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COMPARATIVE STUDY OF FOOD OF BIGEYE AND YELLOWFIN TUNA IN THE CENTRAL PACIFIC

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COMPARATIVE STUDY OF FOOD OF BIGEYE AND YELLOWFIN TUNA IN THE CENTRAL PACIFIC

By JOSEPH E. KING and ISAAC I. IKEHARA, *Fishery Research Biologists*

The predominant species of tuna captured on longline-fishing surveys of the Fish and Wildlife Service's Pacific Oceanic Fishery Investigations (POFI) are the yellowfin, *Neothunnus macropterus* (Temminck and Schlegel), and the bigeye, *Parathunnus sibi* (Temminck and Schlegel), with a catch ratio of about 5 to 1 in favor of the yellowfin. These are large tunas, the yellowfin occasionally reaching a weight of 200 pounds and the bigeye a weight of 300 pounds in the tropical Pacific. The two species have a marked superficial resemblance in general body shape and coloration and are not always differentiated in the commercial catch.

Murphy and Shomura (1953a, 1953b), in discussing results of experimental longline fishing conducted by POFI, point out interesting differences in the distribution of these two species. In the tropical Pacific, the bigeye have been taken in greatest numbers north of latitude 5° N. The best catches of yellowfin, on the other hand, have been made in the general region of the Equator, sometimes to the north when the area is under the influence of southeast tradewinds, and sometimes to the south when the northeast trades are dominant. This shift in abundance that appears to be related to changes in the prevailing winds can now be explained, at least partially, from our knowledge of the ocean currents and their effect on the basic food supply (Cromwell 1953).[1] Although the peaks in abundance do not correspond exactly, the general area of high yellowfin catch is also the area of greatest zooplankton abundance (King 1954). The horizontal distribution of the bigeye, however, does not seem to conform to the general pattern that the most fish are found where food is most abundant.

There is also some evidence of difference in the vertical distribution of yellowfin and bigeye. While the results are rather variable, there have been indications on certain POFI cruises to the equatorial area that the best catches of bigeye came from greater depths than those of the yellowfin (Murphy and Shomura 1953b). In Hawaiian waters the bigeye occurs in greatest numbers during the winter months from October to May, whereas the yellowfin is most abundant from May to September (Otsu 1954). Brock (1949) points out that the Hawaiian longline fishermen try to increase the catch of bigeye after the yellowfin season by lengthening the hook lines in order to fish deeper. Also, unlike the yellowfin, the bigeye—at least the adults—are rarely taken by surface-fishing methods. Nakamura (1949) states that the bigeye is thought to occur at the deepest levels of any of the tunas. It appears that the bigeye prefers somewhat colder water than does the yellowfin, or perhaps the two species have different feeding habits or food preferences which influence their distribution.

The purposes of this study are to describe the food of bigeye tuna in the central Pacific, to compare the foods of bigeye and yellowfin tuna[2] captured at about the same time and place, to determine whether differences occur which are associated with the horizontal and vertical distribution of these fish, and to obtain information on food preferences of each fish which may be useful to the commercial fishery. The experimental fishing carried out by POFI has provided collections of bigeye and yellowfin stomachs which are essentially alike in respect of time and area and which were obtained with standardized fishing methods. Therefore, we believe the resulting data should provide reliable comparisons of the food of these fish because these several variables have been controlled.

There is an extensive literature, reviewed previously by Reintjes and King (1953), dealing with the food of yellowfin, whereas there are only a very

[1] Also a manuscript by O. E. Sette: Nourishment of central Pacific stocks of tuna by the equatorial current system (Proceedings of the 8th Pacific Science Congress).

[2] The food of yellowfin was previously described by Reintjes and King (1953).

few references pertaining specifically to the food of bigeye. Suyehiro (1942) describes this species as a very voracious fish and lists the following items as appearing in its food: amphipods, shrimp, cuttlefish, squid, sardines, sauries, bonitos, needle fish, and a viper fish. In the report of the South Seas Tuna Fishery Investigations for 1950 (Kanagawa et al. 1951), the food of 27 bigeye is shown to include the following: 7 squid, 1 octopod, 3 decapod Crustacea, 1 fan fish, 15 needle fish, 1 file fish, 6 pomfret, and 4 lantern fish. This suggests that the bigeye, like many other tunas, has a varied diet.

A large number of the tuna stomachs reported on here were examined by John W. Reintjes, Sueto Murai, and T. J. Roseberry, former employees of POFI. We appreciate their services in a difficult and generally disagreeable task. We are grateful to other staff members of POFI for assistance in handling these large fish aboard the vessels and in removing and preserving the stomachs.

SOURCE OF MATERIALS

This report is based on examination of 439 yellowfin and 166 bigeye stomachs collected on 11 cruises of Fish and Wildlife Service vessels during the years 1950 to 1953 (table 1). The yellowfin data include 125 stomachs collected in 1950 and 1951 and previously reported on by Reintjes and King (1953). These collections and the additional 314 yellowfin stomachs obtained in 1952 and 1953 were obtained at the same stations, or near the same stations, as furnished the bigeye stomachs included in this report. The sampling area (fig. 1) extended along the Equator between latitudes 119° W. and 180° and approximately from latitude 17° N. to latitude 14° S. at its greatest width.

The tuna were captured by longline at depths of about 150 to 500 feet. This method of fishing, as practiced by POFI, has been reviewed by Murphy and Shomura (1953a); the design and construction of the gear was described by Niska (1953).

Only fish caught 25 miles or more from land are considered in this study; therefore local differences due to reef faunas should be reduced to a minimum. The sampled fish varied widely in size, from 87 to 172 cm. fork length for the yellowfin, and from 77 to 196 cm. fork length for the bigeye (fig. 2). Weights of fish given in this paper were

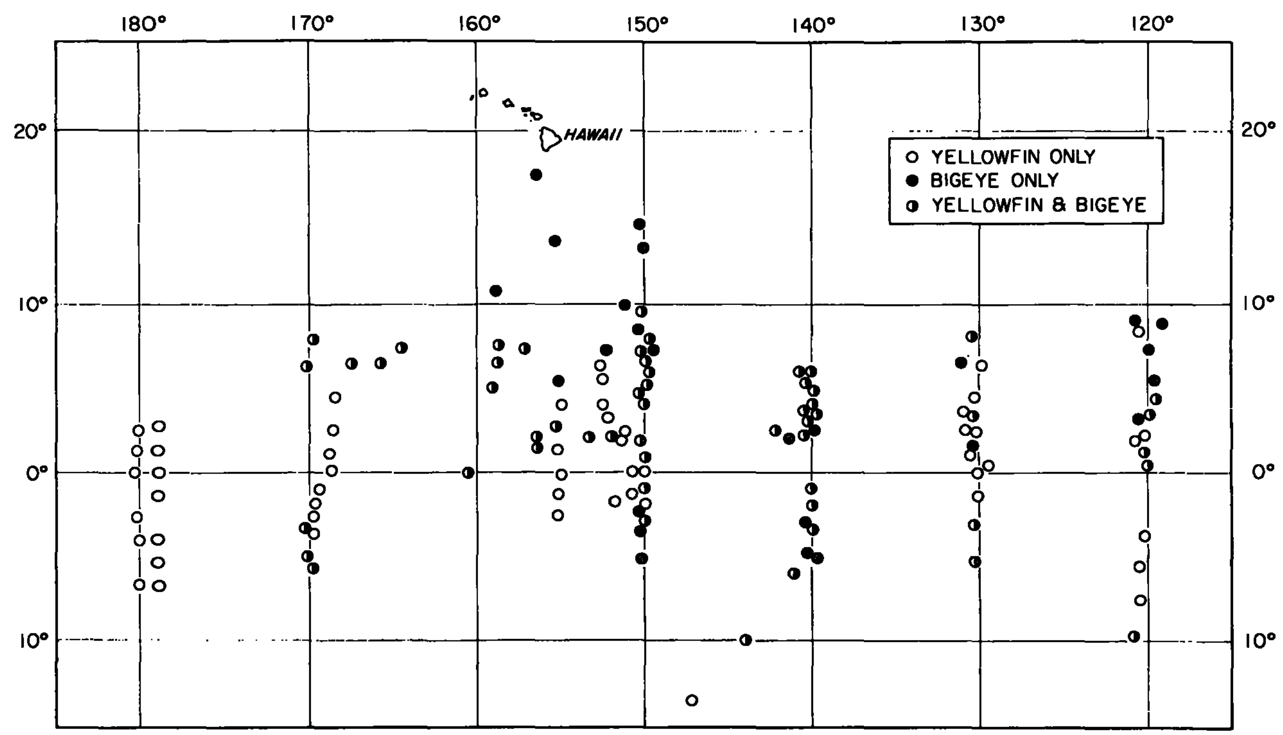

FIGURE 1.—Locations of the stomach collections of yellowfin and bigeye tuna captured by experimental longline fishing in the central Pacific, 1950–53.

TABLE 1.—*Distribution of yellowfin and bigeye stomachs collected from the central Pacific, identified by vessel, cruise, time of year, and locality*

Vessel	Cruise No.—	Period	Sampling area		Yellowfin			Bigeye		
			Range of longitude (W.)	Range of latitude	Number captured	Number of stomachs examined	Percent of catch sampled	Number captured	Number of stomachs examined	Percent of catch sampled
Hugh M. Smith	7	Oct.–Nov. 1950	157°–167°	11° N–0°	132	106 [1]	80	22	14	64
Hugh M. Smith	11	Aug.–Sept. 1951	150°–156°	15° N–4° S	457	153 [2]	34	93	36	39
John R. Manning	11	Jan.–Mar. 1952	155°–180°	5° N–7° S	210	59	28	30	6	20
Charles H. Gilbert	1	May–June 1952	119°–130°	9° N–1° S	72	44	61	43	17	40
Cavalieri	1	June–July 1952	140°	6° N–5° N	42	7	17	11	2	18
Cavalieri	2	Aug.–Sept. 1952	140°–142°	6° N.–2° N	720	19	3	60	13	22
John R. Manning	12	Aug.–Sept. 1952	140°–150°	7° N.–5° S	146	1	1	28	5	18
John R. Manning	13	Oct.–Nov. 1952	151°–170°	17° N.–5° S	135	55	41	29	10	34
Hugh M. Smith	18	Oct.–Nov. 1952	120°–131°	9° N.–10° S	60	40	67	50	17	34
John R. Manning	14	Jan.–Mar. 1953	140°–150°	4° N.–14° S	106	69	65	19	19	100
John R. Manning	15	Apr.–June 1953	150°–170°	10° N.–6° S	197	20	10	46	27	59

[1] Of this number, only 38 (29 percent of the catch) were considered comparable in respect to time and place to the bigeye collections and were included in this report.
[2] Of this number, only 87 (19 percent of the catch) were included in this report for the same reason as above.

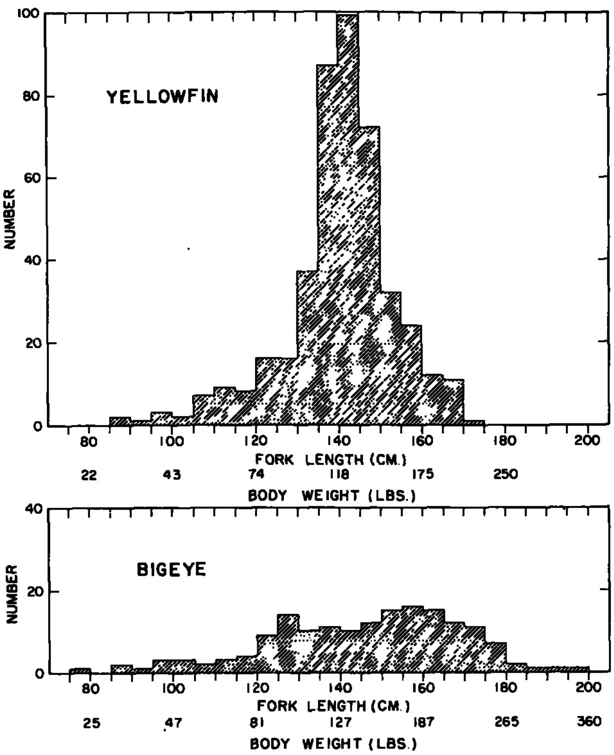

FIGURE 2.—Length-frequency distribution of yellowfin and bigeye tuna from which stomachs were collected.

derived from length measurements converted by means of length-weight tables provided in the POFI Scientific Field Manual (unpublished).

METHODS

At sea, the stomach was removed as soon as possible after the fish was captured, placed with any regurgitated material in an unbleached-muslin bag, and preserved in 10-percent formalin. A label bearing date, species name, fork length, fishing method, hook number, bait used, name of observer, vessel, and cruise number was placed with each stomach. Tuna landed with their stomachs everted were not sampled.

The stomach was removed by one of the following methods: (1) The abdominal cavity was opened by a longitudinal midventral incision, the small intestine was severed posterior to the pyloric valve, and the stomach was freed by cutting through the esophagus; or (2) the gill membrane was slit along the line of attachment with the cleithrum posterior to the fourth gill arch, the viscera was pulled out, and the stomach was removed by cutting through the small intestine and esophagus.

In the laboratory, the stomachs were soaked in fresh water for a period of 16 to 24 hours to remove excess formalin. Each stomach was then slit open, and the contents were carefully removed and separated into groups according to kind of organism. Identifications were made as completely as was practicable, and the number of each species or group of organisms present was recorded. Each species or group was measured volumetrically by the displacement of water in a graduated cylinder of appropriate size. Bait used to capture the tuna was omitted from this analysis. The methods and literature used in the identification of the food organisms were essentially the same as that employed by Reintjes and King (1953) and will not be reviewed here. Berg's (1947) system of classification and nomenclature was primarily used for the family names of the forage fishes.

A detailed list of the food organisms found in the tuna stomachs is presented in the appendix (table 11). For each kind or group of organisms there are shown (1) the total number of such organisms, (2) the number of stomachs in which they occurred, (3) the percentage of occurrence, (4) the total aggregate volume of each food element, and (5) the percentage of total volume.

Regardless of the method or methods of analysis used, there are many uncontrollable variables inherent in food studies which detract from the precision of the results. It is our belief, however, that for a fish with a generalized diet, such as that of the tuna, any of the commonly used methods of evaluation will give substantially the same results if a sufficiently large number of specimens are examined. In reporting the results of our studies on tuna food we use both the percentage-of-occurrence and the percentage-of-volume measurements (as described by Reintjes and King 1953) and the average volume of food per stomach. The food items that rank high in number, volume, and frequency of occurrence are most likely to be important foods.

No attempt has been made to apply statistical tests of significance to the data. It is likely that the variates used—volume of food per stomach, percentage of occurrence, and percentage of total volume of the organism—are not distributed normally and that the means are correlated with the variances or standard deviations. To apply meaningful tests of significance, transformation of the data would be necessary. Moreover, several of the comparisons that will be made involve two-way or three-way classification of the data. Even if suitable transformations were derived, the application of advanced analysis of variance techniques would be hampered by unequal subclass numbers.

Furthermore, it appears that in both yellowfin and bigeye there is an increase in mean volume of food per stomach with increase in size of fish,

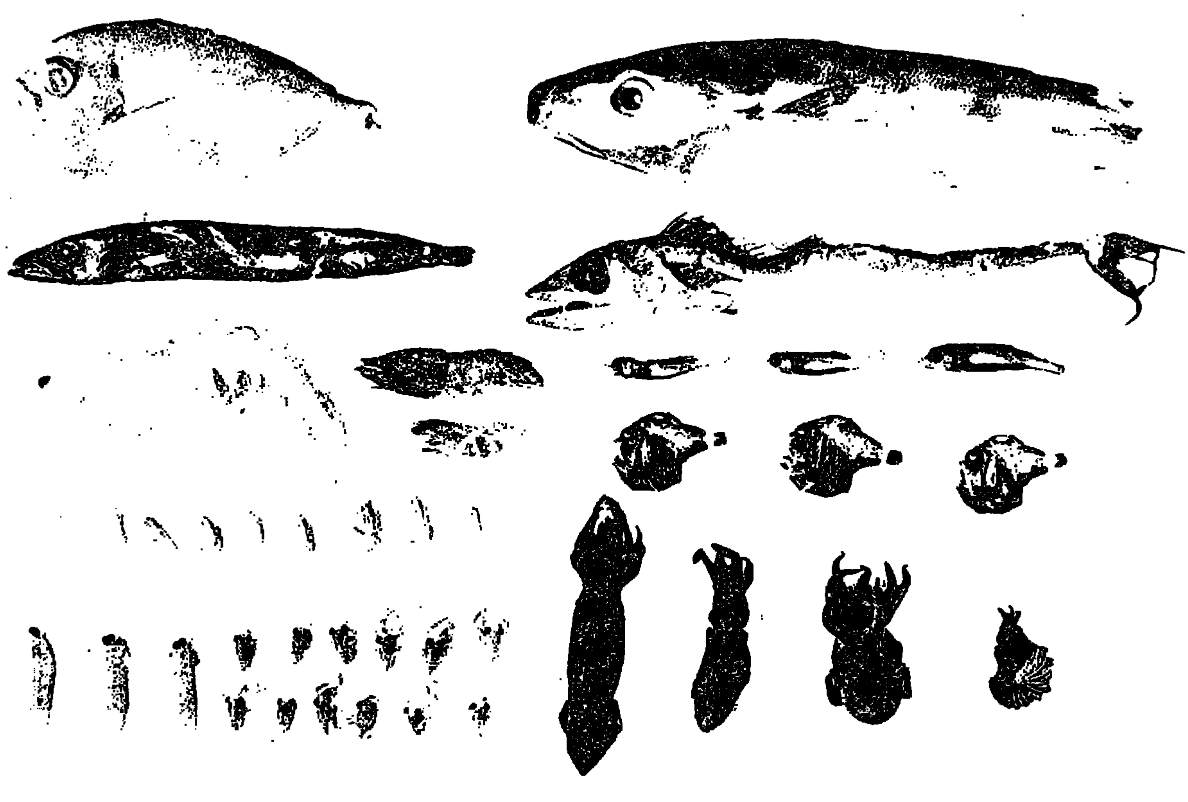

FIGURE 3.—Examples of types of food commonly found in stomachs of yellowfin and bigeye tunas: Left to right: pomfret (1), truncated sunfish (1), snake mackerel (1), lancet fish (1), shrimps (3), viper fish (3), hatchet fish (3), euphausids (8), juvenile stomatopods (3), crab megalopa (12), squid (3), and paper nautilus (1).

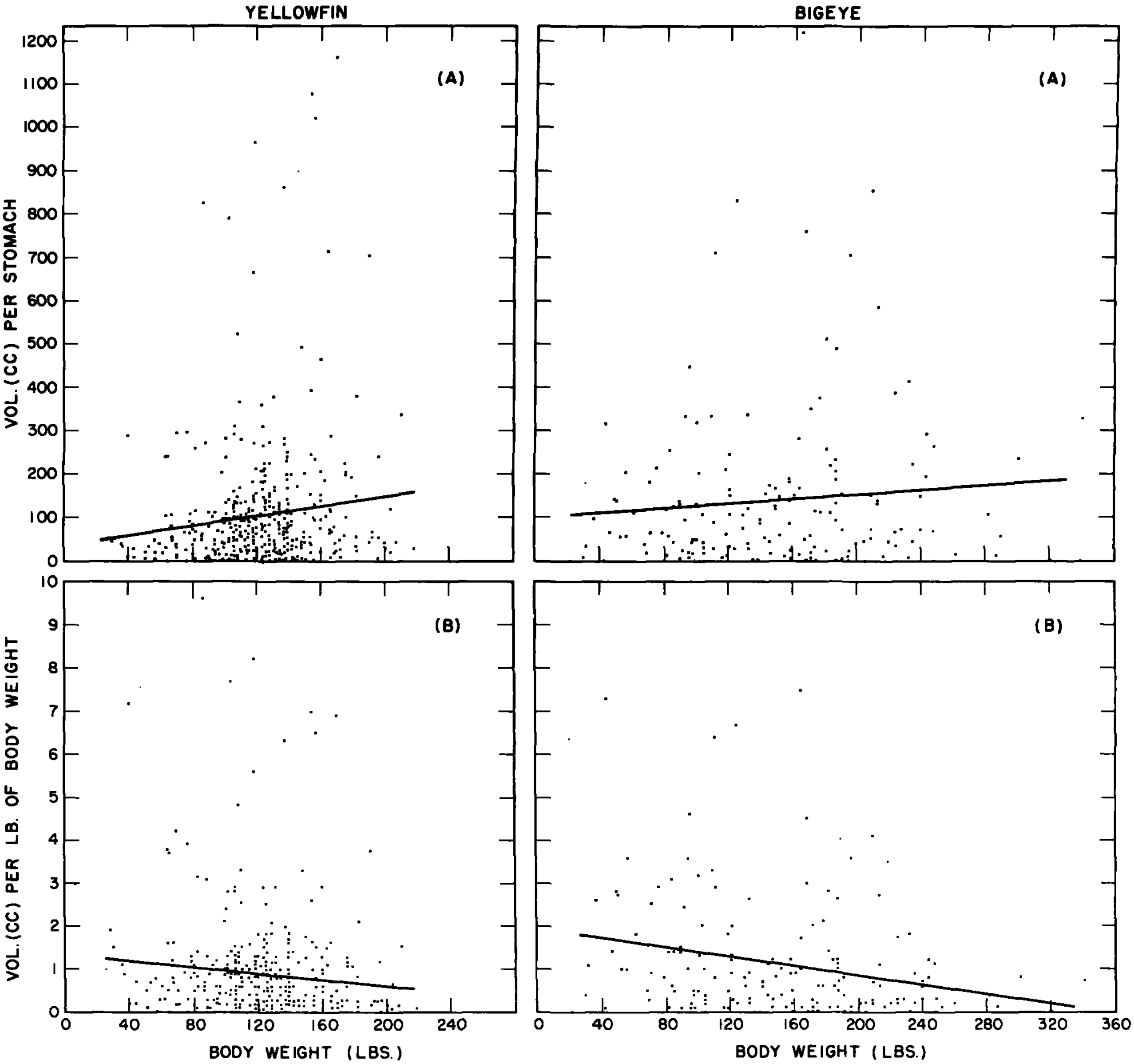

FIGURE 4.—Regressions of (A) food volume per stomach and (B) food volume per unit body weight on total body weight for 439 yellowfin and 166 bigeye captured on longlines.

and there is also a decrease in average stomach content per unit of body weight (cc./lb.) with increase in size of fish. The least-squares trend lines shown in figure 4 (there is no *a priori* reason for assuming rectilinearity) indicate the need for covariance methods of statistical analysis, again after suitable transformations. Finally we must point out the great variability of the data as illustrated by the wide scatter of points about the trend lines. This great variability reduces the opportunity of demonstrating statistically significant differences, particularly when the data are analyzed in subgroups which contain few specimens in each.

Because of the difficulties outlined above, in the following sections we have tabulated average values and have discussed differences and trends without attempting to appraise their statistical significance. Consequently, the inferences that we make must be regarded as suggestions only. They may form the bases for hypotheses which can be tested more stringently in the future.

RESULTS

The food of both the yellowfin and the bigeye was primarily fish, of great variety, and squid (table 11, Appendix). Other mollusks, such as the argonauts and octopods, and crustaceans were of minor importance.[3] Figure 5 illustrates the percentage of occurrence of the major food items. Figure 6 shows the percentage of aggregate total volume of each major food element, which indicates its relative importance by bulk.

Representatives of 48 fish families and 11 invertebrate orders were found among the stomach contents of the yellowfin, as compared with 36 fish families and 9 invertebrate orders for the bigeye.[4] Despite this great variety in the food, only a few items were of primary importance to either species. For both the yellowfin and the bigeye, those food elements ranking high in number, volume, and frequency of occurrence were squid, of the families Ommastrephidae and Loliginidae, and among the fish the pomfret (*Collybus drachme*) and snake mackerel (*Gempylus serpens*) were important. Certain fishes, such as the tunas (Thunnidae) and the sun fishes (Molidae), were relatively important in volume but ranked low in number and frequency of occurrence, indicating that they are only occasionally utilized. Crustacea of the order Stomatopoda, prominant in number in the food of yellowfin, were completely lacking from the bigeye stomachs. The young of other tunas, especially skipjack, formed a much more important part of the yellowfin diet than that of the bigeye. In the following sections of this report we shall try to describe the major differences and similarities in the foods of these two species of tuna as related to such factors as size of the tuna, area and depth of capture, season, and features of the equatorial-current system.

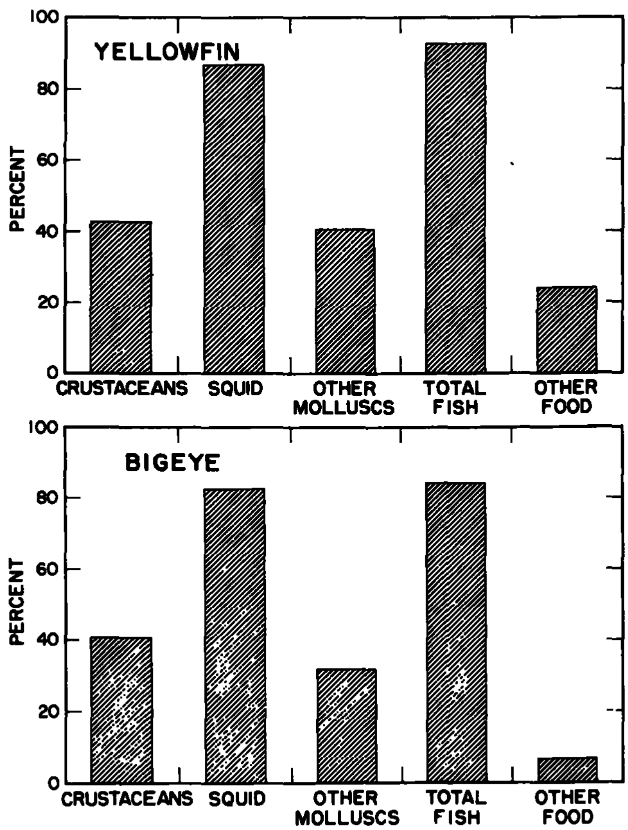

FIGURE 5.—Percentage of occurrence of the major food elements.

[3] Among the results of this study, not referred to elsewhere in the report but perhaps worthy of mention, were observations on the number of stomach parasites. Among the bigeye, 26 percent of the stomachs examined were infested with nematodes and 32 percent with trematodes. The infestation was somewhat less among the yellowfin, being 16 percent for nematodes and 26 percent for trematodes.

[4] The greater variety in the food of the yellowfin as compared with the bigeye is due, we believe, simply to the fact that more than twice as many yellowfin stomachs were examined.

Variation in Food with Size of Tuna

In general, for both yellowfin and bigeye, there was an increase in food volume per stomach with an increase in size of the tuna (fig. 4). With the hope of minimizing the effects of this factor, in our examination of differences in the food specifically related to size of tuna we have split the data for both species into two size groups, (1) those less than 140 cm.[5] and (2) those 140 cm. and over, in fork length (table 2). This provided for each species two groups of fish roughly equal in number. In the yellowfin the larger size group contained 29 percent more food per stomach, and in the bigeye it contained 16 percent more. The ratios of stomach content to body weight are almost identical for the two species (table 2). Although Crustacea make up a very small percentage of the food of these large, deep-swimming fish, in both species the smaller specimens consumed greater amounts of such organisms as crab larvae, shrimp, and amphipods. In both species, the larger specimens consumed less fish and more mollusks—as percentage of total volume—than did the smaller size group; this was particularly true for the bigeye. The per-

[5] A 140-cm. yellowfin from the equatorial Pacific weighs approximately 118 pounds, while a 140-cm. bigeye weighs approximately 127 pounds.

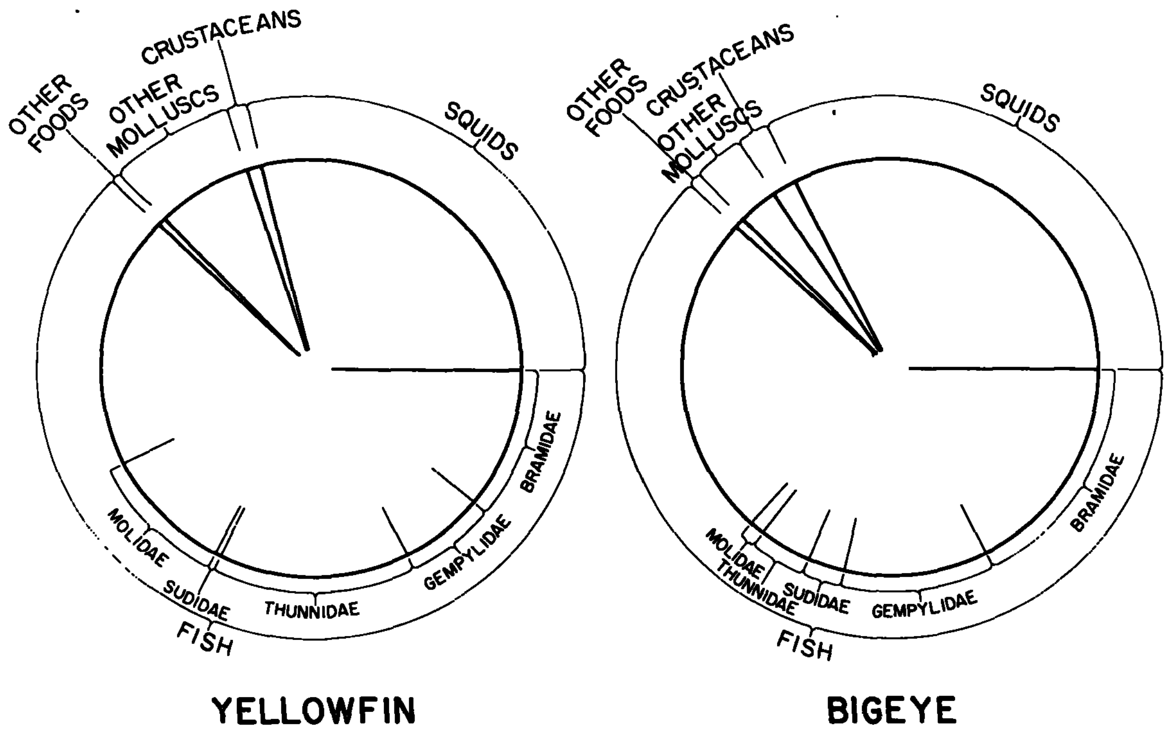

FIGURE 6.—Comparative importance, in volume, of the major food elements.

centage by occurrence and percentage by volume for the fish families prominent in the diet exhibited little variation with the size of the tuna.

Variation in Food with Depth of Capture

Figure 7 is a diagram of one unit (a basket) of POFI longline gear, showing the arrangement of hook-bearing dropper lines and the general lay of the line with respect to the surface. Although an attempt is made to set the line at each station in a standard fashion, with an average distance between buoys of about 900 feet, the actual depth of fishing is quite variable depending upon the amount of sag in the main line, which is greatly influenced by wind and current conditions.

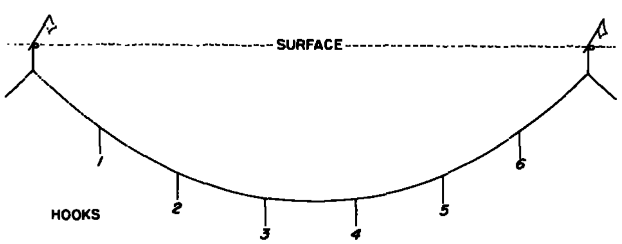

FIGURE 7.—Arrangement of a unit (basket) of POFI standard longline gear showing the float lines, main line, hook-bearing dropper lines, and the general lay of the line with respect to the surface.

Murphy and Shomura (1953a) have calculated that the maximum possible depth for hooks 1 and 6, with a 900-foot buoy interval, is 310 feet; for hooks 2 and 5, it is 450 feet; and for hooks 3 and 4, it is 530 feet. These maximum depths are seldom achieved, however, because of the relatively strong surface currents generally prevailing in this region. The minimum depths are even more uncertain; therefore it is difficult to define a depth range for each of the hooks. We postulate that hooks 1 and 6 may fish at depths of 150 to 300 feet, hooks 2 and 5 at depths of 250 to 400 feet, and hooks 3 and 4 at depths of 300 to 500 feet. Despite this variation and the uncertainties involved, it is worthwhile, without attempting to designate actual fishing depths, to make comparisons between the shallow (hooks 1 and 6), intermediate (hooks 2 and 5), and deep (hooks 3 and 4) levels of capture with respect to differences in stomach contents. Because of the rather slight differences in composition of the food associated with the size of the tuna, the two size groups ($<$140 cm. and $>$140 cm.) were combined for this study.

Table 3 shows the variation in composition of stomach contents with depth of capture; the variation in the two general categories, squid and fish,

TABLE 2.—*Variation in volume and composition of stomach contents of yellowfin and bigeye tuna, by size groups*

Food organisms	Average volume (cc.) per stomach in fish—		Percentage of occurrence in fish—		Percentage of total volume in fish—	
	Less than 140 cm., fork length	140 cm., and larger, fork length	Less than 140 cm., fork length	140 cm., and larger, fork length	Less than 140 cm., fork length	140 cm., and larger, fork length
Crustaceans:						
Yellowfin	1.5	0.9	45.2	41.0	1.7	0.8
Bigeye	2.8	2.0	38.1	41.7	2.3	1.4
Squids:						
Yellowfin	24.8	33.3	89.4	85.3	28.6	29.5
Bigeye	32.1	51.4	81.0	83.5	26.2	36.3
Other mollusks:						
Yellowfin	3.3	10.4	29.8	48.6	3.8	9.2
Bigeye	1.6	5.7	28.6	34.0	1.3	4.0
Fish (total):						
Yellowfin	56.6	67.7	90.4	94.8	65.2	60.0
Bigeye	85.8	82.4	84.1	84.5	70.1	58.2
Bramidae:						
Yellowfin	9.1	12.9	53.7	65.7	10.4	11.4
Bigeye	33.3	17.3	36.5	31.1	27.2	12.2
Gempylidae:						
Yellowfin	6.0	7.3	24.5	37.4	6.9	6.5
Bigeye	19.2	12.5	42.9	34.0	15.7	8.8
Thunnidae:						
Yellowfin	10.0	18.6	6.9	9.2	11.5	16.5
Bigeye	0.3	8.6	1.6	3.9	0.3	6.0
Sudidae:						
Yellowfin	0.4	0.5	9.0	5.2	0.5	0.4
Bigeye	1.7	5.2	15.9	17.5	1.4	3.7
Molidae:						
Yellowfin	13.4	7.2	3.7	2.0	15.4	6.4
Bigeye	2.0	1.4	3.2	1.0	1.6	1.0
Other foods:						
Yellowfin	0.6	0.6	23.9	24.3	0.7	0.5
Bigeye	0.1	0.2	1.6	9.7	0.0	0.1
All foods:						
Yellowfin	86.9	112.9				
Bigeye	122.4	141.6				
Number of stomachs examined:						
Yellowfin	188	251				
Bigeye	63	103				
Average fork length (cm.):						
Yellowfin	117	149				
Bigeye	122	160				
Average weight, lbs.:						
Yellowfin	69	142				
Bigeye	85	187				
Average volume (cc.) of food per lb. of body weight:						
Yellowfin	1.3	0.8				
Bigeye	1.4	0.8				

is illustrated in figure 8. For the yellowfin, there is an increase in average volume of stomach contents with increasing depth of capture; for the bigeye, the largest average volume was found at the intermediate depth, with the deep-caught fish ranking second. For both species, the most consistent feature was the low average food volume for the shallow-caught fish.

In the yellowfin, the increase with depth is largely due to a higher consumption of fish, particularly juvenile tunas (Thunnidae) and sunfishes (Molidae), at the intermediate and deep levels; the squid are utilized about equally at all three depths. In the bigeye taken on the deeper hooks, there is also greater utilization of fish, particularly pomfrets (Bramidae) and snake mackerels (Gempylidae), with squid decreasing in relative importance with depth but varying irregularly in absolute volume. Despite these rather minor differences, there is no marked variation in composition of stomach contents over this range of depth (estimated at 150 to 500 feet), which may be evidence that both the forage organisms and the tuna range throughout this water layer.

Variation in Food with Distance from Land

In the routine processing of the stomach data, the records were classified according to the distance of the place of capture from the nearest emergent land. An arbitrary scale (0–24 miles, 25–99 miles, 100–399 miles, and 400 miles and more) was used as in the previous study (Reintjes and King 1953). No bigeye stomachs were collected at 0–24 miles, and few (eight) were collected in the 25–99 mile interval; therefore, the data do not provide the desired information on differences in the food related to this feature. There was some indication that the consumption of squid and pomferts by the bigeye increased in an offshore direction, as compared with their uniform utilization by the

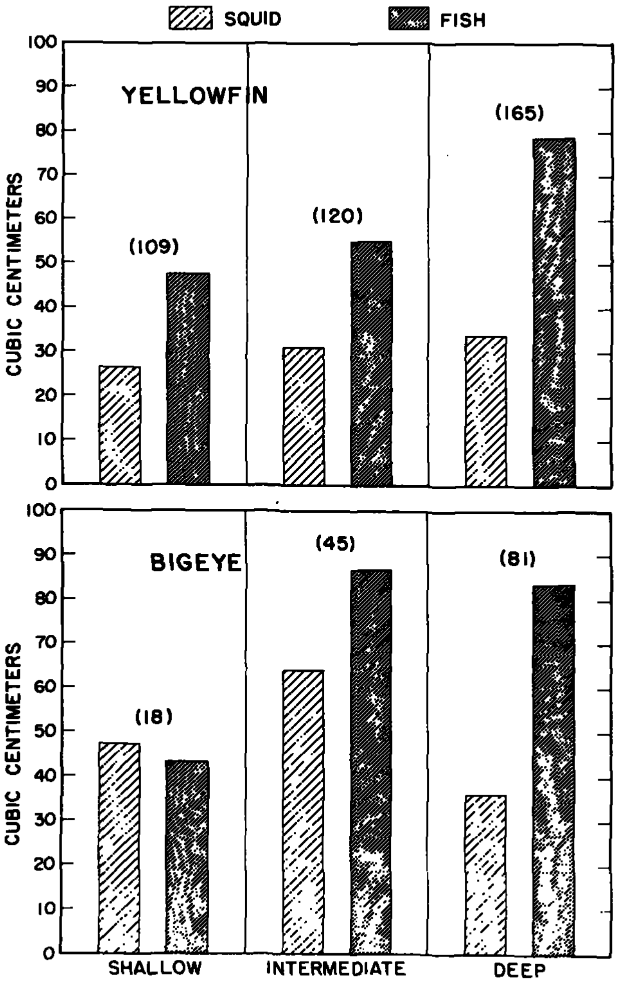

FIGURE 8.—Variation in the major food categories (total fish and squid) as related to the depth at which the tuna were captured. Number of stomachs is shown in parentheses.

yellowfin (table 4), and in the bigeye the average food volume increased with greater distance from land while in the yellowfin the volume varied irregularly.

Variation with Season and Longitude

To examine differences related to time of sampling, the various cruises were grouped into four seasonal periods, as indicated in table 5. For both species the largest average volume of food occurred in the April–July period, with October-November averaging the lowest in the yellowfin and August-September the lowest in the bigeye. If we consider the average volume per stomach of the major food elements, we find that, in our samples of both tunas, fish were consumed in greatest amount during April-July and in least amount during August-September (fig. 9 and table 5). The average volumes of squid and the major fish families represented in the food did not vary in parallel fashion for the bigeye and yellowfin.

When the data from the various cruises are combined with regard to longitude but without regard to time of year, we obtain the results presented in table 6, with the variation in availability

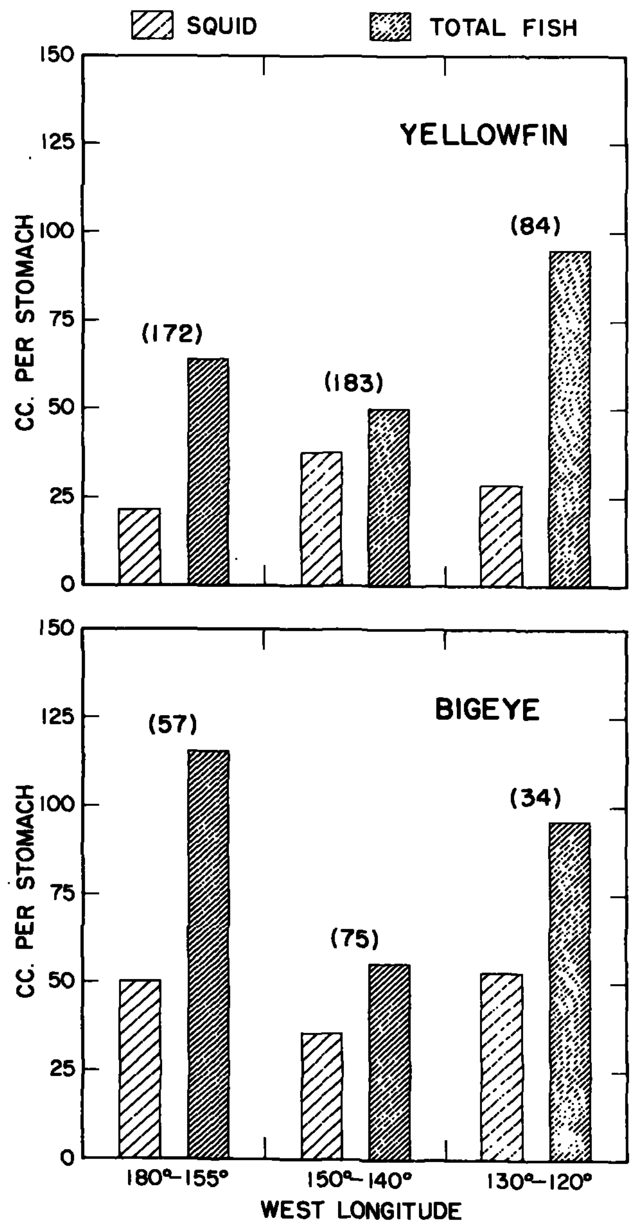

FIGURE 9.—Variation in the major foods as related to time of year that the tuna were captured. Number of stomachs is shown in parentheses.

TABLE 3.—*Variation in volume and composition of stomach contents with depth of capture of yellowfin and bigeye tuna*

Food organisms	Average volume (cc.) per stomach			Percentage of occurrence			Percentage of total volume		
	Shallow	Intermediate	Deep	Shallow	Intermediate	Deep	Shallow	Intermediate	Deep
Crustaceans:									
Yellowfin	1.8	0.7	1.1	39.4	44.2	46.7	2.0	0.8	0.9
Bigeye	0.7	1.4	3.2	33.3	35.6	46.9	0.7	0.9	2.5
Squids:									
Yellowfin	26.6	30.7	33.7	84.4	90.0	90.3	30.2	33.3	27.7
Bigeye	47.2	63.9	36.0	72.2	84.4	83.9	51.4	41.7	27.7
Other mollusks:									
Yellowfin	11.8	5.4	7.4	47.7	49.2	37.0	13.5	5.8	6.1
Bigeye	0.8	0.9	6.9	33.3	17.8	40.7	0.8	0.6	5.3
Fish (total):									
Yellowfin	47.4	54.9	78.6	91.7	91.7	93.9	53.8	59.5	64.6
Bigeye	43.2	86.7	83.7	72.2	86.7	85.2	47.0	56.5	64.5
Bramidae:									
Yellowfin	9.0	10.8	13.4	53.2	64.2	66.7	10.2	11.7	11.0
Bigeye	5.3	22.5	21.1	27.8	26.7	35.8	5.8	14.7	16.3
Gempylidae:									
Yellowfin	5.3	6.7	9.0	33.9	35.0	33.9	6.0	7.3	7.4
Bigeye	4.4	22.7	14.5	33.3	42.2	39.5	4.8	14.8	11.2
Thunnidae:									
Yellowfin	10.6	14.4	22.2	9.2	9.2	9.1	12.0	15.6	18.2
Bigeye	0.0	0.5	2.5	0.0	2.2	2.5	0.0	0.3	1.9
Sudidae:									
Yellowfin	1.0	0.4	0.3	11.9	4.2	7.3	1.2	0.4	0.2
Bigeye	5.0	6.0	3.5	11.1	17.8	22.2	5.5	3.9	2.7
Molidae:									
Yellowfin	1.8	4.4	12.8	1.8	1.7	2.4	2.0	4.8	10.5
Bigeye	0.0	3.4	1.4	0.0	4.4	1.2	0.0	2.2	1.1
Other foods:									
Yellowfin	0.5	0.4	0.9	27.5	23.3	27.3	0.5	0.5	0.8
Bigeye	0.0	0.3	0.1	5.5	8.8	7.4	0.0	0.2	0.0
All foods:									
Yellowfin	88.1	92.2	121.7						
Bigeye	91.9	153.3	129.9						
Number of stomachs examined:									
Yellowfin	109	120	165						
Bigeye	18	45	81						
Average fork length (cm.):									
Yellowfin	141	140	142						
Bigeye	152	148	142						
Average weight (lbs.):									
Yellowfin	120	118	122						
Bigeye	162	148	133						
Average volume (cc.) food per pound of body weight:									
Yellowfin	0.7	0.8	1.0						
Bigeye	0.6	1.0	1.0						

TABLE 4.—*Variation in volume and composition of stomach contents with distance of place of capture from nearest emergent land*

Food organisms	Average volume (cc.) per stomach			Percentage by occurrence			Percentage of total volume		
	25–99 miles	100–399 miles	400 mi. and over	25–99 miles	100–399 miles	400 mi. and over	25–99 miles	100–399 miles	400 mi. and over
Crustaceans:									
Yellowfin	1.2	1.8	0.4	53.3	52.7	7.7	1.1	2.2	0.4
Bigeye	3.7	1.9	2.5	75.0	42.8	35.8	8.2	1.7	1.6
Squids:									
Yellowfin	30.7	24.2	34.8	90.0	89.6	84.1	27.1	29.0	29.6
Bigeye	9.8	17.9	64.2	75.0	76.2	87.4	21.7	15.4	41.8
Other mollusks:									
Yellowfin	1.2	4.4	11.1	13.3	36.8	48.1	1.1	5.3	9.5
Bigeye	3.0	2.2	5.5	25.0	34.9	30.5	6.6	1.9	3.6
Fish (total):									
Yellowfin	79.2	52.1	71.1	96.7	94.5	90.9	69.8	62.5	60.3
Bigeye	28.0	94.0	81.5	62.5	85.7	85.3	62.0	80.9	53.0
Bramidae:									
Yellowfin	14.7	9.5	12.4	43.3	61.7	62.0	13.0	11.4	10.5
Bigeye	1.5	15.0	30.7	25.0	25.4	38.9	3.4	12.9	20.0
Gempylidae:									
Yellowfin	4.8	5.8	8.0	36.7	31.8	31.2	4.2	6.9	6.8
Bigeye	21.9	18.5	12.2	12.5	38.1	38.9	48.5	15.9	7.9
Thunnidae:									
Yellowfin	1.6	5.9	25.5	10.0	5.0	11.1	1.4	7.0	21.7
Bigeye	0.0	10.8	2.4	0.0	3.2	3.2	0.0	9.3	1.5
Sudidae:									
Yellowfin	0.7	0.6	0.3	10.0	10.4	2.9	0.6	0.7	0.3
Bigeye	3.7	5.1	3.1	12.5	17.5	16.8	8.2	4.4	2.0
Molidae:									
Yellowfin	38.2	9.6	6.0	6.7	3.0	1.9	33.7	11.5	5.1
Bigeye	0.0	4.2	0.0	0.0	4.8	0.0	0.0	3.6	0.0
Other foods:									
Yellowfin	1.1	0.8	0.3	26.7	32.8	15.4	1.0	1.0	0.3
Bigeye	0.7	0.2	0.1	12.5	6.3	6.3	1.5	0.1	0.0
All foods									
Yellowfin	113.4	83.9	117.9						
Bigeye	45.1	116.2	153.8						
Number of stomachs:									
Yellowfin	30	201	208						
Bigeye	8	63	95						
Average fork length (cm.):									
Yellowfin	138	140	142						
Bigeye	153	139	148						
Average weight (lbs.):									
Yellowfin	112	118	123						
Bigeye	166	125	149						
Average volume (cc.) food per pound of body weight:									
Yellowfin	1.0	0.7	1.0						
Bigeye	0.3	0.9	1.0						

TABLE 5.—*Variation in volume and composition of stomach contents with time of year at which the tunas were captured*

Food organisms	Average volume (cc.) per stomach				Percentage by occurrence				Percentage of total volume			
	Jan.–March	April–July	Aug.–Sept.	Oct.–Nov.	Jan.–March	April–July	Aug.–Sept.	Oct.–Nov.	Jan.–March	April–July	Aug.–Sept.	Oct.–Nov.
Crustaceans:												
Yellowfin	1.1	0.2	0.6	2.1	60.1	26.8	29.9	43.6	1.2	0.1	0.7	2.4
Bigeye	1.9	1.4	1.1	5.3	48.0	37.0	25.9	48.8	1.4	0.7	1.1	4.6
Squids:												
Yellowfin	27.0	34.4	40.3	21.1	94.5	76.0	96.3	91.0	28.8	22.2	41.2	25.1
Bigeye	21.8	72.4	40.3	30.9	80.0	78.3	85.1	92.7	16.0	37.3	40.9	26.8
Other mollusks:												
Yellowfin	7.9	14.5	4.5	5.4	46.9	47.9	39.3	21.0	8.4	9.3	4.7	6.4
Bigeye	3.2	3.9	5.6	2.9	48.0	30.4	13.0	26.8	2.3	2.0	5.6	2.5
Fish (total):												
Yellowfin	56.9	105.7	52.0	54.8	96.1	91.5	90.7	97.0	60.6	68.1	53.2	65.1
Bigeye	109.5	116.4	51.4	76.2	92.0	89.1	70.3	95.2	80.2	60.0	52.1	66.0
Bramidae:												
Yellowfin	8.0	14.9	14.1	10.8	60.1	50.7	69.2	60.9	8.5	9.6	14.4	12.9
Bigeye	29.1	51.8	4.5	12.8	24.0	43.5	33.3	31.7	21.3	26.7	4.6	11.1
Gempylidae:												
Yellowfin	8.1	8.0	1.9	8.6	45.3	23.9	24.3	28.6	8.7	5.2	2.0	10.2
Bigeye	11.5	16.9	8.0	24.3	48.0	37.0	28.0	39.0	8.4	8.7	8.1	21.4
Thunnidae:												
Yellowfin	10.4	25.7	25.1	5.2	7.8	16.9	5.6	5.3	11.1	16.6	25.7	6.2
Bigeye	......	4.9	......	16.6	......	6.5	......	4.9	......	2.5	......	14.4
Subidae:												
Yellowfin	0.9	0.2	0.0	0.5	13.3	7.0	0.9	5.3	1.0	0.1	0.0	0.6
Bigeye	13.0	2.6	2.2	1.8	36.0	19.6	5.6	12.2	9.5	1.3	2.2	1.5
Molidae:												
Yellowfin	0.0	32.9	0.2	14.7	0.0	12.6	0.9	2.3	0.0	21.2	0.2	17.5
Bigeye	......	3.0	......	3.0	......	2.2	......	4.9	......	1.6	......	2.6
Other foods:												
Yellowfin	0.9	0.3	0.3	0.8	43.7	9.9	7.5	25.6	0.9	0.2	0.3	0.9
Bigeye	0.2	0.03	0.2	0.1	12.0	6.5	3.7	9.8	0.2	0.02	0.2	0.08
All foods:												
Yellowfin	93.8	155.2	97.7	84.1	......	......	......	......	......	......	......	......
Bigeye	136.6	194.1	98.7	115.3	......	......	......	......	......	......	......	......
Number of stomach examined:												
Yellowfin	128	71	107	123	......	......	......	......	......	......	......	......
Bigeye	25	46	54	41	......	......	......	......	......	......	......	......
Average fork length (cm.):												
Yellowfin	140	141	140	141	......	......	......	......	......	......	......	......
Bigeye	148	141	149	146	......	......	......	......	......	......	......	......
Average weight (lbs.):												
Yellowfin	119	121	116	120	......	......	......	......	......	......	......	......
Bigeye	148	129	151	142	......	......	......	......	......	......	......	......
Average volume (cc.) food per pound of body weight:												
Yellowfin	0.8	1.3	0.8	0.7	......	......	......	......	......	......	......	......
Bigeye	0.9	1.5	0.7	0.8	......	......	......	......	......	......	......	......

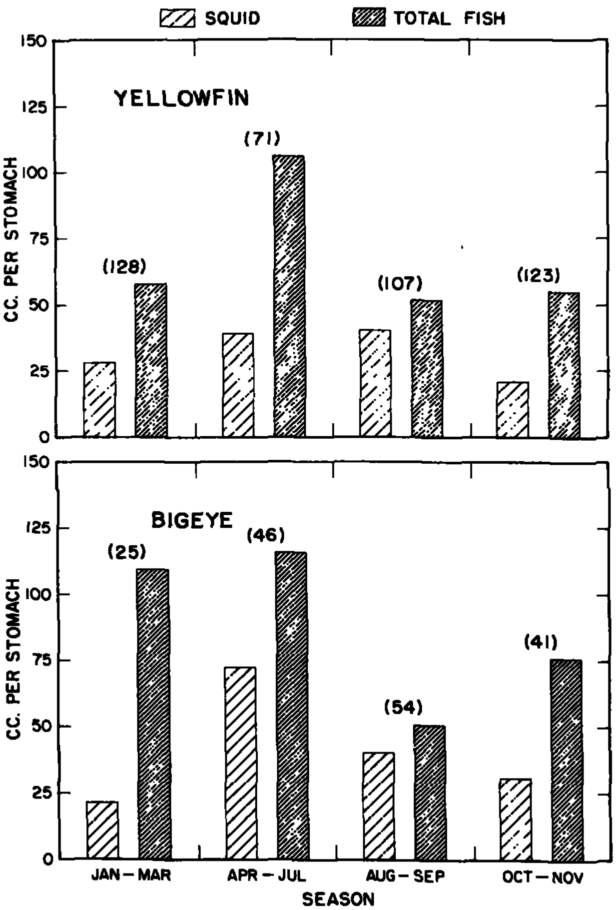

FIGURE 10.—Variation in the major foods as related to the general longitude of capture of the tunas. Number of stomachs is shown in parentheses.

of the major food items shown in figure 10. The chief similarity between the two species lies in the lower volume of total fish in the food of tunas captured in the region of 140°–150° W. longitude. The utilization of squid, Bramidae, Gempylidae, and Thunnidae does not vary in any regular pattern for the two species. A majority of the Thunnidae appearing in the food of yellowfin captured in the area of 120°–130° W. were *Auxis thazard*, which was not prominent in the food in the more western regions and which in the bigeye was represented by only one specimen, also from the 120°–130° W. region.

For both bigeye and yellowfin, the largest specimens were captured in the eastern region (120–130° W.) and the smallest in the western region (155° W–180°). When the variation in volume of stomach contents is considered in terms of unit volume per unit of body weight, we find only slight regional differences for the yellowfin but a rather large variation for the bigeye (table 6). In the bigeye, specimens from the western region contained 1.5 cc. of food per pound of body weight, as compared with 0.6 cc. for specimens from the central region and 1.0 cc. for specimens from the eastern region. These three values closely parallel the corresponding average volumes of total fish per stomach (115.3, 55.4, and 95.8 cc.).

Variation with the Current System

The general pattern of the Pacific equatorial-current system has been described by Sverdrup and associates (1942, pp. 708–712). In brief, the major surface currents of this region are the North and South Equatorial Currents flowing toward the west, with the eastward-flowing Equatorial Countercurrent sandwiched in between. Although the width of the Countercurrent (CC) may vary with longitude and season, its southern and northern boundaries are ordinarily near latitudes 5° N. and 10° N. in the Central Pacific. The South Equatorial Current (SEC) is therefore on both sides of the Equator, while the North Equatorial Current (NEC) is confined entirely to the Northern Hemisphere.

The prevailing east to southeast tradewinds, together with the Coriolis force resulting from the earth's rotation, induce a divergence of the surface waters at the Equator that is accompanied by upwelling. Under certain conditions, described by Cromwell (1953) a convergence may be formed, between the Equator and the southern boundary of the CC, which, we hypothesize, may tend to concentrate plankton and, consequently, the tuna forage organisms.

Over the range of latitude sampled (17° N.–14° S.), there are therefore certain natural subdivisions of the environment that may be established on the basis of the features mentioned above. These may be defined as follows: (1) The NEC from the northern limit of our sampling (17° N.) to the northern boundary of the CC; (2) the CC, with its boundaries determined at the time of each crossing from vertical temperature sections;[6] (3) a zone of convergence in the SEC extending—according to our definition—from the southern boundary of the CC to latitude 1½° N.; (4) a zone of divergence or upwelling in the SEC along the Equator from latitude 1½° N. to latitude 1½° S.; and (5)

[6] Provided in the reports of Murphy and Shomura (1953a, 1953b, 1955).

TABLE 6.—*Variation in volume and composition of stomach contents with longitude of place of capture*

Food organisms	Average volume (cc.) per stomach			Percentage by occurrence			Percentage of total volume		
	180°–155° W	150°–140° W	130°–120° W	180°–155° W	150°–140° W	130°–120° W	180°–155° W	150°–140° W	130°–120° W
Crustaceans:									
Yellowfin	1.8	0.8	0.4	48.3	42.6	29.8	1.9	0.9	0.3
Bigeye	2.1	1.4	5.0	49.1	30.7	35.3	1.2	1.4	3.1
Squids:									
Yellowfin	21.6	37.7	28.8	90.7	96.7	78.5	23.3	40.0	21.1
Bigeye	50.1	35.5	52.9	82.4	84.0	88.2	29.4	36.5	33.4
Other mollusks:									
Yellowfin	4.6	5.3	17.5	26.2	46.4	40.5	5.0	5.7	12.8
Bigeye	2.7	4.9	4.5	33.3	24.0	20.6	1.6	5.1	2.8
Fish (total):									
Yellowfin	64.0	49.8	89.7	97.1	92.9	91.6	68.8	52.9	65.7
Bigeye	115.3	55.4	95.8	91.2	76.0	94.1	67.7	56.9	60.5
Bramidae:									
Yellowfin	10.5	12.1	11.9	56.4	72.7	45.2	11.4	12.9	8.7
Bigeye	48.3	6.0	19.8	36.8	30.7	38.2	28.3	6.2	12.5
Gempylidae:									
Yellowfin	6.3	3.8	14.3	27.3	38.2	26.2	6.7	4.0	10.5
Bigeye	16.5	9.4	24.8	31.6	34.7	47.0	9.7	9.6	15.7
Thunnidae:									
Yellowfin	7.3	15.4	29.4	7.0	4.4	17.8	7.8	16.4	21.5
Bigeye	12.3		5.9	7.0		2.9	7.2		3.8
Sudidae:									
Yellowfin	0.7	0.2	0.6	9.3	6.6	2.4	0.7	0.2	0.4
Bigeye	3.8	5.1	1.1	24.6	12.0	8.8	2.2	5.2	0.7
Molidae:									
Yellowfin	19.1	0.1	11.9	6.4	0.5	1.2	20.6	0.1	8.7
Bigeye	4.6			5.3			2.7		
Other foods:									
Yellowfin	0.9	0.5	0.2	29.7	22.4	15.5	1.0	0.5	0.2
Bigeye	0.09	0.2	0.1	7.0	5.3	11.8	0.05	0.2	0.08
All foods:									
Yellowfin	92.9	94.1	136.6						
Bigeye	170.3	97.4	158.4						
Number of stomachs examined:									
Yellowfin	172	183	84						
Bigeye	57	75	34						
Average fork length (cm.):									
Yellowfin	136	141	147						
Bigeye	136	150	152						
Average weight (lbs.):									
Yellowfin	108	121	138						
Bigeye	116	155	160						
Average volume (cc.) food per pound of body weight:									
Yellowfin	0.9	0.8	1.0						
Bigeye	1.5	0.6	1.0						

the SEC from 1½° S. to the southern limit of our sampling (14° S.).

These areas have the following characteristics affecting the abundance of fish food: Area 1 is a region of low zooplankton concentrations (King and Demond 1953) and shallow thermocline. In area 2 the thermocline deepens to the south, and zooplankton shows some increase in abundance. Area 3 has a deep thermocline and a relatively high concentration of zooplankton. In area 4 at the Equator, upwelling is evidenced by a doming of the isotherms, a reduction in surface temperature, an increase in surface inorganic phosphate, and frequently by the greatest concentration of zooplankton. In area 5 the thermocline deepens, and the zooplankton concentration is reduced.

When the yellowfin and bigeye catch records [7] during the years 1950–53 are combined according to these natural features of the environment, we observe (fig. 11, A) that the area of best catch for yellowfin was in the convergence zone (area 3), while the best catches of bigeye came from the NEC (area 1) and the CC (area 2). Thus the longline catch provides some indication of an inverse relation in the abundance of these two species.

The stomach-content volumes were combined in the same manner—disregarding the rather minor differences associated with depth of capture, longitude, and season—to produce parts B and C of figure 11.[8] For the yellowfin, we find no correspondence between catch per 100 hooks and

[7] Summarized in reports of Murphy and Shomura (1953a, 1953b, 1955).

[8] Parts B and C of figure 11 are based on the 439 yellowfin stomachs employed in this report, which were considered comparable with the bigeye collections, and not on our total yellowfin-stomach data from the central Pacific.

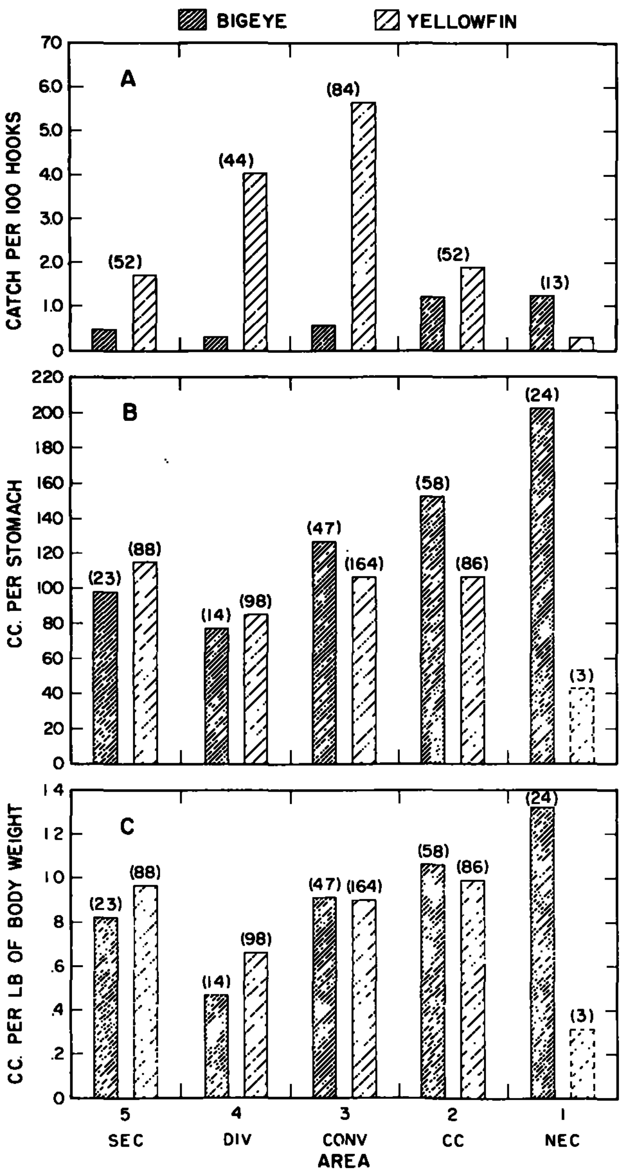

FIGURE 11.—Variations with the current system in (A) yellowfin and bigeye catch on longline gear, (B) average volume of food per stomach, and (C) average volume of food per pound of body weight. Boundaries for each division of the current system are defined in the text. Part A is derived from cruises 7, 11, and 18 of the *Hugh M. Smith*, cruises 11, 12, 13, 14, and 15 of the *John R. Manning*, cruise 1 of the *Charles H. Gilbert*, and cruise 1 of the *Cavalieri*. Number of observations, as stations fished (part A) or stomachs examined (parts B and C), is shown in parentheses.

volume of stomach contents.[9] The divergence zone at the Equator produced good catches of yellowfin, but these fish contained the lowest food volumes. On the basis of both the average volume of food per stomach and the average volume of food per pound of body weight—disregarding the three stomachs collected from the NEC—we judge that the yellowfin captured in areas 2, 3, and 5 were equally well fed. In the bigeye, there is a suggestion of parallel variation in catch rate and volume of stomach contents. This species was the best fed in areas 1 and 2, which were also the areas of best catch. The bigeye from near the Equator (area 4), where catches were poorest, contained the lowest food volumes.

Table 7 illustrates variations in certain food components as related to the system of currents. The consumption of Crustacea by yellowfin is roughly in accordance with the varying abundance of zooplankton as determined from our plankton surveys (King and Demond 1953, King 1954). Their utilization by bigeye is quite different, however, and may be related to differences in the kinds of organisms involved. In the food of yellowfin, for example, the crustacean fraction was principally amphipods, with isopods and crab larvae of some importance; the bigeye had fed chiefly on shrimp and euphausids. The complex variations in the consumption of squid, Bramidae (chiefly *Collybus drachme*), Gempylidae (chiefly *Gempylus serpens*), and total fish are difficult to understand, since we lack information on the latitudinal variations in abundance of these forage organisms.

We should like next to examine in greater detail the differences between the CC (area 2) and the convergent zone (area 3) with respect to volume and composition of food utilized as related to depth of capture of the tunas. As previously stated, the CC is a region of relatively good catch for bigeye and of poor catch for yellowfin. Bigeye from this region contained about 50 percent more food in their stomachs than did the yellowfin, but they averaged somewhat larger in body size.

[9] It was previously reported (Reintjes and King 1953) that on one cruise (cruise 11, *Hugh M. Smith*) there was some indication that for yellowfin the average volume of stomach contents varied directly with the catch rate.

TABLE 7.—*Variations in average volume per stomach of the major food categories as related to the current system*

[Boundaries of each area or division of current system are defined in text; volume is measured in cc.]

Food organisms	Area 1, NEC	Area 2, CC	Area 3, Conv.	Area 4, Div.	Area 5, SEC
Crustaceans:					
Yellowfin	----	0.3	0.6	2.9	0.8
Bigeye	0.1	2.1	3.3	1.8	3.8
Squids:					
Yellowfin	34.3	38.0	30.7	33.1	16.6
Bigeye	38.9	73.1	32.3	29.2	11.9
Other mollusks:					
Yellowfin	----	2.7	12.5	4.1	6.1
Bigeye	7.1	1.3	8.1	0.7	1.4
Fish (total):					
Yellowfin	8.0	64.9	62.2	44.0	91.6
Bigeye	155.7	75.4	82.6	45.5	80.6
Bramidae:					
Yellowfin	0.7	8.5	16.4	6.6	9.1
Bigeye	5.0	41.0	22.5	0.5	5.4
Gempylidae:					
Yellowfin	4.0	8.1	4.2	5.0	12.8
Bigeye	37.2	6.9	18.1	11.7	16.5
Thunnidae:					
Yellowfin	----	20.2	18.3	16.6	1.5
Bigeye	28.3	3.5	----	----	----
Sudidae:					
Yellowfin	----	----	0.2	0.1	1.3
Bigeye	0.6	1.6	5.7	1.1	10.9
Molidae:					
Yellowfin	----	2.5	1.2	----	44.6
Bigeye	5.2	----	----	----	6.1
Other foods:					
Yellowfin	----	0.2	5.7	0.7	0.9
Bigeye	----	----	0.2	0.1	0.3
All foods:					
Yellowfin	42.3	106.6	106.6	84.8	115.3
Bigeye	201.9	152.0	126.4	77.3	97.9
Number of stomachs examined:					
Yellowfin	3	86	164	98	88
Bigeye	24	58	47	14	23
Average fork length (cm.):					
Yellowfin	147	136	141	144	140
Bigeye	149	146	145	153	138
Average weight (lbs.):					
Yellowfin	138	108	119	129	118
Bigeye	153	143	139	164	120
Average volume (cc) food per pound of body weight:					
Yellowfin	0.3	1.0	0.9	0.7	1.0
Bigeye	1.3	1.1	0.9	0.5	0.8

On the basis of average volume of food per pound of body weight there was little difference between the two species.

The region of convergence has yielded the best yellowfin catches but has produced consistently poor bigeye catches. In this region the bigeye had about 20 percent more food in their stomachs than did the yellowfin, but the bigeye were also larger in average body size. Again the two species were almost identical with respect to average volume of food per pound of body weight.

In the CC, the thermocline occurs at shallow to moderate depths, while in the convergent zone it lies much deeper. Accompanying changes in the depth and velocity of the surface currents may greatly affect the fishing depth of the longline. In the region of shallow thermocline it is possible that, as a result of the streaming of the line caused by the marked shear between the moving surface waters and the relatively quiet waters below the thermocline, all hooks may be fishing at about the same level (Murphy and Shomura 1953b), and no marked difference might be expected in the food between the various hook levels. In a region of deep thermocline the longline can hang vertically and lie entirely within the homogenous surface layer. A marked difference in hook depth and possible differences in the stomach contents of the catch may then result.

Data have been assembled in table 8 and figure 12 to illustrate the variations in average volume per stomach for the major food categories with depth of capture of the tunas in these two ocean areas. In the CC there is greater change in the food of yellowfin with depth than in the convergent zone; this is evidenced by a consistent increase with depth, in the CC, in the utilization of Bramidae, Gempylidae, and total fish. In the bigeye the only important and consistent variation shown in the CC is a marked increase with depth in the amount of Crustacea eaten and a decrease in the importance of Gempylidae, as contrasted with

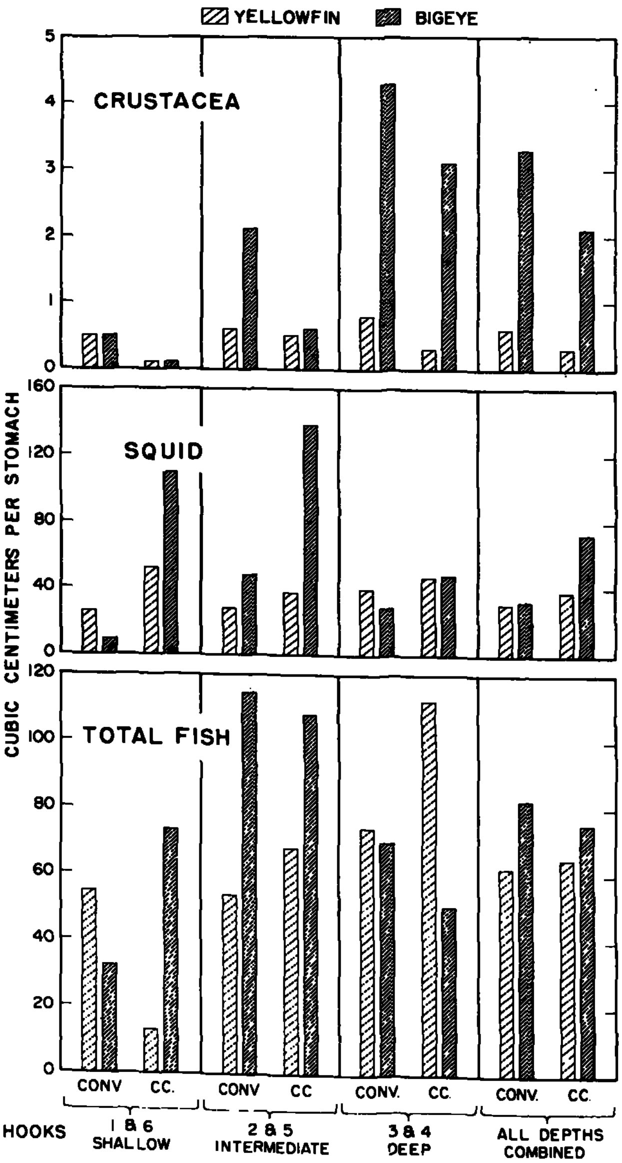

FIGURE 12.—Variations in average volume per stomach of the major food categories with depth of capture of 250 yellowfin and 105 bigeye tuna taken by longline in the Countercurrent and the convergent zone.

the increase with depth in Gempylidae as noted for yellowfin. In the convergent zone there is a similar increase with depth in the utilization of Crustacea and Bramidae.

The major foods are of about equal importance in both areas. There is no indication that the tunas have one set of foods in the CC and another in the convergent zone. The main difference between the two species is the much greater consumption of Crustacea by the bigeye in both the CC and the convergent zone. If we may consider the longline catch rate as an index to abundance, it would appear that the bigeye responds in a different manner than the yellowfin to the more favorable foraging conditions which, we hypothesize, exist in the convergent zone.

OTHER VARIATIONS IN VOLUME OF STOMACH CONTENTS

When the stomach-content volumes are classified according to an arbitrary scale, the results (table 9) indicate for both species a rather low percentage of empty or near-empty stomachs; the average stomach contained a relatively small amount of food. This may mean that feeding is almost continuous, as contrasted with an irregular or spasmodic feeding habit, and that these fish have a high rate of digestion. For instance, it is hard to believe that a food volume of less than 100 cc., which was found in more than 50 percent of the stomachs (table 9), constitutes a daily or even semidaily ration for these large active fish. Unfortunately, our food studies provide no information on rate of food consumption or digestion.

In longline fishing, the gear is ordinarily set at daybreak and is hauled in during the afternoon. The time of landing is known, but not the time that the fish took the hook. On some cruises, 50 percent or more of the tuna are dead when landed. One might assume that these fish had been on the line for a longer period of time than the fish that were landed alive. On the basis of this hypothesis we examined the records from certain cruises for which we had the greatest number of observations supplying information on condition when landed. These data, as summarized in table 10, seem to indicate that the fish that were dead when landed contained larger volumes of food, on the average, than those that were landed alive. Although we cannot satisfactorily explain this difference, we believe that it may be related to the tendency for more dead fish to occur on the deep hooks than on the hooks fishing at shallow and intermediate depths; and in the yellowfin, at least, we have found an increase in volume of stomach contents with depth of capture (table 3). A combination of these factors might produce the results shown in table 10.

TABLE 8.—*Variations in average volume of food per stomach in pelation to depth of capture, comparing yellowfin and bigeye tuna taken by longline in the Countercurrent and convergent zone*

[Organisms making up less than 1 percent of the total food volume for each depth category were omitted from table; volume is measured in cc.]

Food organisms	*Convergent zone*						Countercurrent					
	Yellowfin			Bigeye			Yellowfin			Bigeye		
	Hooks 1 and 6 (shallow)	Hooks 2 and 5 (intermediate)	Hooks 3 and 4 (deep)	Hooks 1 and 6 (shallow)	Hooks 2 and 5 (intermediate)	Hooks 3 and 4 (deep)	Hooks 1 and 6 (shallow)	Hooks 2 and 5 (intermediate)	Hooks 3 and 4 (deep)	Hooks 1 and 6 (shallow)	Hooks 2 and 5 (intermediate)	Hooks 3 and 4 (deep)
Crustacea (total)	0.5	0.6	0.8	0.5	2.1	4.3	0.1	0.5	0.3	0.1	0.6	3.1
Penaeidae						4.2						2.6
Squids (total)	25.5	27.6	39.4	9.2	47.7	28.4	52.1	37.4	46.5	110.0	138.5	47.8
Loliginidae:												
Loligo sp						1.7						
Sepioteuthis sp			1.8			2.9	12.3		2.8	43.0	4.9	14.6
Unidentified Loliginidae	3.1		4.6		20.1	3.7		8.2	18.0	39.6	11.0	2.5
Onycoteuthidae					5.2							1.3
Enoploteuthidae:												
Abralia sp						1.2						
Unidentified Enoploteuthidae						3.3	2.1	1.8	1.9	7.1		5.5
Ommastrephidae:												
Ommastrephes sp									3.4			
Notodarus sp												5.5
Unidentified Ommastrephidae	7.3	4.6	2.1	5.1	5.0	8.8	5.0	7.3	3.6	8.1	103.1	4.5
Sepiolidae		2.0						2.9	3.4		17.6	
Cranchiidae:												
Liocranchia globulus								1.4	2.9			12.0
Unidentified Cranchiidae												
Other mullusks (total)	14.3	8.4	15.4		0.9	12.3	1.4	3.3	2.6		1.5	1.1
Octopodidae	2.0	2.3	10.6			7.5		1.5				
Argonautidae:												
Argonauta sp			2.1			1.9						
A. bottgeri	1.6	1.0				2.5						
Unidentified Argonautidae	10.3	3.5	1.2				0.9	1.6				1.1
Fish (total)	54.7	53.8	74.2	32.5	114.6	70.0	12.9	68.0	111.9	73.3	107.9	50.7
Gonostomidae: *Vinciguerria lucetia*						1.2						
Sternoptychidae:												
Sternoptyx diaphana	9.7					2.7						
Unidentified Sternoptychidae				0.6		0.6				3.6		1.1
Sudidae:												
Paralepis sp					9.0	1.8						
Unidentified Sudidae				26.3		0.5						4.2
Alepisauridae: *Alepisaurus* sp												2.1
Exocoetidae:												
Cyselurus sp		1.7										
Unidentified Exocoetidae		0.1						3.4				
Trachypteridae: *Trachypterus* sp						1.4						
Caulolepidae									3.6			
Atherinidae: *Atherinus insularum*						2.0						
Priacanthidae: *Priacanthus cruentatus*							1.2					
Carangidae:												
Seriola sp	1.8											
Naucrates sp	2.4											
Scombroides sp		2.4										
Bramidae:												
Collybus drachme	10.1	15.3	8.5	3.5		9.9		4.0	12.4		61.7	17.9
Taractes sp	1.4	1.1	4.6		8.2	14.9			4.1		4.5	
Unidentified Bramidae	2.6	1.0	0.4		1.3	7.7	4.6	3.5	0.6		1.4	2.4
Chiasmodontidae												1.3
Gempylidae:												
Gempylus serpens	2.0	1.3	5.2		39.0	4.2	1.2	4.3	15.5	9.5	9.5	2.3
Unidentified Gempylidae	1.2	1.7	1.3	0.6		0.4		1.0	3.2	9.5	0.4	2.9
Nomeidae:												
Nomeus sp						2.3						
Unidentified Nomeidae						0.1	0.8					
Thunnidae:												
Katsuwonus pelamis	8.1	4.4	12.8					28.2	41.1			
Neothunnus macropterus			15.8									
Auxis thazard		6.4	4.2									9.2
Unidentified Thunnidae			1.1					0.3				1.0
Echeneidae:												
Echeneis sp	1.4											
Remora remora							0.9	3.8				
Unidentified Echeneidae	0.2						0.3	0.8				
Balistidae:												
Balistes nycteris	1.2	4.3										
Unidentified Balistidae	0.2	0.8										
Ostraciidae:												
Ostracion diaphanus			1.9									
Lactoria schlemmeri						2.3						
Unidentified Ostraciidae			3.3				0.7					
Tetrodontidae: *Tetrodon* sp		1.3										
Molidae: *Ranzania* sp	4.0							6.8	1.7			
Other foods	0.5	0.4	0.8		0.7				0.6			0.1
All foods	95.6	90.8	130.4	42.2	166.0	115.3	66.5	109.5	161.9	183.4	248.6	103.9
Number of stomachs examined	49	49	61	3	14	28	9	25	25	7	13	22
Average fork length (cm.)	141	141	141	146	153	141	131	135	139	153	146	140
Average weight (lbs.)	120	120	120	139	164	130	97	106	115	162	144	127
Average volume of food per pound of body weight (cc.)	0.8	0.8	1.1	0.3	1.0	0.9	0.7	1.0	1.4	1.1	1.7	0.8

TABLE 9.—*Distribution of the volume of stomach contents of 439 yellowfin and 166 bigeye caught by longline fishing in the central Pacific*

Volume (cc.)	Less than 140 cm. long			140 cm. or larger		
	Number	Percent of total number	Accumulated percentage	Number	Percent of total number	Accumulated percentage
Empty:						
(0–0.9):						
Yellowfin	6	3.2	3.2	4	1.6	1.6
Bigeye	2	3.2	3.2	6	5.8	5.8
1.0–9.9:						
Yellowfin	17	9.0	12.2	17	6.7	8.3
Bigeye	4	6.3	9.5	10	9.7	15.5
10.0–24.9:						
Yellowfin	21	11.2	23.4	22	8.7	17.0
Bigeye	9	14.3	23.8	9	9.4	24.9
25.0–49.9:						
Yellowfin	45	24.0	47.4	50	19.9	36.9
Bigeye	10	15.8	39.6	13	12.6	37.5
50.0–99.9:						
Yellowfin	49	26.1	73.5	66	26.2	63.1
Bigeye	11	17.5	57.1	18	17.5	55.0
100.0–199.9:						
Yellowfin	31	16.5	90.0	56	22.2	85.3
Bigeye	13	20.6	77.7	24	23.3	78.3
200.0–499.9:						
Yellowfin	15	8.0	98.0	30	11.9	97.2
Bigeye	12	19.0	96.7	17	16.5	94.8
500.0–999.9:						
Yellowfin	4	2.1	100.0	3	1.2	98.4
Bigeye	2	3.2	100.0	5	4.9	99.7
1000.0 and over:						
Yellowfin	0	0.0		3	1.2	100.0
Bigeye	0	0.0		1	1.0	100.0
Total:						
Yellowfin	188			251		
Bigeye	63			103		

TABLE 10.—*Summary of data relating average volume of stomach contents to condition of fish, whether dead or alive, at time of landing*

Cruise	Yellowfin			Bigeye		
	Average volume of stomach contents	Number of stomachs examined	Average fork length	Average volume of stomach contents	Number of stomachs examined	Average fork length
Hugh M. Smith cruise 11:	*cc.*		*cm.*	*cc.*		*cm.*
Landed dead	93.7	64	135	174.9	11	152
Landed alive	50.6	23	141	83.5	24	148
John R. Manning cruise 14:						
Landed dead	95.6	37	143			
Landed alive	71.4	32	144			
John R. Manning cruise 15:						
Landed dead				100.9	9	119
Landed alive				280.5	10	137

SUMMARY AND CONCLUSIONS

1. This study is based on the quantitative analysis of the stomach contents of 166 bigeye tuna (*Parathunnus sibi*) and of 439 yellowfin tuna (*Neothunnus macropterus*) caught at the same time or nearly the same time as the bigeye.

2. These tuna were captured in the central Pacific during the period October 1950–June 1953 by means of longline-gear fishing at depths of 150 to 500 feet.

3. The food of the yellowfin consisted of fish (62 percent by volume), squid (29 percent), other mollusks (7 percent), and crustaceans (1 percent); the food of bigeye consisted of fish (62 percent), squid (33 percent), other mollusks (3 percent), and crustaceans (2 percent).

4. Both species of tuna appear to utilize a great variety of animal food, ranging from small plankton organisms to large squid and fish. Food items of major importance to both species were pomfret (*Collybus drachme*), snake mackerel (*Gempylus serpens*), and squid of the families Ommastrephidae and Loliginidae.

5. This great diversity of diet suggests that many forms of fish, squid, and shrimp—if available through culture or capture—might be effective as live bait or longline bait in tuna fishing.

6. Stomatopod crustaceans, common in the food of yellowfin, were completely lacking from the bigeye stomachs. The young of other tunas, mostly skipjack, formed a much more important part of the yellowfin diet than of the bigeye diet.

7. In both species, the larger tuna had more food in their stomachs than did the smaller fish, but the larger fish contained less food per pound of body weight than did the smaller fish. There were few completely empty stomachs.

8. In both tunas, the smaller individuals consumed a greater proportion by volume of crustaceans and fish and a lesser proportion of mollusks than the larger size group. The same fish families were prominent in the diet of both size groups.

9. There was an increase in volume of stomach contents with depth of capture for the yellowfin; in the bigeye, the largest volumes were found in specimens from intermediate depths. There was no marked variation in composition of stomach contents over the range of depth sampled (estimated at 150 to 500 feet), which may be evidence that both the forage organisms and the tuna range rather freely throughout this water layer.

10. In both yellowfin and bigeye, fish were consumed in greatest amount during the period April–July, and in least amount during August and September. There was little correspondence between the two species in the seasonal variation in the other major food items.

11. In respect to longitudinal variations in the food, the two species were similar in the lower volume of total fish in the stomach contents of those tunas captured in the central region (140°–150° W. longitude) of the sampled area. The utilization of specific foods did not vary with longitude in any regular pattern for the two species.

12. When classified according to natural subdivisions of the equatorial current system, the volume of stomach contents in the bigeye varied directly with the longline catch rate, while in the yellowfin there was little change in volume of stomach contents with even a marked change in catch rate.

13. Tuna that were dead when landed contained, on the average, more food in their stomachs than those landed alive.

14. Despite the differences that we have pointed out, the foods of the yellowfin and bigeye are remarkably similar. We conclude, therefore, that when occupying the same general area the two species have essentially the same feeding habits. If there is any marked food selection, it must be exercised by seeking different areas for feeding.

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APPENDIX

TABLE 11.—*Check-list of food organisms found in the stomachs of 439 yellowfin and 166 bigeye tuna captured on longline in the Central Pacific, 1950–53*

[Family names of fishes are as given in Berg 1947]

Food organisms	Yellowfin: Number of organisms	Yellowfin: Stomachs in which occurred: Number	Yellowfin: Stomachs in which occurred: Percent	Yellowfin: Aggregate total volume: Cubic centimeters	Yellowfin: Aggregate total volume: Percent [1]	Bigeye: Number of organisms	Bigeye: Stomachs in which occurred: Number	Bigeye: Stomachs in which occurred: Percent	Bigeye: Aggregate total volume: Cubic centimeters	Bigeye: Aggregate total volume: Percent [1]
CTENOPHORA						1	1	0.6	0.1	
ARTHROPODA										
Crustacea	[1,761]	[188]	[42.8]	[496.1]	[1.1]	[669]	[67]	[40.4]	[398.0]	[1.7]
Mysidacea:										
Mysidae:										
Mysis sp	8	1	0.2	6.3						
Unidentified mysids	52	2	0.5	4.9						
Isopoda:										
Idotheidae	175	44	10.0	34.4		103	12	7.2	3.7	
Cymotheidae	27	2	0.5	1.5		2	1	0.6	0.4	
Tanaidae	1	1	0.2	0.1						
Unidentified isopods	54	12	2.7	11.4		19	4	2.4	2.1	
Amphipoda:										
Hyperiidae	4	2	0.5	2.0						
Gammaridae:										
Gammarus sp	17	6	1.4	13.9		3	2	1.2	1.1	
Lysianissidae	519	10	2.3	167.6	0.4					
Phronimidae:										
Phronima sp	170	62	14.1	43.6		3	3	1.8	1.0	
Unidentified Phronimidae	2	2	0.5	0.3						
Caprellidae:										
Caprella sp	2	1	0.2	0.1						
Unidentified Caprellidae	2	2	0.5	1.0						
Unidentified amphipods	139	29	6.6	34.4		33	9	5.4	4.7	
Euphausiacea:										
Euphausiidae:										
Euphausia sp	67	5	1.1	11.5		93	2	1.2	27.0	0.1
Unidentified euphausids	93	10	2.3	17.7		168	15	9.0	53.9	0.2
Decapoda:										
Penaeidae:										
Penaeus sp	1	1	0.2	1.4		71	5	3.0	116.8	0.5
Unidentified Penaeidae	27	9	2.1	9.3		90	15	9.0	103.3	0.5
Palaemonidae:										
Palaemon sp	9	7	1.6	11.5		19	8	4.8	34.2	0.2
Unidentified Palaemonidae	27	4	0.9	3.8		16	1	0.6	0.2	
Hippolytidae	1	1	0.2	7.5						
Nephropsidae:										
Enoplometopus sp	7	3	0.7	2.5						
Unidentified Nephropsidae	2	1	0.2	0.5						
Palinuridae:										
Panulirus sp	1	1	0.2	0.9						
Unidentified Palinuridae	1	1	0.2	0.8						
Megalopa larvae	212	31	7.1	42.0		1	1	0.6	0.1	
Phyllosoma larvae	2	2	0.5	0.2						
Unidentified decapods	48	10	2.3	36.4		47	4	2.4	38.5	0.2
Stomatopoda										
Squillidae:										
Squilla sp	6	4	0.9	1.4						
S. alba	1	1	0.2	0.2						
Pseudosquilla sp	2	2	0.5	0.9						
P. occulta	6	3	0.7	3.5						
Lysiosquilla sp	7	4	0.9	3.7						
Coronida sp	2	2	0.5	0.6						
Gonodactylus sp	10	8	1.8	2.6						
G. guerini	32	7	1.6	7.3						
Odontodactylus sp	1	1	0.2	0.6						
O. hensenii	18	7	1.6	6.7						
Unidentified stomatopods	2	2	0.5	0.3						
Unidentified crustaceans	4	3	0.7	0.8		1	1	0.6	1.0	
MOLLUSCA	[3,537]			[16,275.2]	[36.4]	[910]			[7,997.3]	[35.9]
Gastropoda										
Heteropoda										
Atlantidae	49	15	3.4	3.0		6	4	2.4	0.5	
Pterotracheidae:										
Pterotrachea sp	1	1	0.2	0.3						
Unidentified heteropods	60	24	5.5	92.0	0.2					
Pteropoda										
Spiratellidae	2	2	0.5	0.7						
Unidentified pteropods	10	1	0.2	5.0						

See footnote at end of table.

TABLE 11.—*Check-list of food organisms found in the stomachs of 439 yellowfin and 166 bigeye tuna captured on longline in the Central Pacific, 1950–53*—Continued

[Family names of fishes are as given in Berg 1947]

Food organisms	Yellowfin					Bigeye				
	Number of organisms	Stomachs in which occurred		Aggregate total volume		Number of organisms	Stomachs in which occurred		Aggregate total volume	
		Number	Percent	Cubic centimeters	Percent [1]		Number	Percent	Cubic centimeters	Percent [1]
Cephalopoda										
Octopoda										
Octopodidae:										
Octopus sp.	2	1	0.2	20.0	...	2	1	0.6	7.7	...
Unidentified Octopodidae	67	22	5.0	1,153.4	2.6	15	11	6.6	273.9	1.2
Argonautidae:										
Argonauta sp.	169	32	7.3	543.4	1.2	45	9	5.4	156.1	0.7
A. hians	72	8	1.8	273.2	0.6	...	...	...	...	...
A. bottgeri	52	16	3.6	254.4	0.6	8	3	1.8	58.0	0.3
Unidentified argonauts	147	43	9.8	727.1	1.6	23	17	10.2	115.7	0.5
Bolitaenidae:										
Eledonnella sp.	2	2	0.5	45.0	0.1	2	1	0.6	20.0	...
Unidentified octopods	7	7	1.6	35.2	...	4	4	2.4	29.4	0.2
Decapoda (squid)	[2,738]	[382]	[87.0]	[13,036.4]	[29.2]	[770]	[137]	[82.5]	[7,311.3]	[32.8]
Sepiidae:										
Sepia sp.	...	...	...	...	...	3	1	0.6	5.8	...
Unidentified sepiidae	13	10	2.3	110.5	0.2	3	2	1.2	9.7	...
Lolinginidae:										
Loligo sp.	2	1	0.2	3.8	...	10	3	1.8	62.8	0.3
Sepioteuthis sp.	22	12	2.7	382.3	0.9	26	7	4.2	1,080.0	4.8
Unidentified Loliginidae	333	59	13.4	2,205.0	4.9	85	24	14.5	1,252.8	5.6
Sepiolidae	7	5	1.1	277.8	0.6	9	5	3.0	334.0	1.5
Onycoteuthidae:										
Onycoteuthis sp.										
O. banksi	...	...	...	...	...	2	2	1.2	147.0	0.7
Teleoteuthis sp.	6	1	0.2	14.0	...	...	...	...	...	...
Unidentified Onycoteuthidae	2	2	0.5	4.5	...	8	2	1.2	99.3	0.4
Histioteuthidae:										
Calliteuthis sp.	1	1	0.2	4.0	...	...	...	...	...	...
Unidentified Histioteuthidae	10	5	1.1	14.2	...	6	3	1.8	34.0	0.2
Enoploteuthidae:										
Abralia sp.	...	...	...	...	...	8	2	1.2	41.0	0.2
A. astrosticta	4	1	0.2	14.2	...	...	...	...	...	...
Enoploteuthis sp.	31	4	0.9	81.5	0.2	5	3	1.8	56.5	0.3
Unidentified Enoploteuthidae	162	67	15.3	397.4	0.9	77	35	21.1	414.8	1.9
Ommastrephidae:										
Notodarus sp.	40	9	2.1	179.9	0.4	2	1	0.6	120.0	0.5
Ommastrephes sp.	16	1	0.2	85.0	0.2	...	...	...	...	...
Unidentified Ommastrephidae	923	175	39.9	3,534.6	7.9	205	42	25.3	2,482.0	11.1
Cranchiidae:										
Helicocranchia sp.	1	1	0.2	2.7	...	1	1	0.6	1.8	...
Liocranchia sp.	...	...	...	...	...	95	4	2.4	131.0	0.6
L. globulus	61	7	1.6	116.1	0.3	74	3	1.8	207.8	0.9
Unidentified Cranchiidae	10	2	0.5	17.0	...	...	...	...	...	...
Unidentified squid	1,094	143	32.6	5,591.9	12.5	151	48	28.9	830.9	3.7
Unidentified cephalopods	159	32	7.3	86.1	0.2	35	5	3.0	4.9	...
CHORDATA										
Tunicata	[375]	[106]	[24.1]	[264.7]	[0.6]	[41]	[10]	[6.0]	[21.8]	...
Thallacea										
Salpidae:										
Salpa sp.	19	1	0.2	1.1	...	...	...	...	...	...
Unidentified Salpidae	349	106	24.1	238.0	0.5	36	7	4.2	9.4	...
Ascidiacea										
Pyrosomatidae	6	4	0.9	23.6	...	3	2	1.2	11.5	...
Unidentified tunicates	1	1	0.2	2.0	...	2	2	1.2	0.9	...
Vertebrata (Pisces)	[4,340]	[408]	[92.9]	[27,643.5]	[61.9]	[1,702]	[140]	[84.3]	[13,890.2]	[62.3]
Gonostomidae (viperfishes):										
Cyclothone sp.	...	...	...	...	...	2	1	0.6	2.0	...
Vinciguerria lucetia	110	2	0.5	44.4	...	181	3	1.8	32.8	0.1
Unidentified Gonostomidae	...	...	...	...	...	1	1	0.6	2.1	...
Sternoptychidae (hatchetfishes):										
Sternoptyx sp.	4	2	0.5	2.2	...	29	2	1.2	14.8	...
S. diaphana	253	2	0.5	517.1	1.2	118	1	0.6	75.0	0.3
Argyropelecus sp.										
A. haemigymnus	...	...	...	...	...	4	1	0.6	14.3	...
Unidentified Sternoptychidae	81	11	2.5	83.1	0.2	82	13	7.8	65.0	0.3
Stomiatidae	13	4	0.9	12.0	...	3	2	1.2	1.6	...
Chauliodontidae	...	...	...	...	...	1	1	0.6	5.0	...
Astronesthidae	1	1	0.2	0.2	...	...	...	...	...	...
Melanostomiatidae	1	1	0.2	43.5	...	...	...	...	...	...
Sudidae:										
Sudis sp.	1	1	0.2	3.6	...	4	2	1.2	76.1	0.3
Paralepis sp.	...	...	...	...	...	27	5	3.0	216.0	1.0
Lestidium sp.	1	1	0.2	2.5	...	24	2	1.2	123.0	0.6
L. nudum	...	...	...	...	...	6	1	0.6	17.5	...
Unidentified Sudidae	47	28	6.4	197.9	0.4	44	18	10.8	214.8	1.0
Alepisauridae (lancet fishes):										
Alepisaurus sp.	41	16	3.6	172.3	0.4	36	17	10.2	635.4	2.8
Scopelidae (lantern fishes)	57	21	4.8	94.5	0.2	21	7	4.2	127.1	0.6
Muraenidae	6	1	0.2	1.4	...	...	...	...	...	...

See footnote at end of table.

TABLE 11.—*Check-list of food organisms found in the stomachs of 439 yellowfin and 166 bigeye tuna captured on longline in the Central Pacific, 1950–53*—Continued

[Family names of fishes are as given in Berg 1947]

Food organisms	Yellowfin					Bigeye				
	Number of organisms	Stomachs in which occurred		Aggregate total volume		Number of organisms	Stomachs in which occurred		Aggregate total volume	
		Number	Percent	Cubic centimeters	Percent [1]		Number	Percent	Cubic centimeters	Percent [1]
Vertebrata—Continued										
Nemichthyidae (snipe eels)	3	1	0.2	3.4		1	1	0.6	0.5	
Belonidae (needle fishes)	13	6	1.4	10.7		7	6	3.6	12.0	
Hemirhamphidae (halfbeaks)	1	1	0.2	7.0						
Exocoetidae (flying fishes):										
Cypselurus sp.	5	4	0.9	321.3	0.7					
Paraexocoetus sp.	2	1	0.2	31.5						
Unidentified Exocoetidae	27	13	3.0	295.3	0.7	6	5	3.0	64.8	0.3
Bregmacerotidae:										
Bregmaceros macclellandi	4	3	0.7	6.6		1	1	0.6	1.0	
Gadidae (cod fishes)	1	1	0.2	1.9						
Lophotidae (oarfishes)						1	1	0.6	2.8	
Trachypteridae (ribbon fishes):										
Trachypterus sp.						2	1	0.6	40.0	0.2
Regalecidae (oarfishes):										
Regalecus sp.						1	1	0.6	190.0	0.9
Berycidae	10	3	0.7	45.0	0.1	1	1	0.6	3.9	
Diretmidae	1	1	0.2	94.0	0.2					
Caulolepidae:										
Anoplogaster sp.	5	2	0.5	21.6						
A. cornutus						9	2	1.2	21.0	
Unidentified Caulolepidae	27	3	0.7	94.0	0.2	1	1	0.6	6.4	
Holocentridae (squirrel fishes):										
Holocentrus sp.	2	1	0.2	0.2						
Unidentified Holocentridae						1	1	0.6	0.1	
Zeidae (John Dories):										
Allocytus sp.	2	2	0.5	5.3						
Caproidae:										
Antigonia sp.										
A. capros						11	1	0.6	33.0	0.1
Atherinidae (silversides):										
A. insularum						150	1	0.6	55.4	0.2
Polynemidae (threadfins)	1	1	0.2	7.2						
Priacanthidae (catalufas):										
Pricanthus cruentatus	2	1	0.2	29.5						
Pseudopriacanthus sp.						1	1	0.6	6.8	
Apogonidae (cardinal fishes):										
Parascombrops pellucida	1	1	0.2	0.6						
Scombropidae:										
Hypoclydonia sp.	7	2	0.5	6.9		4	1	0.6	9.2	
Scombrops sp.	8	2	0.5	4.6		1	1	0.6	1.9	
Unidentified Scombropidae						1	1	0.6	1.2	
Carangidae (jacks):										
Seriola sp.	1	1	0.2	88.0	0.2					
Naucrates sp.	1	1	0.2	118.0	0.3					
Carangus sp.						1	1	0.6	8.6	
Scombroides sp.	1	1	0.2	115.7	0.3					
Unidentified Carangidae	1	1	0.2	1.8						
Bramidae (pomfrets):										
Collybus drachme	1,012	190	43.3	3,465.9	7.8	76	26	15.7	2,550.8	11.4
Taractes sp.	88	33	7.5	786.3	1.8	34	22	13.3	835.5	3.7
Pteraclis sp.	1	1	0.2	3.0						
P. ocellatus	2	1	0.2	4.2		1	1	0.6	14.8	
Unidentified Bramidae	244	66	15.0	675.2	1.5	18	10	6.0	476.9	2.1
Coryphaenidae (dolphins):										
Coryphaenus sp.	2	2	0.5	118.1	0.3					
C. hippurus	3	1	0.2	1.4						
Unidentified Coryphaenidae	2	2	0.5	3.3		3	2	1.2	2.6	
Lutianidae (snappers)	1	1	0.2	1.5						
Leiognathidae	8	1	0.2	21.0						
Mullidae (goat fishes):										
Pseudupeneus sp.										
P. porphyreus	1	1	0.2	1.2						
Unidentified Mullidae						1	1	0.6	3.7	
Chaetodontidae (butterfly fishes)	5	3	0.7	29.3						
Pomacentridae (damsel fishes)	3	2	0.5	4.4		1	1	0.6	7.0	
Champsodontidae: *Champsodon* sp.	26	10	2.3	39.5		1	1	0.6	2.0	
Chiasmodontidae	12	3	0.7	24.8		7	3	1.8	29.9	0.1
Acanthuridae (surgeon fishes):										
Hepatus sp.	6	1	0.2	12.8						
Unidentified Acanthuridae	31	10	2.3	97.9	0.2					
Zanclidae (Moorish Idol)	1	1	0.2	21.9						
Gempylidae (snake mackerels):										
Gempylus serpens	202	80	18.1	2,119.5	4.7	86	43	25.9	2,023.7	9.1
Ruvettus sp.	1	1	0.2	0.4		2	1	0.6	2.4	
Nealotus tripes	19	1	0.2	21.5		1	1	0.6	4.4	
Promethichthys prometheus	7	1	0.2	36.0						
Neoephinnula orientalis						1	1	0.6	5.5	
Rexea solandrii						2	1	0.6	2.8	
Mimusca taeniosoma	1	1	0.2	1.8		18	1	0.6	80.0	0.4
Unidentified Gempylidae	149	62	14.1	786.2	1.8	48	18	10.8	376.8	1.7

See footnote at end of table.

TABLE 11.—*Check-list of food organisms found in the stomachs of 439 yellowfin and 166 bigeye tuna captured on longline in the Central Pacific, 1950–53*—Continued

[Family names of fishes are as given in Berg 1947]

Food organisms	Yellowfin					Bigeye				
	Number of organisms	Stomachs in which occurred		Aggregate total volume		Number of organisms	Stomachs in which occurred		Aggregate total volume	
		Number	Percent	Cubic centimeters	Percent [1]		Number	Percent	Cubic centimeters	Percent [1]
Vertebrata—Continued										
Scombridae (mackerels):										
Scomber sp.	9	2	0.5	21.4						
Unidentified Scombridae	4	3	0.7	68.6	0.2					
Nomeidae (rudder fishes):										
Nomeus sp.	41	16	3.6	102.3	0.2	34	6	3.6	76.9	0.3
Cubiceps sp.	14	4	0.9	30.8		8	3	1.8	22.8	0.1
C. thompsoni	2	1	0.2	10.0						
Psenes sp.	41	12	2.7	79.0	0.2	4	2	1.2	10.4	
Monodactylus sp.						1	1	0.6	5.6	
Unidentified Nomeidae	58	25	5.7	122.6	0.3	15	10	6.0	75.0	0.3
Thunnidae (tuna fishes):										
Sardi sp.						3	1	0.6	17.5	
Katsuwonus pelamis	48	17	3.9	3,497.1	7.8					
Neothunnus macropterus	2	2	0.5	962.0	2.2	1	1	0.6	662.0	3.0
Germo alalunga	1	1	0.2	22.2						
Auris thazard	68	12	2.7	1,961.0	4.4	2	2	1.2	224.0	1.0
Parathunnus sibi	1	1	0.2	70.0	0.2					
Unidentified Thunnidae	6	4	0.9	12.2		1	1	0.6	1.0	
Echeneidae (remoras):										
Echeneis sp.	16	8	1.8	144.8	0.3					
Remoropsis brachypterus	4	2	0.5	26.6						
Remora sp.	4	3	0.7	14.3						
R. remora	12	11	2.5	145.8	0.3					
Unidentified Echeneidae	26	20	4.6	116.3	0.3	7	3	1.8	5.6	
Balistidae (trigger fishes):										
Balistes sp.	8	5	1.1	72.6	0.2					
B. nycteris	23	12	2.7	412.5	0.9					
B. ringens	5	3	0.7	134.0	0.3					
Xanthichthys sp.	1	1	0.5	6.8						
Unidentified Balistidae	8	7	1.6	71.9	0.2					
Monacanthidae (file fishes)	11	7	1.6	27.8						
Ostraciidae (trunk fishes):										
Ostracion sp.	33	14	3.2	78.3	0.2	15	2	1.2	23.0	0.1
O. diaphanus	78	29	6.6	322.7	0.7	8	2	1.2	29.7	0.1
Lactoria sp.	3	3	0.7	15.3		1	1	0.6	2.5	
L. schlemmeri	18	13	3.0	243.4	0.5	2	2	1.2	69.5	0.3
Unidentified Ostraciidae	11	10	2.3	27.1		1	1	0.6	0.6	
Tetrodontidae (puffers):										
Sphoeroides lagocephalus	9	6	1.4	77.0	0.2					
Lagocephalus sp.	3	2	0.5	57.5	0.1					
Tetrodon sp.	3	2	0.5	215.7	0.5					
Unidentified Tetrodontidae	7	7	1.6	118.1	0.3	1	1	0.6	16.6	
Diodontidae (porcupine fishes):										
Diodon sp.	1	1	0.2	10.0						
Cheilomycteris sp.	5	5	1.1	66.1	0.1					
C. affinis	3	1	0.2	54.0	0.1					
Unidentified Diodontidae	13	10	2.3	162.3	0.4	1	1	0.6	0.1	
Molidae (sun fishes):										
Ranzania sp.	19	12	2.7	4,318.8	9.7	1	1	0.6	113.0	0.5
Unidentified Molidae						2	2	1.6	151.0	0.7
Antennariidae (frogfishes):										
Antennarius sp.	1	1	0.2	0.8						
Other and unidentified fish	1,160	213	48.5	2,968.9	6.6	511	81	48.8	3,884.0	17.4
Total food				44,679.5					22,297.3	
Number of stomachs examined				439					166	

[1] Given only when 0.1 percent or greater.

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