212	69
17	"	0602	64	1204	243	63
18	40	0603	67	1207	161	67
19	45	0616	70	1155	209	63
20	"	0615	68	1203	226	63
21	"	0607	72	1207	230	63
22	"	0600	74	1210	240	65
23	"	0610	71	1206	225	71
24	"	0607	64	1205	214	63
25	"	0604	68	1205	215	65
26	"	0600	73	1158	234	66
27	40	0608	70	1200	250	62
Average time for 40-basket sets			64.4 min.		202.3 min.	63.6 min. (mean for all sets)
Average time for 45-basket sets			67.0 min.		218.6 min.	

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[1] Fish-handling break came midway during hauling period.

Table 2.--Time taken for setting and hauling the longline, *Charles H. Gilbert* Cruise 1.

Station[1]	Time started to set	Time taken for setting (min.)	Time started to haul	Actual time taken for hauling (min.)	Fish handling break[2] (min.)
1	0612	58	1235	225	25
2	0600	50	1245	188	27
3	0600	55	1225	193	42
4	0605	50	1225	175	30
5	0605	50	1300	135	25
6	0605	50	1255	165	35
7	0610	50	1300	230	30
8	0615	55	1255	140	40
9	0545	60	1247	133	40
10	0555	55	1255	145	50
11	0550	55	1255	150	45
12	0555	55	1305	155	40
13	0605	60	1315	155	40
14	0600	55	1300	235	50
Average		54.1		173.1	37.1

[1] 40 baskets were used at each station.

[2] Fish-handling break came midway during the hauling period.

The five section lines discussed in this report were fished during the period January to June on 120°, 130°, 155°, 169°, and 180° W. longitude. In general the period January to June is characterized by either northeast or variable trade winds, although southeast winds begin to predominate towards the end of the period, particularly at the eastern end of the area (120°-130°). According to U. S. Pilot Charts the period of fishing along 120° W. in late May 1952 was preceded by about a month of predominant but moderate southeast trades as was the 130° W. section fished in early June of 1952. Fishing on the 155° W. and 169° W. sections in February and March of 1952 was preceded by winds about equally divided between northeast and southeast, and the 180° section fished in February of 1952 was preceded by predominantly northeast winds. The actual winds experienced during the fishing of these sections (table 3) are entirely compatible with the mean picture presented by the Pilot Charts, indicating that the winds during and possibly preceding this fishing closely resembled the normal or average picture.

Table 3.--Average wind direction and Beaufort force at the fishing stations, *John R. Manning* Cruise 11, *Charles H. Gilbert* Cruise 1.

Latitude	Longitude				
	180°	169°W	155°W	130°W	120°W
9°N	-	-	-	-	E -03
8°N	-	-	NE-06	SE-04	-
7°N	-	-	NE-06	-	S -05
6°N	-	-	-	SE-02	-
5°N	-	-	NE-06	S -01	S -05
4°N	-	NE-05	E -05	-	S -04
3°N	NE-03	NE-04	E -06	S -04	SE-04
2°N	-	-	-	SE-04	SE-03
1°N	NE-03	NE-04	E -05	-	-
Equator	NE-02	E -04	N -03	E -04	SE-03
1°S	NE-03	E -04	NE-04	-	SE-04
2°S	-	-	-	-	-
3°S	NE-04	NE-04	E -04	-	-
4°S	NE-05	NE-04	-	-	-
5°S	NE-05	E -04	-	-	-
6°S	-	-	-	-	-
7°S	NE-04	E -05	-	-	-
8°S	NE-04	-	-	-	-

Turning to the temperature sections along each fishing line (figs. 3 and 4), it is apparent that, as might be expected from the wind observations, some upwelling was taking place in the vicinity of the Equator in each instance. Note especially the decreased surface temperature and the doming up of the isotherms near the Equator. The approximate location of the easterly flowing Countercurrent, included for orientation in figures 3 and 4, was determined on the three western sections by a combination of ship's drifts, drifts of the longline while on station, and GEK[3] fixes by the Hugh M. Smith while in close company with the fishing vessel. On the two eastern sections (120° and 130°) the location of the Countercurrent was taken from U. S. Pilot Charts for the appropriate months.

Consideration of the results of the longline fishing (fig. 5) with the observations on the hydrographic structure (figs. 3 and 4), the winds observed during the fishing (table 3), and the mean or average winds represented on the Pilot Charts indicates good agreement with what might have been expected *a priori*. Each of the five sections (fig. 5 and table 4) shows a zone near the Equator in which yellowfin tuna were more abundant than to the north and south and which, in all likelihood, is associated with the upwelling suggested in the temperature sections. The more precise latitudinal location of the greatest concentration of yellowfin appears compatible with the average winds recorded on the Pilot Charts and the observed winds during the fishing. For instance the 120° and 130° sections which were associated with southeast winds, had their peaks of abundance north of the Equator. The 155° and 169° sections, which were associated with variable winds, had their peak abundance of yellowfin nearly centering on the Equator, and the 180° section, associated with northeast winds, had its peak of yellowfin abundance displaced to the south.

Including the two sections previously reported on by Murphy and Shomura (1953), there are seven sections reconcilable with the theory that, through upwelling, southeast winds create a favorable environment north of the Equator, northeast winds tend to create a favorable environment south of the Equator, and variable or east winds create a favorable environment tending to center on the Equator. This is advanced with no implications as to the exact level of abundance that the yellowfin will attain in the "zone of greatest abundance." Predictions of the level of abundance would appear to involve many more complexities than simple prediction of the location of the greatest abundance on the basis of prevailing winds at and near the Equator.

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[3] Geomagneticelectrokinetograph, an instrument for measurement of surface currents.

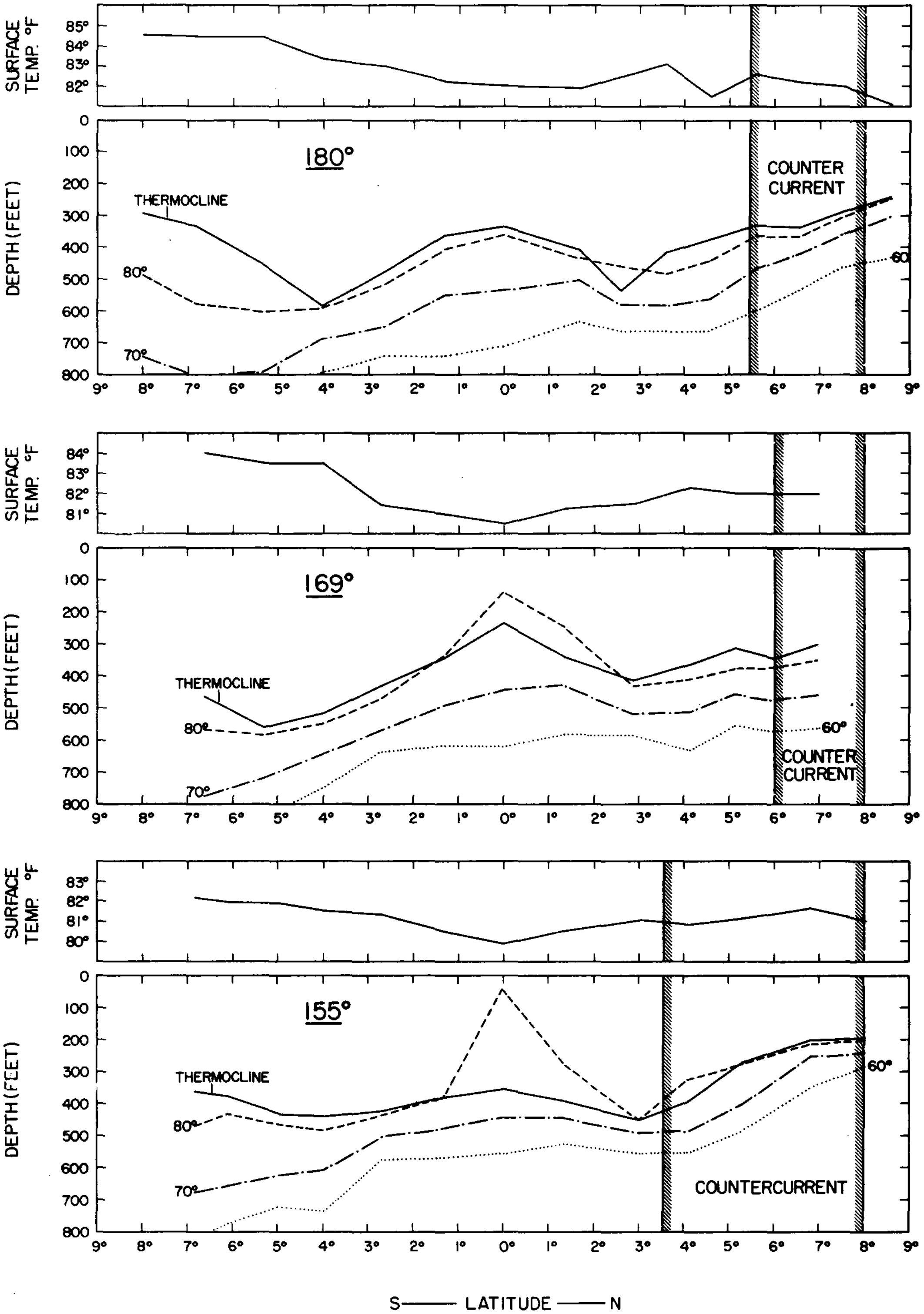

FIG. 3. TEMPERATURE SECTIONS CORRESPONDING TO FISHING ON 155°, 169°, AND 180° W. LONGITUDE.

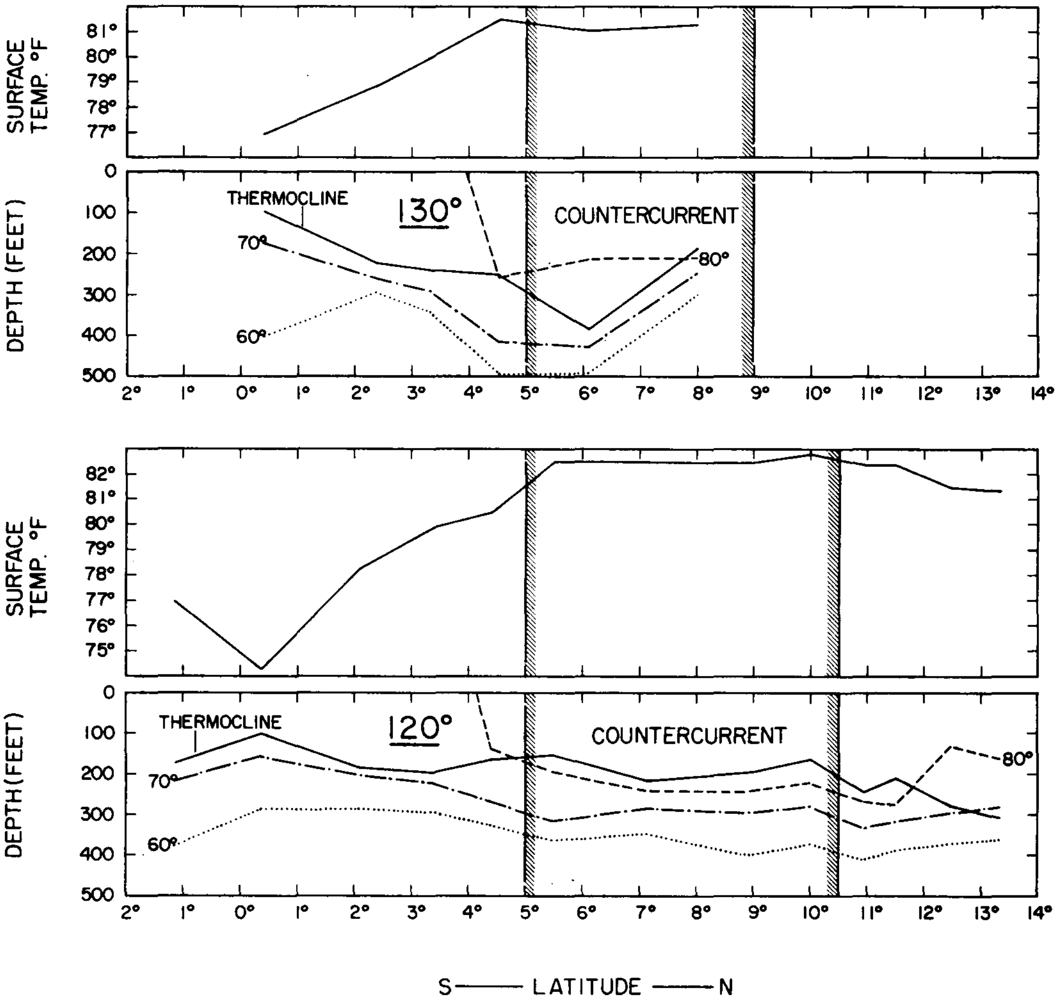

FIG. 4. TEMPERATURE SECTIONS CORRESPONDING TO FISHING ON 120° AND 130° W. LONGITUDE.

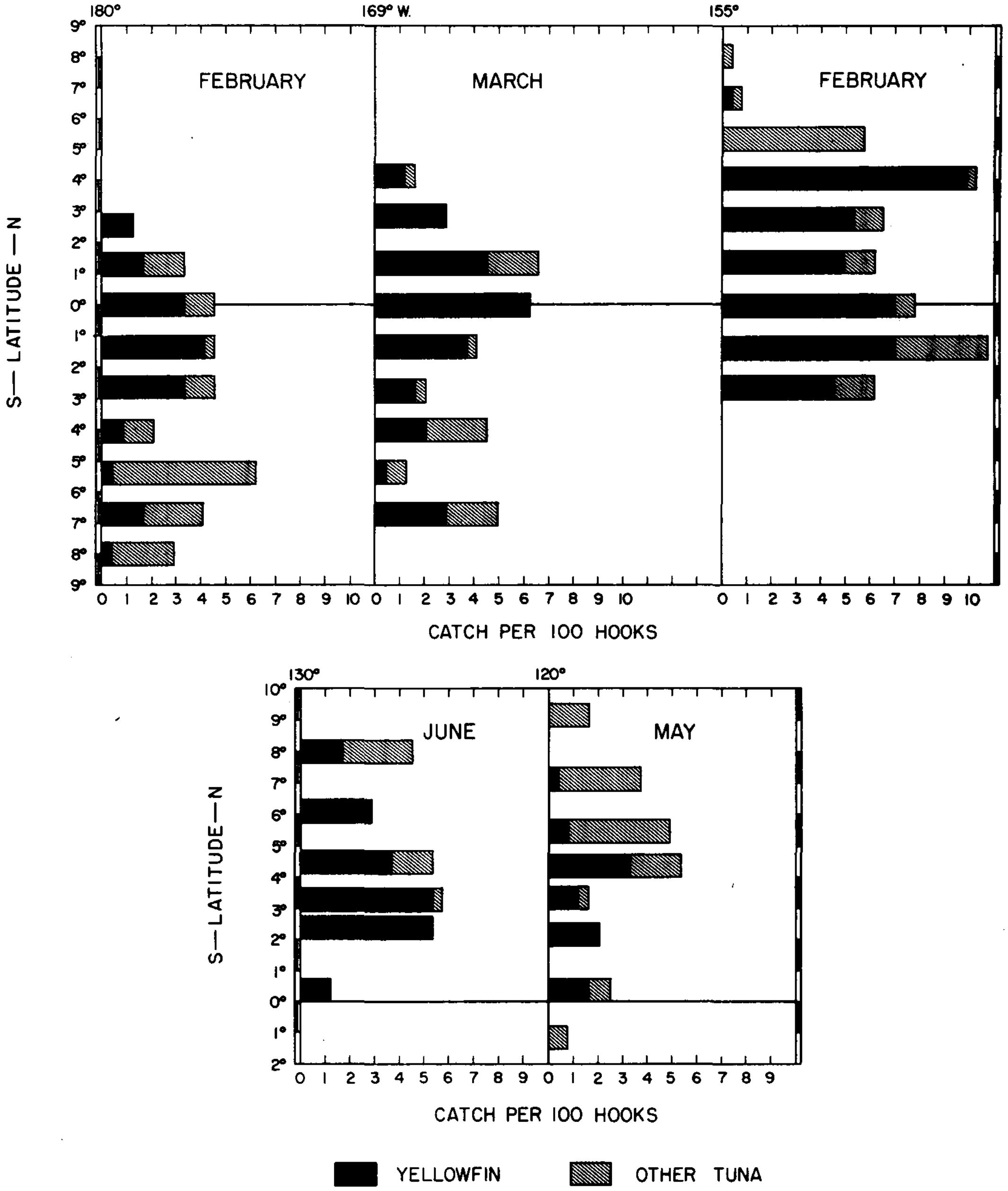

FIG. 5. TUNA CATCHES ON FIVE LONGLINE FISHING SECTIONS ACROSS THE EQUATOR DURING THE PERIOD FEBRUARY TO JUNE 1952.

Table 4.--Summary of the tuna catching rates, *John R. Manning* Cruise 11 and *Charles H. Gilbert* Cruise 1.

				Number caught per hundred hooks			
Station	Date	Latitude	Longitude	Yellow-fin	Big-eye	Alba-core	Skip-jack
Manning Cruise 11							
1	1-29-52	08°02'N	154°58'W	-	0.41	-	-
2	1-30-52	06°40'N	155°05'W	0.41	0.41	-	-
3	1-31-52	05°20'N	155°00'W	-	5.79	-	-
4	2-1-52	04°04'N	154°56'W	9.92	-	-	0.41
5	2-2-52	02°46'N	155°11'W	5.37	1.24	-	-
6	2-3-52	01°20'N	155°03'W	4.96	0.83	-	0.41
7	2-4-52	00°02'S	154°57'W	7.02	-	-	0.83
8	2-5-52	01°20'S	155°06'W	7.02	0.83	0.83	2.07
9	2-6-52	02°41'S	155°06'W	4.54	-	1.24	0.41
10	2-16-52	02°35'N	179°55'E	1.24	-	-	-
11	2-17-52	01°18'N	179°55'E	1.65	0.41	0.83	0.41
12	2-18-52	00°01'S	179°50'E	3.30	0.41	0.83	-
13	2-19-52	01°18'S	180°00'	4.13	-	-	0.41
14	2-20-52	02°39'S	179°54'E	3.30	0.41	0.83	-
15	2-21-52	04°03'S	179°58'E	0.83	0.41	0.83	-
16	2-22-52	05°22'S	179°57'E	0.41	-	5.79	-
17	2-23-52	06°44'S	179°58'W	1.65	-	2.48	-
18	2-24-52	08°00'S	179°56'W	0.41	-	2.48	-
19	3-4-52	06°40'S	169°03'W	2.89	-	2.07	-
20	3-5-52	05°18'S	169°03'W	0.41	-	0.83	-
21	3-6-52	04°02'S	169°04'W	2.07	0.41	1.65	0.41
22	3-7-52	02°43'S	169°00'W	1.65	0.41	-	-
23	3-8-52	01°20'S	169°00'W	3.72	-	0.41	-
24	3-9-52	00°00'	169°02'W	6.20	-	-	-
25	3-10-52	01°21'N	169°01'W	4.54	-	0.41	1.65
26	3-11-52	02°51'N	169°00'W	2.89	-	-	-
27	3-12-52	04°10'N	168°40'W	1.24	0.41	-	-
Gilbert Cruise 1							
1	5-28-52	09°10'N	119°40'W	-	1.24	-	0.41
2	5-29-52	07°09'N	119°00'W	0.41	3.31	-	-
3	5-30-52	05°27'N	119°38'W	0.83	4.13	-	-
4	5-31-52	04°18'N	119°35'W	3.31	2.07	-	-
5	6-1-52	03°18'N	119°54'W	1.24	0.41	-	-
6	6-2-52	02°05'N	120°11'W	2.07	-	-	-
7	6-3-52	00°19'N	119°58'W	1.65	0.83	-	-
8	6-4-52	01°09'S	119°41'W	-	0.83	-	-
9	6-8-52	00°21'N	129°23'W	1.24	-	-	-
10	6-9-52	02°19'N	130°07'W	5.37	-	-	-
11	6-10-52	03°17'N	130°28'W	5.37	0.41	-	-
12	6-11-52	04°30'N	130°15'W	3.72	1.65	-	-
13	6-12-52	06°06'N	129°55'W	2.89	-	-	-
14	6-13-52	08°00'N	130°24'W	1.65	2.89	-	-

ALBACORE

One of the more interesting results of the fishing on 180° W. longitude was the surprisingly high catch of albacore at 5°-8° S. latitude (table 4). A relatively high catch was also made at 169° W. longitude, 7° S. latitude (table 4). These catches were made up of large individuals (table 5), many of which appeared to be sexually mature. It is possible that this area contains concentrations of albacore capable of maintaining a sizeable commercial fishery.

Table 5.--Length frequencies of albacore and skipjack, _John R. Manning_ Cruise 11.

Albacore			Skipjack		
Length cm.	Number	Approximate weight pounds	Length cm.	Number	Approximate weight pounds
83	1	25	62	-	-
84	1	26	63	-	-
85	1	26	64	-	-
86	3	27	65	-	-
87	1	28	66	1	14
88	1	29	67	1	15
89	4	30	68	-	-
90	8	31	69	-	-
91	9	32	70	-	-
92	3	33	71	-	-
93	1	35	72	-	-
94	2	36	73	-	-
95	2	37	74	-	-
96	3	38	75	-	-
97	1	39	76	3	24
98	1	40	77	4	25
99	3	42	78	3	27
100	2	43	79	1	29
101	1	44	80	2	30
102	1	46	81	1	31
103	1	47	82	1	32
104	1	48	83	-	-

SIZES OF YELLOWFIN AND BIGEYE

The sizes of the yellowfin tuna taken on the five section lines increase from west to east (table 6) with fish averaging about 110 pounds at 180° and 140 pounds at 120° W. longitude. West of 180° the trend to smaller tuna continues in an irregular manner to 135° E. longitude, where Japanese commercial longline catches averaged 62 pounds (Murphy and Otsu[4]). A parallel trend is evident in the bigeye tuna east of 180° (table 7), and similarly west of 180° longline catches of this species were roughly 40 pounds lighter in weight (Murphy and Otsu[4]) than between 180° and 120° W. longitude.

SEX RATIOS

With the exception of albacore the various species of tuna in the catches (table 8) have a preponderance of males, although the yellowfin tuna disproportion is the only one that is statistically significant. The excess of males in longline catches of bigeye and yellowfin has been previously noted in catches from 140° E. longitude to 150° W. longitude (Murphy and Otsu[4], Murphy and Shomura 1953). In albacore the excess of females is not statistically significant.

JAPANESE FISHING

Japanese longline fishermen began operating in the central Pacific in May of 1952. A summary of the most pertinent data from these operations in May and June of 1952 is given in table 9. This fishing along 170° W. to 180° shows very clearly that there was a concentration of yellowfin from the Equator north to about 5° N. latitude, and that yellowfin were relatively scarce north of this zone during both May and June of 1952. It also furnishes a good indication that bigeye tuna were considerably more abundant north of 5° N. latitude than south of that parallel. Because of the relative scarcity of bigeye and because of the necessarily limited extent of our fishing, it has not been possible to make any such definitive statement from our data, although there have been similar indications in nearly every fishing section. The catches of the other species included in table 9 do not show such pronounced differences in abundance with latitude.

The general levels of abundance (catch per hundred hooks) of both yellowfin and bigeye tuna are in close agreement with results obtained by the Manning's fishing (compare tables 4 and 9), even though the Japanese fishing took place 3 months later in the year. This is an indication that our catch rates made with 240-hook sets are comparable with catch rates from the 1,500- to 2,000-hook sets used by commercial fishermen. In addition the sizes of the tunas were very similar (compare tables 6 and 7 with table 10), for the exploratory fishing and the full-scale commercial operations.

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[4] Murphy, Garth I., and T. Otsu. MS. Analysis of the catches of nine Japanese tuna longline expeditions to the western Pacific Ocean.

Table 6.--Length frequencies of yellowfin tuna, *John R. Manning* Cruise 11, *Charles H. Gilbert* Cruise 1.

Length	Longitude West					Approximate weight
	180°	169°	155°	130°	120°	
cm.						pounds
92	-	-	-	1	-	33
97	-	-	-	-	-	39
102	-	-	1	-	-	46
107	-	-	1	-	-	53
112	1	-	3	-	-	60
117	1	-	4	-	-	69
122	2	3	6	-	-	78
127	7	8	6	1	1	88
132	9	5	3	1	1	100
137	11	5	10	2	1	110
142	14	23	19	5	6	123
147	9	10	16	4	3	137
152	1	4	4	8	3	150
157	-	1	2	2	1	166
162	-	-	-	5	2	182
167	-	-	-	2	1	200
Total	55	59	75	31	19	
Mean length	136.7	139.5	136.6	148.3	147.0	

Table 7.--Length frequencies of bigeye tuna, *John R. Manning* Cruise 11, *Charles H. Gilbert* Cruise 1.

Length cm.	Longitude West 180°	 169°	 155°	 130°	 120°	Approximate weight pounds
107	-	-	1	-	-	58
112	-	-	-	-	1	66
117	-	-	2	-	-	75
122	-	-	3	-	1	85
127	-	-	2	-	1	95
132	-	-	2	1	4	107
137	1	-	2	-	-	119
142	1	-	2	1	1	132
147	1	1	1	-	-	146
152	-	-	1	2	2	161
157	-	1	3	-	4	177
162	-	-	-	1	3	195
167	-	-	-	1	3	198
172	-	-	-	1	1	232
177	-	-	-	1	2	252
182	-	-	-	-	1	273
187	-	-	-	1	1	296
192	-	-	-	1	-	320
197	-	-	-	-	1	345
Total	3	2	19	10	26	
Mean length	142.0	152.0	134.5	163.5	155.5	

Table 8.--Sex ratios, *John R. Manning* Cruise 11 and *Charles H. Gilbert* Cruise 1

Cruise	Yellowfin Male	 Female	Bigeye Male	 Female	Albacore Male	 Female	Skipjack Male	 Female
Manning 11	120	73	17	10	25	33	9	7
Gilbert 1	33	23	19	9	-	-	-	-
Total	153	96	36	19	25	33	9	7
Percent	61	39	65	35	43	57	56	44

Table 9.--Summary of Japanese commercial fishing in the central Pacific during May and June 1952. Adapted from Kanagawa Prefecture Fisheries Experiment Station Monthly Report No. 2, July 1952.

Item	May	May	June	June
	00 - 05°N 176° W	07 - 11.5°N 178° - 164°W	00 - 04°N 179 - 166°W	09 - 11.5°N 180 - 164°W
Number of boats	1	7	4	7
Hook-days	21,000	187,020	106,800	180,590
Catch per hundred hook-days:				
Yellowfin tuna	3.33	0.06	6.41	0.09
Bigeye tuna	1.67	2.61	0.37	2.71
Albacore	-	0.01	0.02	-
Skipjack	0.13	0.11	0.21	0.30
Black marlin	0.52	0.58	0.29	0.74
White marlin	-	0.03	0.01	-
Striped marlin	-	0.02	-	-
Broadbill	0.01	0.03	0.01	0.02
Sailfish	0.03	0.10	0.15	0.10
Miscellaneous	0.05	0.14	0.20	0.21
Sharks	0.67	1.18	0.46	0.68
All species	6.41	4.87	8.15	4.85

Table 10.--Length frequencies of tunas taken by Japanese commercial fishermen in the central Pacific during May and June 1952. Adapted from Kanagawa Prefecture Fisheries Experiment Station Monthly Reports No. 1, June 1952, and No. 2, July 1952.

Length	Bigeye tuna			Yellowfin tuna	
	May	June		June	
	07-11.5°N 164-178°W	00-11.5°N 180-172°W	Approximate weight	00-0.5°N 179-172°W	Approximate weight
cm.			pounds		pounds
less than 100	4	-	-	-	-
101-110	21	7	55	5	50
111-120	174	13	71	68	65
121-130	277	21	91	178	84
131-140	414	38	114	343	106
141-150	581	35	140	413	131
151-160	554	54	171	85	160
161-170	436	30	205	-	192
171-180	230	12	244	-	230
over 181	75	3	-	-	-

VERTICAL DISTRIBUTION OF THE CATCHES

The depth at which the deep-swimming tunas are most abundant is of considerable interest biologically and of practical importance commercially. It has been previously noted (e.g. Nakamura 1943, Ochi 1952, and Murphy and Shomura 1953) that in general yellowfin and bigeye tuna were taken in greater numbers on the lowermost hooks of the longline.

In the absence of information on the actual depth of capture, the catches can be examined for catch rates at three relative depth levels (shallow, intermediate, and deep). Examination of the catches of yellowfin and bigeye tuna by relative depth of capture for Manning Cruise 11 (tables 11 and 12) show that the deeper-fishing hooks usually had higher catches than the shallow hooks. Both chi-square analyses, however, show significant interaction chi-squares, which indicates that the pattern of more fish on the deep hooks was not consistent. Significantly more yellowfin were taken on the shallow hooks at stations 7, 23, and 24 (table 11). The bigeye data (table 12) show a reversal in the relationship of the intermediate and deep hooks. These deviations may well be expected if the position of the line with respect to critical isotherms or the thermocline is different from station to station. The distribution of the albacore catches (table 13) gives good evidence that this species occupies the deeper, cooler strata of water in the tropics.

The depth data from Gilbert Cruise 1 (tables 14 and 15) indicate that, when those sections on 120° and 130° W. longitude were fished, the yellowfin were not stratified with depth so far as the depth range fished by our gear is concerned. The bigeye, on the other hand, gave evidence of being more abundant at the levels fished by the deep hooks. The failure of the deep hooks to catch more yellowfin may be a function of the shallow thermoclines experienced during this fishing (fig. 4). These shallow thermoclines, with the possible attendant streaming of the line, might have placed all of the hooks at more nearly the same level than usual. Since the yellowfin are the least markedly stratified with depth, it might be imagined that if the differential between shallow and deep hooks were small, little or no difference would be noted in the catches at the three relative depth levels.

In an attempt to ascertain the actual depth of the main line a depth indicator was attached to the base of one of the central or deep hooks at 10 stations during Cruise 11 of the Manning. This gauge was designed to furnish an estimate of the deepest point reached by the portion of the line to which the instrument was attached. The correlation of the depths indicated by the gauge and the depth of the top of the thermocline (table 16) is 0.662, $P < 0.05$, suggesting that under some circumstances the thermocline limits the penetration of the gear. This result might be expected at least part of the time as the thermocline is the boundary between moving surface water and the relatively still deeper layers.

Table 11.--Chi-square analysis of yellowfin catches by hook depth, *John R. Manning* Cruise 11.

Station	Number of fish			Total number of fish	χ^2
	Shallow hooks	Intermediate hooks	Deep hooks		
4	7	6	11	24	1.750
5-6[1]	6	9	10	25	1.039
7	10	2	4	16	6.500*
8	3	5	8	16	2.376
9-11[1]	5	6	7	18	0.334
12-13[1]	6	7	5	18	0.334
14-17[1]	-	3	12	15	15.600**
18-22[1]	2	8	8	18	4.001
23-24[1]	15	4	5	24	9.250**
25-27[1]	5	7	9	21	1.142
Total	59	57	79	195	42.326** Total χ^2 (d.f.20) 4.554 Pooled χ^2 (d.f.2) 37.772** Interaction χ^2 (d.f.18)

Hypothesis: The population of yellowfin tuna is homogeneously distributed with respect to depth; therefore a 1:1:1 ratio is expected from the three depth zones.

Conclusions: The significant interaction χ^2 of 37.772 (d.f. 18, $P < 0.01$) indicates the data are not consistent; therefore the pooled values cannot be accepted without reservation.

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[1] Stations lumped to give minimum expected numbers of about 5.

* indicates a significant ($P < 0.05$) chi-square value.

** indicates a highly significant ($P < 0.01$) chi-square value.

Table 12.--Chi-square analysis of bigeye tuna catches by hook depth, *John R. Manning* Cruise 11.

Station	Number of fish			Total number of fish	χ^2
	Shallow hooks	Intermediate hooks	Deep hooks		
1-3[1]	3	4	9	16	3.875
4-27[1]	2	9	3	14	6.142*
Total	5	13	12	30	10.017* Total χ^2 (d.f. 4) 3.800 Pooled χ^2 (d.f. 2) 6.217* Interaction χ^2 (d.f. 2)

Hypothesis: The population of bigeye tuna is homogeneously distributed with respect to depth; therefore a 1:1:1 ratio is expected from the three depth zones.

Conclusions: The significant interaction χ^2 of 6.217 (d.f. 2, $P < 0.05$) indicates the data are not consistent; therefore the pooled values cannot be accepted without reservation.

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[1] Stations lumped to give minimum expected numbers of about 5.

* indicates a significant ($P < 0.05$) chi-square value.

Table 13.--Chi-square analysis of albacore catches by hook depths, John R. Manning Cruise 11.

Station	Number of fish			Total number of fish	χ^2
	Shallow hooks	Intermediate hooks	Deep hooks		
8-16[1]	-	8	19	27	20.222**
17-25[1]	-	8	17	25	17.360**
Total	-	16	36	52	37.582** Total χ^2 (d.f.4) 37.540** Pooled χ^2 (d.f.2) 0.042 Interaction χ^2 (d.f.2)

Hypothesis: The population of albacore tuna is homogeneously distributed with respect to depth; therefore a 1:1:1 ratio is expected from the three depth zones.

Conclusions: There is a definite difference of catch with depth, with the lowermost hooks catching more. This is indicated by the significant individual, total and pooled χ^2's and by a very low non-significant interaction χ^2.

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[1] Stations lumped to give minimum expected numbers of about 5.

** indicates a highly significant ($P < 0.01$) chi-square value.

Table 14.--Chi-square analysis of yellowfin tuna catches by hook depths, *Charles H. Gilbert* Cruise 1.

Station	Number of fish			Total number of fish	χ^2
	Shallow hooks	Intermediate hooks	Deep hooks		
1-6[1]	3	10	6	19	3.895
7-10[1]	8	6	5	19	0.738
11-14[1]	10	8	15	33	2.364
Total	21	24	26	71	6.997 Total χ^2 (d.f.6) 0.536 Pooled χ^2 (d.f.2) 6.461 Interaction χ^2 (d.f.4)

Hypothesis: The population of yellowfin tuna is homogeneously distributed with respect to depth; therefore a 1:1:1 ratio is expected from the three depth zones.

Conclusions: The data available indicates a homogeneous population of yellowfin tuna. There are no differences in the number of fish caught with respect to depth.

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[1] Stations lumped to give minimum expected numbers of about 5.

Table 15.--Chi-square analysis of bigeye tuna catches by hook depths, *Charles H. Gilbert* Cruise 1.

Station	Number of fish Shallow hooks	 Intermediate hooks	 Deep hooks	Total number of fish	χ^2
1-3[1]	4	5	12	21	5.428
4-14[1]	5	6	11	22	2.818
Total	9	11	23	43	8.246 Total χ^2 (d.f.4) 8.000* Pooled χ^2 (d.f.2) 0.246 Interaction χ^2 (d.f. 2)

Hypothesis: The population of bigeye tuna is homogeneously distributed with respect to depth; therefore a 1:1:1 ratio is expected from the three depth zones.

Conclusions: The presence of a difference in the number of bigeye tuna caught with depth is indicated by a significant pooled χ^2 of 8.000 (d.f.2, $P < 0.05$) and a low nonsignificant interaction χ^2.

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[1] Stations lumped to give minimum expected numbers of about 5.

* indicates a significant ($P < 0.05$) chi-square value.

Table 16.--Estimated main-line depths from gauge readings and thermocline depths, *John R. Manning* Cruise 11.

Station	Gauge depth feet	Depth to top of thermocline feet
4	510	396
19	410	464
20	497	560
21	480	516
22	450	430
23	370	346
24	285	236
25	300	340
26	455	412
27	520	360

These results, coupled with earlier findings (Murphy and Shomura 1953), indicate that the actual depth reached by the line is a function of a complex of factors. Only one of these is readily ascertainable and that is the distance between buoys. Since this distance governs the maximum amount the main line can sag down between buoys it gives the maximum possible depth that the line can reach. During Cruise 11 of the Manning the deepest hooks could have been fishing at about 550 feet (table 17), with the other hooks at lesser depths. Even this figure is approximate as there is variation in buoy distance between baskets and there is probably variation within a basket while it is soaking.

Table 17.--Average buoy distance as determined from setting speed and time and maximum possible depth to deep hooks, John R. Manning Cruise 11[1].

Station	Average buoy distance	Depth to deep hooks
1	630	628
2	830	558
3	740	588
4	790	578
5	1040	448
6	920	518
7	1040	448
8	820	568
9	830	558
10	760	588
11	810	568
12	790	568
13	770	578
14	640	618
15	830	558
16	710	598
17	760	588
18	900	528
19	830	558
20	810	568
21	850	448
22	870	438
23	840	548
24	760	588
25	810	568
26	860	548
27	930	508

[1] Depth estimated from buoy distances from curves in Murphy and Shomura (1953).

CATCHES ON EXPERIMENTAL GEAR

Analysis of earlier longline cruises indicated that the catch of yellowfin and bigeye tuna was greater on the deeper-fishing hooks (Murphy and Shomura 1953). If abundance were truly a function of depth, it should be possible to increase the catches by fishing at deeper levels. Accordingly 5 baskets of special gear were fished at each of 16 stations on Manning Cruise 11. On stations 10-17 (180° longitude) the gear had 50-fathom float lines instead of the usual 10. Thirty-fathom float lines were used on stations 19-26 (169° W. longitude). Operationally, the special gear worked well. The hauling time was a little greater because of the long float lines, and there was somewhat more strain on the line hauler, but there did not appear to be any reason why such gear could not be used in large-scale operations.

The catches of the 19 baskets of regular gear that were hauled after the break and that were adjacent to the special gear were used as a basis for comparison in order to minimize any possible effect of unequal fishing time. These comparisons, given in table 18, indicate there was little if any difference in the yellowfin-catching efficiency of the two types of gear. It is of interest that the albacore, the species showing the greatest relative catch on the deep hooks of the standard baskets, shows a 60-percent increase in catch over the expected when 50-fathom float lines were used, even though the difference is not statistically significant. In regard to relative depth distribution, the special gear caught fewer yellowfin on the deep hooks and equal numbers of albacore at all three hook levels in contrast to the usual distribution on the standard gear. For instance, the capture of 6 albacore on the shallow hooks of 40 baskets of special gear, contrasted with no albacore on the shallow hooks of 320 baskets of regular gear, appears significant. These numerical data are too scant to carry great weight, but indications are that the long float lines were allowing the hooks to sink deeper so that the deepest hooks may have been beyond the greatest concentration of yellowfin and all of the hooks may have been in the best albacore depths.

Table 18.--Analysis of catch of tuna with type of gear used.

Station	Species of tuna	Regular gear	Special gear [1]	χ^2
10-17	Yellowfin tuna	21	6	0.038
	Albacore tuna	20	10	2.917
19-26	Yellowfin tuna	33	7	0.250
	Albacore tuna	13	2	0.417

[1] The special gear on stations 10 through 17 differed from the regular gear by having 50-fathom float lines. On stations 19 through 26 the length of float lines of the special gear was 30 fathoms.

SUMMARY

1. During January, February, and March, the John R. Manning occupied fishing stations on 155°, 169°, and 180° W. longitude. Fishing on 120° and 130° W. longitude was done with the Charles H. Gilbert during May and June.

2. The catches made during these cruises gave further proof of the presence of a "rich zone" of yellowfin tuna previously reported for the equatorial region.

3. The latitudinal variation of this zone generally coincided with differences in the prevailing winds. Where southeasterly winds prevailed, the concentration of tuna was to the north of the Equator, and where the winds were northeasterly or variable the zone was displaced to the south.

4. The high catches of albacore tuna made in southern latitudes on 169° and 180° W. longitude point to a possible area of commercial exploitation for this species.

5. Both the yellowfin and bigeye tuna increase in average size from west to east.

6. With the exception of the albacore, the tunas (yellowfin, bigeye, and skipjack) showed a greater catch of males than females.

7. Results of Japanese commercial fishing in the central Pacific agreed closely as to catching rate and sizes of tuna taken with those obtained by POFI vessels fishing in the same general area 3 months earlier.

8. Both yellowfin and bigeye tuna were usually caught in greater numbers on the deeper hooks. Exceptions probably were due to streaming of the line when the thermocline was at shoal levels. The albacore catches revealed a more definite stratification, with deep hooks consistently showing the highest catch rate.

9. Experimental fishing with longer float lines indicated that the modified gear was fishing at a deeper level, and was more efficient in the capture of albacore.

Table 19.--Numbers of fish caught on John R. Manning Cruise 11 (40 baskets with 10-fathom float lines).

Station	Yellow-fin	Big-eye	Alba-core	Skip-jack	Marlin	Sharks			Others
						White-tipped	Silky	Great blue	
1	-	1	-	-	-	-	-	1	5[1]
2	1	1	-	-	-	-	-	5	1[2]
3	-	14	-	-	1	-	-	5	2[3]
4	24	-	-	1	1	1	-	4	1[4]
5	13	3	-	-	-	-	-	1	-
6	12	2	-	1	2	2	-	2	1[5]
7	17	-	-	2	-	4	-	-	1[4]
8	17	2	2	5	-	3	-	1	-
9	11	-	3	1	1	1	-	1	3[6]
10	3	-	-	-	-	4	-	1	1[5]
11	4	1	2	1	-	8	-	5	-
12	8	1	2	-	2	7	-	2	-
13	10	-	-	1	-	9	-	1	-
14	8	1	2	-	2	5	-	3	-
15	2	1	2	-	1	1	-	1	-
16	1	-	14	-	-	1	-	2	-
17	4	-	6	-	-	2	-	-	1[7]
18	1	-	6	-	3	-	-	-	1[5]
19	7	-	5	-	2	1	-	-	1[5]
20	1	-	2	-	-	3	-	2	1[4]
21	5	1	4	1	-	-	-	5	-
22	4	1	-	-	-	-	1	1	-
23	9	-	1	-	-	2	2	1	-
24	15	-	-	-	-	5	1	-	-
25	11	-	1	4	-	1	1	-	-
26	7	-	-	-	-	3	23	1	-
27	3	1	-	-	1	1	-	1	-

[1] 3 lancet fish, 2 unidentified shark.

[2] 1 bonito shark.

[3] 2 lancet fish.

[4] 1 unidentified shark.

[5] 1 wahoo.

[6] 2 sailfish, 1 lancet fish.

[7] 1 barracuda.

Table 20.--Numbers of fish caught on the 5 special baskets, *John R. Manning* Cruise 11 (stations 10-17, 50-fathom float lines; stations 19-26, 30-fathom float lines).

Station	Yellowfin	Albacore	Marlin	Sharks		
				White-tipped	Silky	Great blue
10	-	1	-	-	-	-
11	-	-	-	-	-	1
12	2	-	1	1	-	1
13	-	-	-	-	-	-
14	2	2	-	-	-	-
15	2	-	-	-	-	-
16	-	6	1	-	-	-
17	-	1	-	-	-	-
19	1	1	-	-	-	-
20	-	-	-	-	-	-
21	2	1	-	1	-	-
22	-	-	-	2	1	-
23	-	-	1	1	1	-
24	2	-	1	2	-	1
25	-	-	-	-	-	2
26	2	-	-	-	1	-

Table 21.--Numbers of fish caught on *Charles H. Gilbert* Cruise 1 (40 baskets with 10-fathom float lines).

Station	Yellowfin	Bigeye	Marlin	Sharks			Others
				White-tipped	Silky	Great blue	
1	-	3	4	2	-	-	2[1]
2	1	8	-	-	3	4	3[2]
3	2	10	1	-	1	1	2[3]
4	8	5	-	3	5	1	-
5	3	1	-	2	-	1	4[4]
6	5	-	-	1	-	-	1[5]
7	4	2	1	8	-	-	1[6]
8	-	2	-	-	-	1	-
9	3	-	-	2	1	-	-
10	13	-	-	3	-	-	-
11	13	1	-	9	1	1	-
12	9	4	-	2	2	2	-
13	7	-	1	-	2	2	3[7]
14	4	7	1	-	1	3	4[8]

[1] 1 unidentified shark, 1 skipjack.

[2] 2 unidentified sharks, 1 wahoo.

[3] 2 unidentified sharks.

[4] 4 lancet fish.

[5] 1 wahoo.

[6] 1 unidentified shark.

[7] 2 dolphins, 1 wahoo.

[8] 3 lancet fish, 1 unidentified shark.

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