Catch Rate, Size, Sex, and Food of Tunas and other Pelagic Fishes taken by Trolling off Oahu, Hawaii, 1951-55

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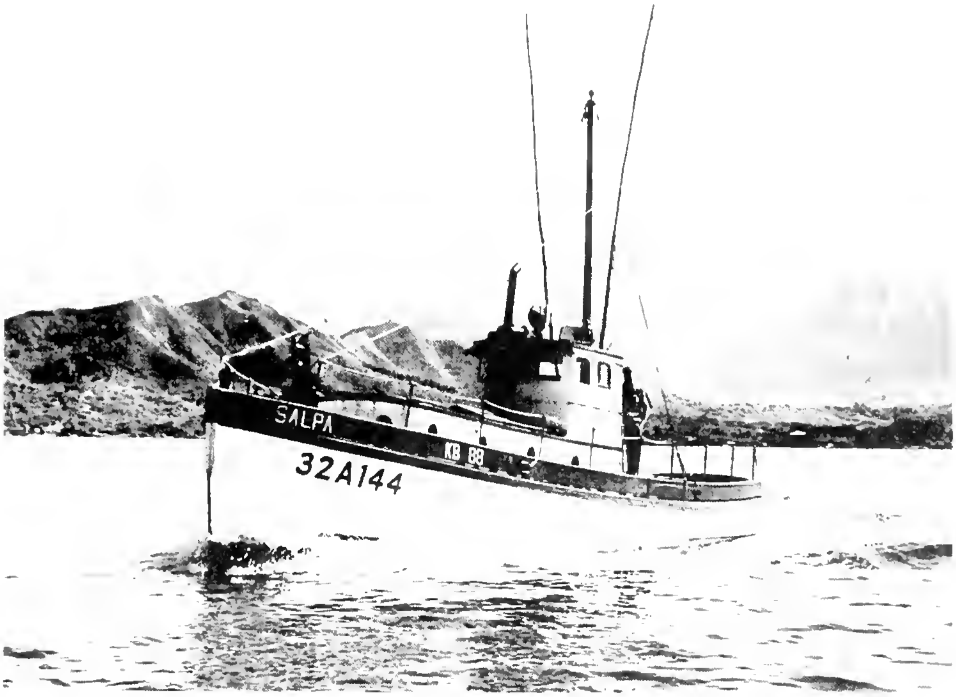

CATCH RATE, SIZE, SEX, AND FOOD OF TUNAS AND OTHER PELAGIC FISHES TAKEN BY TROLLING OFF OAHU, HAWAII, 1951-55

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ABSTRACT

Catch rate, lure preference, size, weight-length relation, sex and maturity, and food data are presented for the following species of fish: skipjack, little tunny, yellowfin, and dolphin. Where available similar data are reported for frigate mackerel, wahoo, and jack. These fishes were caught by trolling off the northeast coast of Oahu, Hawaii, during the period 1951-55.

The following inferences were made: The highest availability for all species combined occurred from May to October; no lure preference was found; the presence of one to several size groups was indicated by the weight distributions for these fishes; weight-length relations indicated a sexual difference in dolphin but not for the others; sex ratios showed a preponderance of males for skipjack, equal proportion of both sexes for little tunny and yellowfin, and a preponderance of females for dolphin, although considerable diversity of sex ratios between schools was observed for the latter; gonad examinations revealed mature specimens for all species except yellowfin; food of these troll-caught fishes consisted primarily of fishes, cephalopods, and crustaceans; interspecific competition for food was indicated.

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CATCH RATE, SIZE, SEX, AND FOOD OF TUNAS AND OTHER PELAGIC FISHES TAKEN BY TROLLING OFF OAHU, HAWAII, 1951-55

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During 1951 to 1955 inclusive, the 46-foot research vessel Salpa (frontispiece) of the Hawaii Marine Laboratory, University of Hawaii, conducted trolling operations off Kaneohe Bay on the windward or northeast side of Oahu. Fishing was undertaken primarily to stock the ponds of the Coconut Island laboratory with tunas and other pelagic fishes for studies of their response to stimuli. The studies were supported by three annual contracts (June 1951 to May 1954) between the University of Hawaii and the Pacific Oceanic Fishery Investigations.

Incidental to the fishing operations, data were accumulated on the catch rate, size, sex, and food of the several species which were caught. The data are summarized in this report primarily to make them available to other research workers studying the biology of these pelagic species. Such inferences as may be made concerning the life histories of the fish are presented briefly and should be considered tentative in view of the paucity of data in many instances.

The species discussed in this report are referred to by their common English names as follows:

Scientific name	English name
Katsuwonus pelamis	Skipjack
Euthynnus yaito	Little tunny
Neothunnus macropterus	Yellowfin
Auxis thazard	Frigate mackerel
Coryphaena hippurus	Dolphin
Caranx stellatus?	Jack
Acanthocybium solandri	Wahoo

METHODS

Fishing methods used in 1951 have been described by Tester (1952) and, in general, did not change in subsequent years. During 1951 and 1952, ordinarily six cotton trolling lines were used, two (about 90 feet in length) from each of two outrigger poles, and one (about 30 feet) from each side of the stern. During 1953 to 1955, the four outrigger lines were used, but for the most part only one line was trolled from the stern and, on infrequent occasions, even this was omitted. Since the catch rate is calculated as the average catch per hour rather than per line per hour[1/] this introduces a bias in year to year comparisons, but this is considered insufficient to account wholly for the changes in catch rate to be noted later.

Stainless-steel leader wires (about 6 feet in length) were snapped to the ends of the cotton lines. To these were attached a variety of lures. Trolling was conducted at a speed of about 6 knots, which kept the lures on or near the surface. After capture, viable fish were retained in the ship's livewell.

Fishing was confined mostly to the morning hours, with the ship leaving the dock at the Coconut Island laboratory between 0700 and 0800 hours and returning between 1200 and 1300 hours. On clearing Kaneohe Bay we would usually bear towards Mokumanu Island (fig. 1) and then head out to sea, the course being governed by such bird flocks as were sighted within the area of fishing. Often the ship would circle under a working bird flock for several minutes. Whenever strikes were made, trolling would be continued in the vicinity until there was reasonable assurance that no further catches could be made. Occasionally trolling would be terminated, even though more fish could have been caught in the vicinity, in order to avoid delay in transporting viable fish to the ponds at Coconut Island. The general fishing area, shown in figure 1, was

1/ Accurate data on number of lines used per trip are not available in some years.

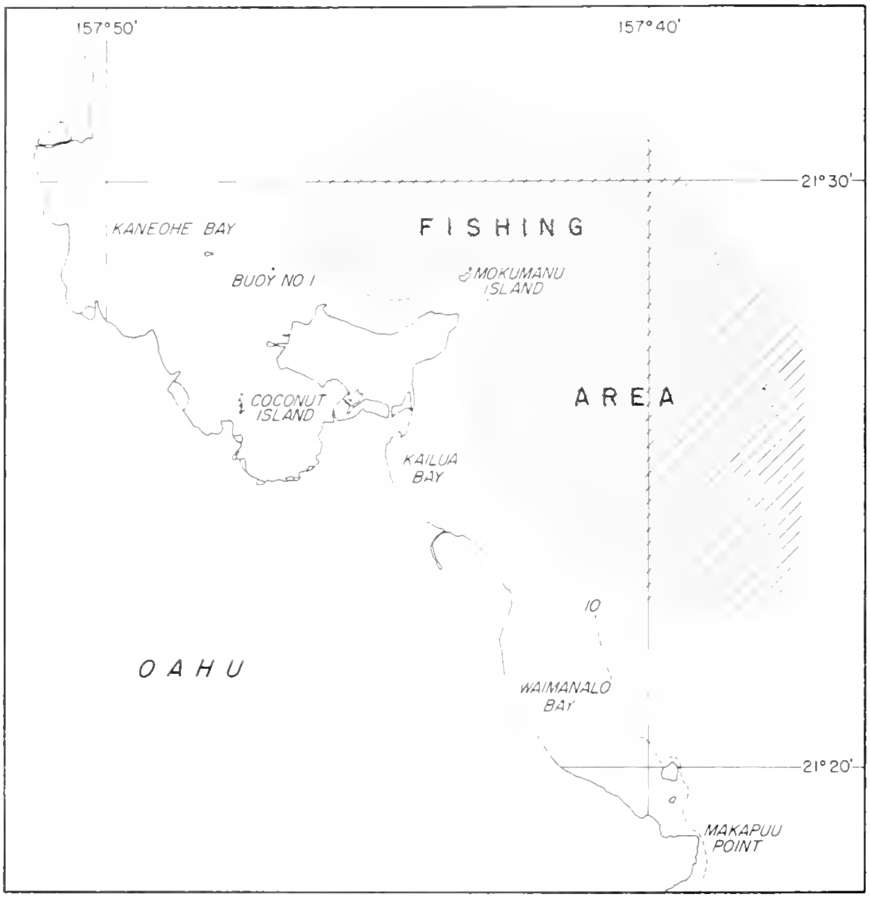

Figure 1.--Fishing area off the northeast coast of Oahu, Territory of Hawaii.

about 4 miles wide and 10 miles long. Only rarely was there fishing outside of this area.

In July and August 1953, 148 skipjack were caught by pole-and-line fishing, using nehu (Stolephorus purpureus) as live bait. These fish were not included in the analysis of troll catch rate, although they were used in certain other analyses in this report.

Fishing was done mostly during the summer months, but some effort was expended in other months of the year. The fishing periods for each year were as follows:

Year	Months of fishing
1951	January to October
1952	June to August; October
1953	June to August
1954	June to December
1955	January; May; July to September

At the laboratory the following determinations were made on the non-viable fish:

length--distance in centimeters from the tip of the closed jaws to the fork of the tail as determined on a measuring board (Hiatt and Hamre 1945)

weight--measured to the nearest one-fourth pound on a dial-type spring scale with weighing pan

sex and maturity--from examination of gonads, with gonad stage indicated by 1, immature; 2, maturing; 3, nearly mature; 4, ripe; and 5, spent

food--stomach contents were removed and preserved in jars containing 10-percent formalin; later, the total amount of food was determined volumetrically, the organisms were identified to the most convenient exclusive category and their percentage by volume of the total was estimated. The number of each type of food item was also recorded. In cases where the fish had gorged itself on a large number of small organisms the number was recorded as "numerous."

For those species which were brought back alive and released into the pond, mostly little tunny and yellowfin, the only sampling data available is an estimate of the weight of each fish. As the estimates are considered reasonably accurate, they are included in the analysis of the weight composition of the catch.

CATCH AND CATCH RATE

Data on the catch according to year, month, and species are included in table 1. In the following discussion our results will be compared with those of Welsh (1949b), who conducted trolling operations in the waters between Hawaii and Kauai, including the present fishing area, from March 1948 to December 1948 and from February 1949 to June 1949. He used both the Salpa and the Territorial Division of Fish and Game's research vessel with fishing methods essentially similar to ours.

Table 1 shows that most of our catch (96 percent) was comprised of four species: skipjack, little tunny, dolphin, and yellowfin. Frigate mackerel, wahoo, and jack made up the remainder. The following tabulation of percentages shows that the same four species formed the bulk of the catch during the earlier period (Welsh 1949b), but that little tunny were of much greater relative abundance:

Species	1951-55	1948-49 (Welsh 1949b)
Skipjack	32.7	8.4
Little tunny	23.7	63.9
Dolphin	23.0	18.4
Yellowfin	16.8	4.2
Frigate mackerel	2.6	-
Wahoo	1.0	3.7
Jack	0.2	1.5

Annual variation in catch rate for all species combined and for each of the four principal species is shown in figure 2. The comparison between years is subject to error because of the variation in number of lines used and because of the variable seasonal coverage.

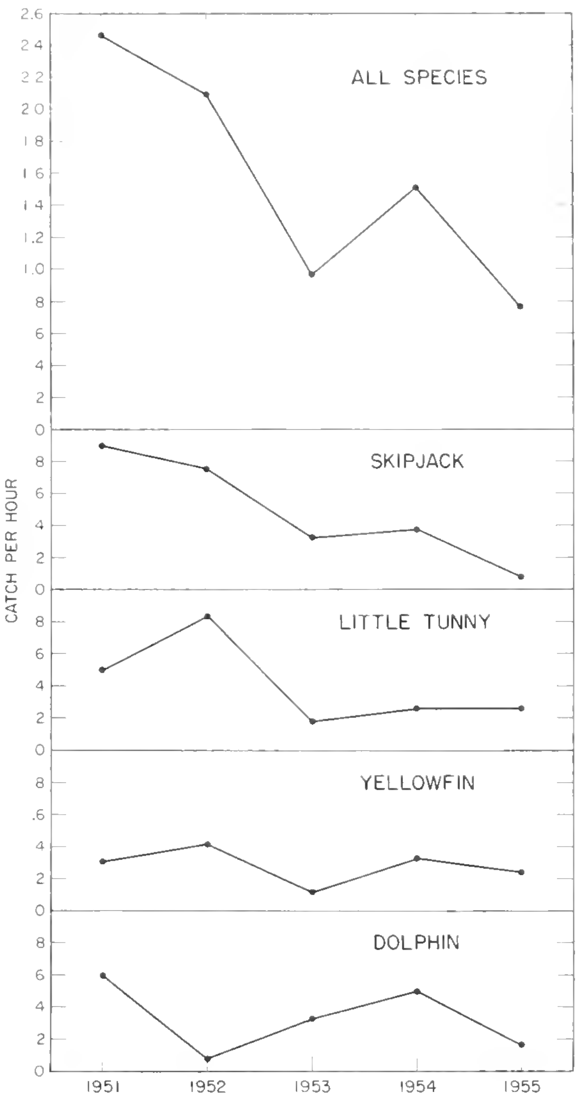

Figure 2.--Average annual catch per hour's trolling for all species combined and for the four most abundant species in the catch over the period 1951 to 1955.

The apparent availability of fish to trolling declined from a high of 2.46 fish per hour in 1951 to 0.97 in 1953, increased to 1.51 in 1954 and then decreased sharply to 0.77 in 1955. The apparent general decline following 1951 persists when the analysis is confined to comparable data for the summer months. The general trend can be attributed chiefly to a decreasing availability of skipjack over the entire period and a low availability of little tunny from 1953 to 1955. These apparent changes, however, may well be

Table 1.--Summary of catches, effort, and catch rate by species, month, and year

Year	Month	Number of trips	Number caught: Skipjack	Little tunny	Yellowfin	Frigate mackerel	Dolphin	Wahoo	Jack	Total	Number of trolling hours	Mean catch per hour
1951	Jan.	2	-	-	-	-	-	-	-	-	3.75	0.00
	Feb.	3	2	-	-	-	1	-	-	3	6.50	0.46
	Mar.	3	1	-	-	-	1	-	-	2	7.50	0.27
	Apr.	4	3	-	-	-	6	1	-	10	13.75	0.73
	May	8	23	5	-	1	24	-	1	54	21.50	2.51
	June	9	38	9	14	12	13	-	-	86	22.75	3.78
	July	8	24	3	4	1	16	-	-	48	20.25	2.37
	Aug.	9	38	15	3	4	23	-	-	83	24.75	3.35
	Sept.	8	19	21	14	4	2	1	-	61	21.75	2.80
	Oct.	6	2	30	16	-	13	-	1	62	23.75	2.61
Total		60	150	83	51	22	99	2	2	409	166.25	2.46
1952	June	10	21	8	6	-	5	-	-	40	23.50	1.70
	July	12	29	29	19	-	-	2	-	79	33.50	2.36
	Aug.	10	12	29	8	-	1	-	-	50	21.25	2.35
	Oct.	1	-	-	1	-	-	-	-	1	3.00	0.33
Total		33	62	66	34	-	6	2	-	170	81.25	2.09
1953	June	13	18	8	7	-	10	-	-	43	32.50	1.32
	July	9	4	4	3	-	16	-	-	27	29.25	0.92
	Aug.	5	5	3	-	-	1	-	-	9	19.75	0.46
Total		27	27	15	10	-	27	-	-	79	81.50	0.97
1954	June	7	5	13	-	-	7	-	-	25	17.50	1.43
	July	6	3	3	1	-	41	-	-	48	17.00	2.82
	Aug.	10	21	5	8	-	10	3	-	47	29.50	1.59
	Sept.	7	11	1	10	-	4	1	-	27	17.50	1.54
	Oct.	8	6	5	18	1	2	-	-	32	24.00	1.33
	Nov.	7	2	6	5	-	-	-	-	13	20.25	0.64
	Dec.	1	-	-	-	-	-	-	-	-	1.50	0.00
Total		46	48	33	42	1	64	4	-	192	127.25	1.51
1955	Jan.	1	1	-	-	-	-	-	-	1	3.00	0.33
	May	3	-	2	1	-	1	-	-	4	9.25	0.43
	July	4	-	3	-	-	3	-	-	6	9.25	0.65
	Aug.	8	3	6	2	-	3	1	-	15	23.75	0.63
	Sept.	3	-	3	10	-	2	-	-	15	8.25	1.82
Total		19	4	14	13	-	9	1	-	41	53.50	0.77

local, i.e., confined to the area of fishing. This is suggested for skipjack, at least, by comparing our trolling results with those of the commercial pole-and-line fishery. Instead of a downward trend over the period 1951 to 1953, in the commercial fishery both 1951 and 1953 were years of high availability whereas 1952 was a year of low availability (Yamashita, In press). The comparison is vitiated in part by differences in size composition of the catches; the troll-caught fish were mostly small, whereas the commercially caught fish were a mixture of small and large sizes.

The average monthly availability of troll-catchable fish for the combined data of the years 1951 to 1955 is shown in figure 3. Although fish were caught in all months of the year except December (when effort was low), the highest availability occurred from May to October. Skipjack and dolphin were taken throughout most of the year but with a peaking of availability during the summer months. The commercial skipjack catch also peaks during the summer months (Yamashita, In press). No little tunny were taken during January to April, but this cannot be regarded as significant in view of the small number of hours trolled during this period. Welsh (1949b) reported good catches of this species during March, April, and May, 1948 and during February and April 1949. The peaking of the availability of yellowfin during September and/or October seems to be a common occurrence, for it was encountered during each of the three years (1951, 1954, and 1955) in which fishing was done during these months.

LURE PREFERENCE

During 1951 and 1953 records were kept of the strikes and catches on the several lures which were used. The lures, as shown in figure 4, were of three general types: (1) "metal squid" with a heavy blue, silver, or red metal body and white rubber arms, (2) "feather" with a heavy white or red metal head or a hollow silver head to which feathers of variegated color are attached, and (3) "rubber squid," with brown pliable rubber body and arms. Other types used to a small extent included a "plastic squid" and a "rubber fish."

Data on catch rate for all species of fish are shown in table 2.[2] By comparing the

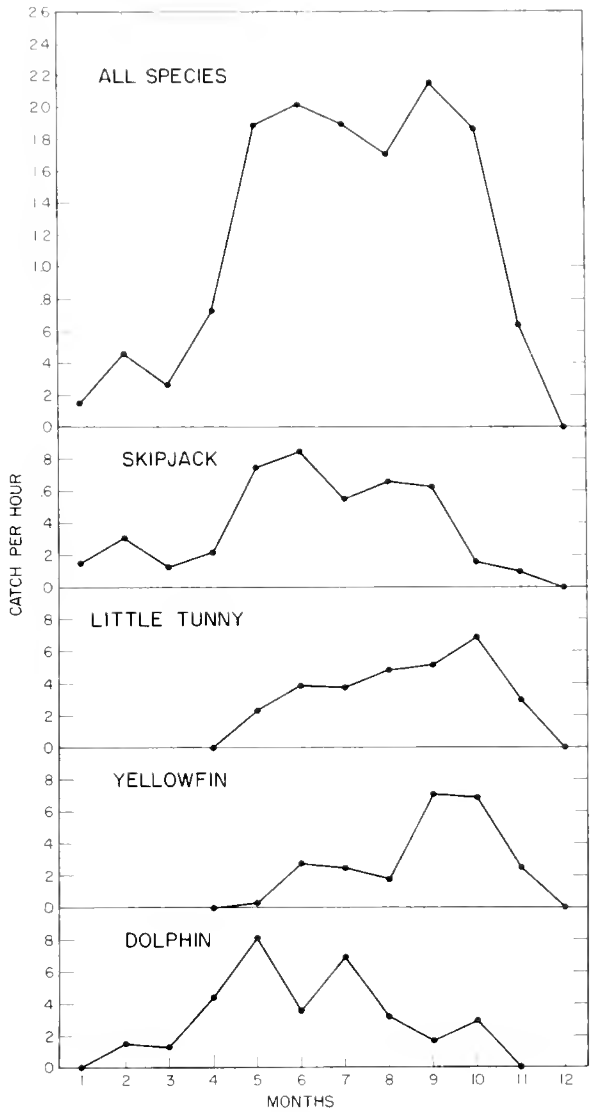

Figure 3.--Average monthly catch per hour's trolling for all species combined and for the four most abundant species in the catch over the period 1951 to 1955.

strikes per lure per hour with the catch per lure per hour, it is at once apparent that about the same proportion of fish was lost from each lure during hauling of the line. Of the 3 lures used most extensively in 1951, the brown rubber squid produced the highest catch rate (0.61 fish per lure per hour), the metal squid with red body the second highest (0.42), followed by the feather lure with white head (0.29). The same order persisted when the data were selected to include only days in which the three lures were used simultaneously, with the following catch rates: 0.66, 0.44, and 0.30. However, in 1953

[2] The fish catch for 1953 does not agree with that of table 1 because lure data were not available for a few days of that year.

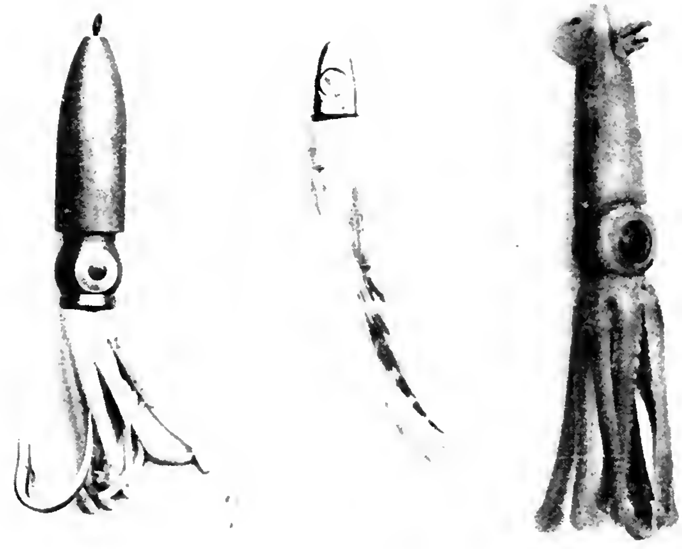

Figure 4.--The three main types of lures used in trolling.

Table 2.--Catch rate for the several lures used in 1951 and 1953

Year	Lure	Hours trolled	Number of strikes	Number of fish caught	Strikes per lure per hour	Catch per lure per hour
1951	Feather: white head	105-1/2	41	31	0.39	0.29
	Feather: red head	13	8	8	0.62	0.62
	Feather: hollow head	43-3/4	25	18	0.57	0.41
	Metal squid: blue body and white rubber arms - "A"	40-3/4	22	19	0.54	0.47
	Metal squid: silver body and white rubber arms - "B"	50-1/4	27	19	0.54	0.38
	Metal squid: red body and white rubber arms - "D"	288	148	121	0.51	0.42
	Metal squid: - "L"	29-1/2	12	8	0.41	0.27
	Metal squid: - "Y"	5-1/4	1	-	0.19	-
	Rubber squid: brown body and arms - "S"	283	213	174	0.75	0.61
	Plastic squid: transparent body and arms - "Z"	33	8	7	0.24	0.21
	Rubber fish: green	9-3/4	4	4	0.41	0.41
1953	Feather: white head	36-1/4	17	13	0.47	0.36
	Metal squid: blue body and white rubber arms - "A"	2-1/2	1	1	0.44	0.44
	Metal squid: red body and white rubber arms - "D"	61-1/4	22	17	0.36	0.28
	Metal squid: "Lai" (Scomberoides sp.) skin skirt	20-1/2	1	1	0.05	0.05
	Rubber squid: brown body and arms - "S"	95-1/2	42	33	0.44	0.35

neither the gross nor the selected data showed the same order. Ranged as above, i.e., brown rubber squid, metal squid with red body, and feather lure, the catch rates were as follows: 0.35, 0.28, and 0.36 for gross data (table 2) and 0.26, 0.18, and 0.26 for selected data. There is no clear evidence that one lure was more attractive than another with respect to form. Similarly there is no significant indication that red lures were more attractive than those of other color, as suggested by Welsh (1949b).

The number of fish caught according to species and lure is shown in table 3 for the four more important species and the three most used lures. In the 1951 data there is the suggestion of a differential attraction; for example, the rubber squid seemed to catch relatively more yellowfin than the other lures. However, the interaction chi-square for the 4 x 3 contingency table is not significant. Moreover, the rather meager 1953 data give no hint of lure preference. Apparently all three lures were about equally attractive to all four species.

SIZE COMPOSITION

The weight distributions of troll-caught skipjack, little tunny, yellowfin, and dolphin are given respectively in tables 4 to 7 and will be discussed below. Formulae for the conversion of weight to length will be given in a later section.

The weight distribution of the remainder of the catch is dismissed with the following notations: 23 frigate mackerel averaged 1-1/2 pounds and ranged from 1 to 2-1/2 pounds; 9 wahoo averaged 26 pounds and ranged from 20 to 33-1/2 pounds; 2 jacks weighed 4 and 8 pounds.

Skipjack

During the 5-year period 288 skipjack (excluding pole-and-line-caught fish) were measured. They averaged 4.9 pounds (47.5 cm.) and ranged from 2 to 17 pounds (30 to 70 cm.) (table 4).

From the monthly weight frequency histograms shown in figure 5 for the combined data of all years, it is evident that the majority of the fish ranged from 3 to 6 pounds with a pronounced mode at 4 pounds. Modal groups of similar size (varying from 44 to 50 cm., i.e., 3-1/2 to 6 pounds) were noted in the commercial catch by Brock (1954), and were considered most likely to be 1-year-olds, i.e., fish near the end of their first or the beginning of their second year of life. As Brock's data indicate that spawning extends over a 7-month period (February to September), a considerable size range of the "1-year-olds" would be expected. Presumably the majority of the troll-caught fish may be placed in this age category.

In figure 5 there is no apparent progression of the modal groups from month to month. This indicates that as the fish grow larger, they no longer frequent the inshore habitat that was fished. That they occur offshore is shown by modal groups ranging from 3-1/2 to 29 pounds (44 to 81 cm.) in samples from the commercial fishery examined by Brock (1954).

Table 3.--Number of fish of the more important species taken by each of the three most used lures

Year	Lure	Skipjack	Little tunny	Yellowfin	Dolphin	Total
1951	Feather: white head	12	10	3	5	30
	Metal squid: red body and white arms	34	31	9	34	108
	Rubber squid: brown body and arms	63	37	28	38	166
	Total	109	78	40	77	304
1953	Feather: white head	4	2	2	5	13
	Metal squid: red body and white arms	5	4	3	5	17
	Rubber squid: brown body and arms	11	6	5	11	33
	Total	20	12	10	21	63

Table 4.--Size frequency of troll-caught skipjack (1951-55)

Year	Month	Pounds																	Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1951	Feb.	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	2
	Mar.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
	Apr.	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	2
	May	-	-	-	10	3	7	1	1	-	-	-	-	-	-	-	-	-	22
	June	-	-	4	12	10	7	2	1	1	-	1	-	-	-	-	-	-	38
	July	-	-	5	6	6	3	2	1	1	-	-	-	-	-	-	-	-	24
	Aug.	-	-	1	19	10	5	2	-	1	-	-	-	-	-	-	-	-	38
	Sept.	-	-	2	13	1	3	-	-	-	-	-	-	-	-	-	-	-	19
	Oct.	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	2
Total		-	-	12	60	32	29	7	4	3	-	1	-	-	-	-	-	-	148
1952	June	-	-	1	10	6	3	-	-	-	-	-	1	-	-	-	-	-	21
	July	-	-	1	17	4	4	2	-	-	-	-	-	-	-	-	-	-	29
	Aug.	-	-	2	8	1	3	-	-	-	-	-	-	-	-	-	-	-	12
Total		-	-	3	35	11	10	2	-	-	-	-	1	-	-	-	-	-	62
1953	June	-	-	7	10	1	-	-	-	-	-	-	-	-	-	-	-	-	18
	July	-	-	1	-	1	2	-	-	-	-	-	-	-	-	-	-	-	4
	Aug.	-	-	2	1	2	-	-	-	-	-	-	-	-	-	-	-	-	5
Total		-	-	10	11	4	2	-	-	-	-	-	-	-	-	-	-	-	27
1954	June	-	-	-	-	4	-	-	1	-	-	-	-	-	-	-	-	-	5
	July	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	3
	Aug.	-	-	2	5	-	7	3	2	-	2	-	-	-	-	-	-	-	21
	Sept.	-	-	-	4	3	1	-	1	1	1	-	-	-	-	-	-	-	11
	Oct.	-	1	2	2	-	-	1	-	-	-	-	-	-	-	-	-	-	6
	Nov.	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Total		-	3	4	13	8	8	4	4	1	3	-	-	-	-	-	-	-	48
1955	Jan.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
	Aug.	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Total		-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1	3

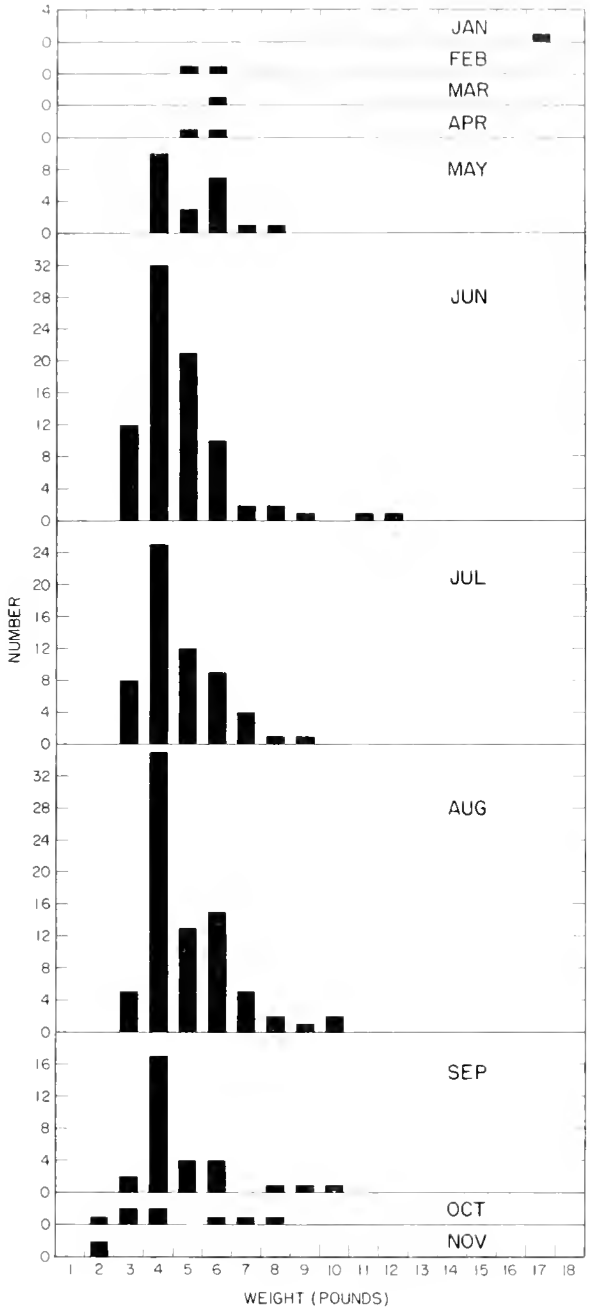

Figure 5.--Weight composition of skipjack by months for the combined data of 1951 to 1955.

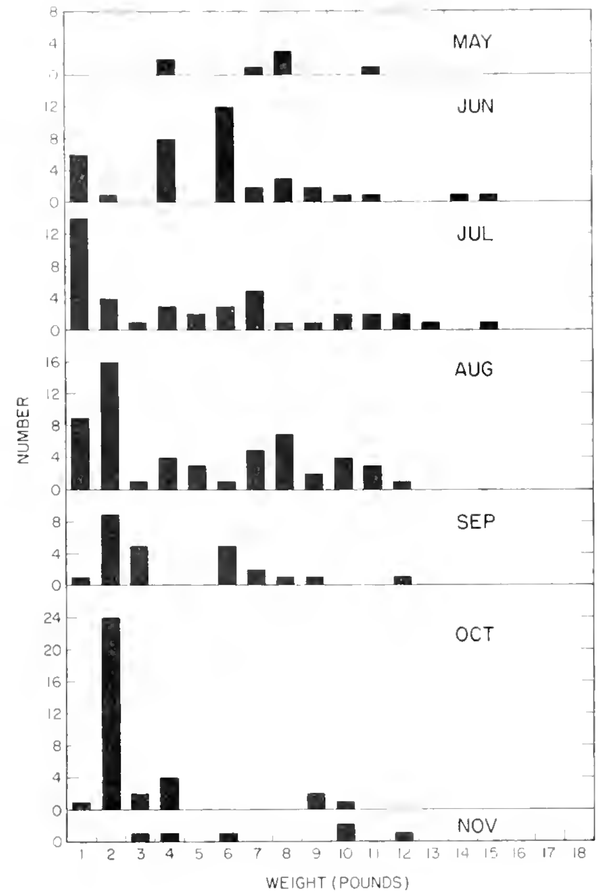

Figure 6.--Weight composition of little tunny by months for the combined data of 1951 to 1955.

Little Tunny

Measurements were made of 208 little tunny, which averaged 4.8 pounds (48 cm.) and ranged from about 1 to 15 pounds (30 to 70 cm.).

The weight composition by months for the combined data of all years, shown in figure 6, suggests a slight progression of modes initially located at 1 and 6 pounds in June. However, the progression may be an artifact caused by combining variable annual data, for it is not indicated in the data for individual years (table 5). Rather, these data show a strong influx of 2-pound (36 cm.) fish during August, September, and October, 1951, and of 1-pound fish (30 cm.) during June, July, and August, 1952. There are relatively small numbers of 1- and 2-pound fish in other years. Fish of 6 to 8 pounds (50 to 57 cm.) seem to form a second modal group in 1951, 1954, and 1955, whereas a third modal group at 10 to 11 pounds (60 to 63 cm.) may be present in 1952. Thus the presence of at least two and possibly three age groups is indicated. Further discussion is not warranted because of the paucity of the present data.

Table 5.--Size frequency of troll-caught little tunny (1951-55)

Year	Month	Pounds																		Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1951	May	-	-	-	2	-	-	-	3	-	-	-	-	-	-	-	-	-	-	5
	June	-	-	-	-	-	6	1	1	-	-	-	-	-	-	1	-	-	-	9
	July	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	3
	Aug.	-	4	-	-	-	1	4	4	-	-	-	-	-	-	-	-	-	-	13
	Sept.	1	8	4	-	-	3	2	1	1	-	-	1	-	-	-	-	-	-	21
	Oct.	1	22	2	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	29
Total		2	34	6	4	-	10	10	9	2	1	-	1	-	-	1	-	-	-	80
1952	June	3	1	-	1	-	-	-	-	-	1	1	-	-	1	-	-	-	-	8
	July	13	3	1	2	-	2	-	1	-	2	2	2	1	-	-	-	-	-	29
	Aug.	9	11	-	2	3	-	-	-	-	2	1	1	-	-	-	-	-	-	29
Total		25	15	1	5	3	2	-	1	-	5	4	3	1	1	-	-	-	-	66
1953	June	2	-	-	4	-	2	-	-	-	-	-	-	-	-	-	-	-	-	8
	July	1	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	4
	Aug.	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Total		3	1	1	6	2	2	-	-	-	-	-	-	-	-	-	-	-	-	15
1954	June	1	-	-	3	-	4	1	2	2	-	-	-	-	-	-	-	-	-	13
	July	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	3
	Aug.	-	-	-	-	-	-	-	1	1	1	2	-	-	-	-	-	-	-	5
	Sept.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
	Oct.	-	2	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	5
	Nov.	-	-	1	1	-	1	-	-	-	2	-	1	-	-	-	-	-	-	6
Total		1	2	1	6	-	7	3	3	4	3	2	1	-	-	-	-	-	-	33
1955	May	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	2
	July	-	1	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	3
	Aug.	-	-	-	1	-	-	1	2	1	1	-	-	-	-	-	-	-	-	6
	Sept.	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3
Total		-	2	1	1	-	1	2	2	2	1	1	-	-	-	1	-	-	-	14

Yellowfin

Measurements were made on 147 yellowfin, which averaged 6.5 pounds (54 cm.) and ranged from 1 to 18 pounds (29 to 72 cm.) (table 6).

The monthly data shown in figure 7 indicate the progression of a mode starting at about 5 or 6 pounds in June and advancing to about 10 pounds in November. This apparent growth agrees well with that observed for a yellowfin held in captivity, which increased in weight from about 5 pounds when it started feeding on July 2, 1951, to 11 pounds when it died on January 13, 1952 (Tester 1952).

Based on a study of the ovaries, June (1953) concludes that yellowfin in Hawaiian waters spawn from the middle of May to the end of October. Moore (1951), from a study of the weight composition of the commercial pole-and-line and longline catches, concludes that yellowfin attain an average weight of about 7 pounds (54 cm.) by the end of their first year and an average weight of 46 pounds (103 cm.) by the end of their second year of life. Our data agree well with Moore's estimate of the weight at the end of the first year, i.e., the mean weight of our troll-caught fish is 6.8 pounds during August, assuming this month to be the middle of the spawning period. However, fish which average 7 pounds in August and 10 pounds in November would have to grow very rapidly during the winter, spring, and early summer to attain a mean weight of 46 pounds during the following August. It may be that our estimate of 10 pounds in November is biased by selective sampling, i.e., the fish may tend to move out of the area as they get larger, although the advancing mode noted above seems to indicate the contrary.

Dolphin

Measurements were made on 198 dolphin which averaged 6.8 pounds (72 cm.) and ranged from 1-1/2 to 37 pounds (41 to 121 cm.) (table 7).

From the monthly weight distribution, shown in figure 8, there is some indication of bimodality

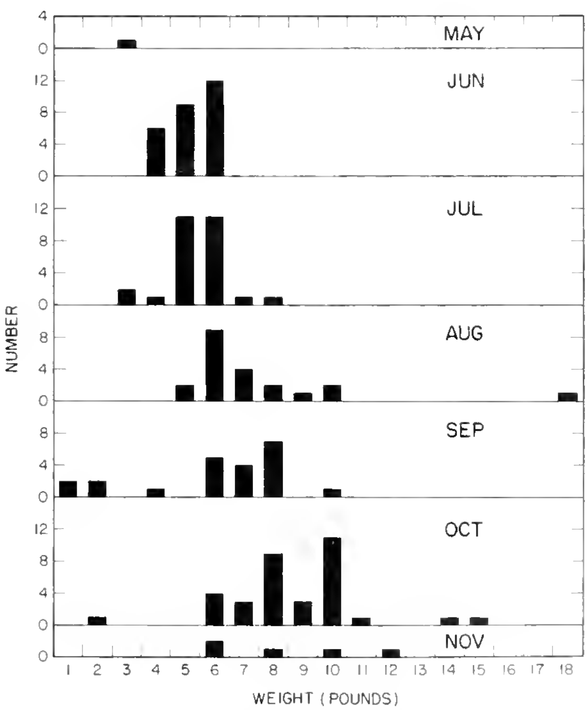

Figure 7.--Weight composition of yellowfin by months for the combined data of 1951 to 1955.

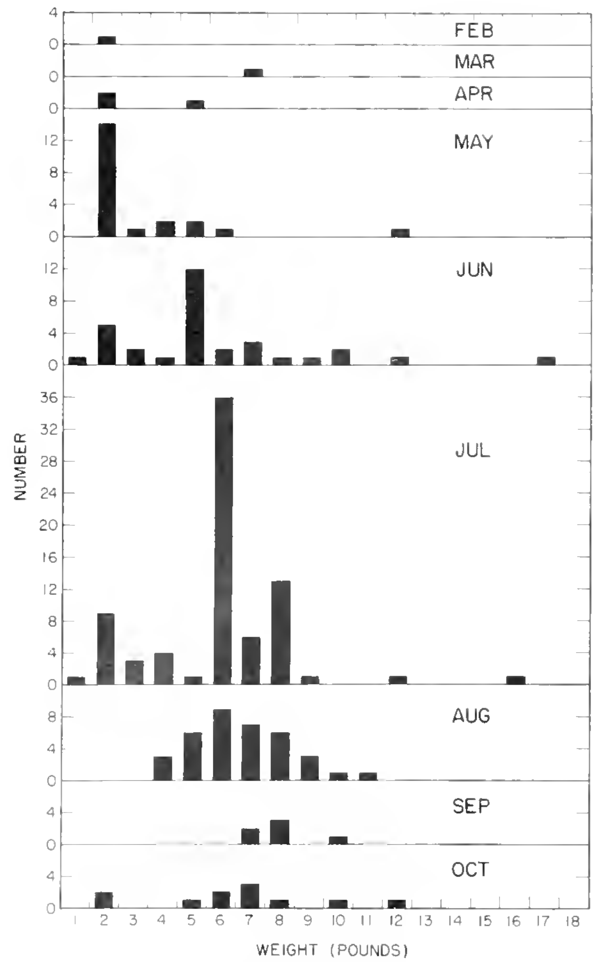

Figure 8.--Weight composition of dolphin by months for the combined data of 1951 to 1955.

Table 6.--Size frequency of troll-caught yellowfin (1951-55)

Year	Month	Pounds																		Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1951	June	-	-	-	-	9	5	-	-	-	-	-	-	-	-	-	-	-	-	14
	July	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	4
	Aug.	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	3
	Sept.	2	2	-	-	-	2	2	6	-	-	-	-	-	-	-	-	-	-	14
	Oct.	-	1	-	-	-	2	-	6	1	5	-	-	-	-	-	-	-	-	15
Total		2	3	2	-	9	13	3	12	1	5	-	-	-	-	-	-	-	-	50
1952	June	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
	July	-	-	-	1	10	8	-	-	-	-	-	-	-	-	-	-	-	-	19
	Aug.	-	-	-	-	2	3	1	-	-	2	-	-	-	-	-	-	-	-	8
	Oct.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Total		-	-	-	7	12	11	1	-	-	3	-	-	-	-	-	-	-	-	34
1953	June	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	7
	July	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	3
Total		-	-	-	-	1	7	1	1	-	-	-	-	-	-	-	-	-	-	10
1954	July	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
	Aug.	-	-	-	-	-	2	2	2	1	-	-	-	-	-	-	-	-	1	8
	Sept.	-	-	-	1	-	3	2	1	-	1	-	-	-	-	-	-	-	-	8
	Oct.	-	-	-	-	-	2	3	3	2	5	1	-	-	1	1	-	-	-	18
	Nov.	-	-	-	-	-	2	-	1	-	1	-	1	-	-	-	-	-	-	5
Total		-	-	-	1	-	10	7	7	3	7	1	1	-	1	1	-	-	1	40
1955	May	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Aug.	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2
	Sept.	-	-	-	-	-	4	4	-	-	-	2	-	-	-	-	-	-	-	10
Total		-	-	1	-	-	6	4	-	-	-	2	-	-	-	-	-	-	-	13

Table 7.--Size frequency of troll-caught dolphin (1951-55)

Year	Month	Pounds																																					Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	
1951	Feb.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Mar.	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Apr.	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
	May	-	14	1	2	2	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	23
	June	-	-	-	1	10	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
	July	-	1	-	1	1	6	1	5	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
	Aug.	-	-	-	-	4	5	5	5	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
	Sept.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	2
	Oct.	-	-	-	-	1	2	3	1	-	1	-	1	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
Total		-	18	1	4	19	14	12	11	1	2	-	3	-	-	-	-	-	-	-	1	1	1	-	1	-	1	-	-	1	-	-	1	-	-	-	-	-	92
1952	June	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	5
	Aug.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Total		-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	6
1953	June	1	1	2	-	2	2	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
	July	-	3	3	3	-	5	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
	Aug.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Total		1	4	5	3	2	7	1	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27
1954	June	-	4	-	-	-	-	-	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
	July	1	5	-	-	-	23	5	6	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41
	Aug.	-	-	-	2	1	4	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
	Sept.	-	-	-	-	-	-	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
	Oct.	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Total		1	11	-	2	1	27	7	10	2	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64
1955	May	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	July	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
	Aug.	-	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
	Sept.	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Total		-	-	-	1	1	2	2	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9

in fish less than 10 pounds in weight, with one mode at 2 pounds (46 cm.) and a second ranging from 5 to 8 pounds (64 to 76 cm.). Only a few specimens larger than 10 pounds were taken over the period.

WEIGHT-LENGTH RELATIONS

Weight-length relations were calculated for each of the four most abundant species according to the usual formula relating weight, W (in pounds), with length, L (in centimeters):

$$W = aL^b$$

$$\log W = \log a + b \log L$$

The constants log a and b as determined by least squares are given in table 8, along with other pertinent data. Although the numbers of fish are small, the calculations are included because samples of small fish are usually unavailable from commercial catches.

With the dolphin, unlike the tunas, there was an indication of sexual dimorphism in the weight-length relation. Beyond 6 pounds (68 cm.) the males tended to be heavier for a given length than the females (fig. 9). This is probably related to a well-known sexual dimorphism in the shape of the head, the males having a much higher forehead than the females (Schuck 1951).

SEX AND MATURITY

Summary data on sex and gonad maturity of six species of fish are given in table 9. The numbers of fish do not agree with those of previous tables as many of the fish, particularly little tunny, yellowfin, and dolphin, were transferred alive to holding ponds and consequently were not examined in respect to sex or stage of maturity.

Skipjack

Of 347 troll- and pole-and-line-caught skipjack, 3 had gonads so undeveloped that the sex could not be determined. The remainder comprised 61.0 percent males and 39.0 percent females. The departure from a 1:1 ratio was statistically significant as determined by the chi-square test.

Brock (1954) points out that, in his samples from the commercial catch, males were significantly more abundant than females in the fall of the year (September to December) but not in spring (March to May) nor in the summer (June to August). When our data are arranged according to season (table 10) there is a significant preponderance of males in the summer. At present we can offer no satisfactory explanation of these differences in sex ratio.

Of the 344 fish which could be sexed, 12 were recorded as "immature" (gonad stage 1) and 4 were "spent" (stage 5). Some of the fish recorded as "immature" may have been spent, for they ranged in weight from 3 to 17 pounds. The four fish classed as "spent" ranged from 5 to 7 pounds. Despite the apparent confusion in separating these two stages, it is evident (table 9) that the majority of the fish were "maturing" or "nearly mature" and that a few may have spawned. Considering their size and assumed age, it seems safe to conclude with Brock that skipjack may mature in 1 year.

Little Tunny

It was impossible to determine the sex of 8 small (1 to 2 pounds) little tunny. Of the remaining 93 fish, males were slightly but not significantly less numerous than females, forming 48.4 percent of the catch.

The gonads of most of the fish were in the "maturing" condition (stages 2 and 3). The 7

Table 8.--Number of fish, size range, and constants in the weight-length relations (log W = log a + b log L) for four species of troll-caught fish

Species	Number of fish	Size range (pounds)	Log a	b
Skipjack	268	2-1/2 to 12-1/2	-4.7262	3.2164
Little tunny	101	1 to 15	-4.6229	3.1544
Yellowfin	59	1 to 17-3/4	-4.2015	2.9045
Dolphin	133	1-1/2 to 12	-4.1966	2.7111

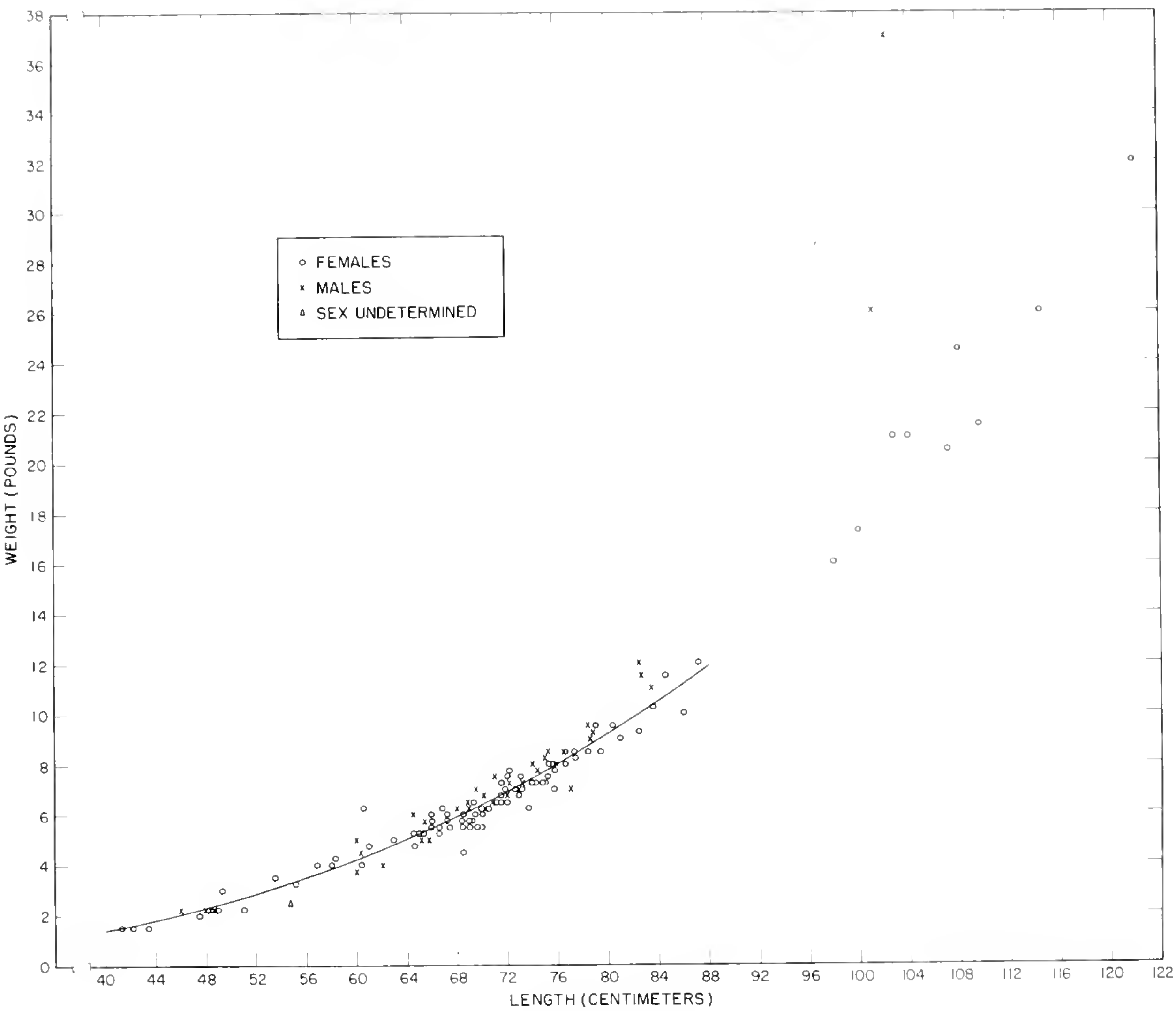

Figure 9. --Weight-length relation of dolphin.

fish classed as "spent" (stage 5) comprised 2 fish of about 5 pounds and 5 fish of 10 to 11 pounds.

Yellowfin

In contrast to skipjack and little tunny, most of the yellowfin were judged to be immature. Of the 59 fish examined for sex, 14 had gonads so immature that the sex could not be ascertained. The remainder were mostly "immature" (stage 1) with a few "maturing" (stage 2). In view of the size of these fish and their presumed age, it would seem doubtful that yellowfin mature by the end of their first year.

Of the yellowfin which could be sexed, males were in the minority (45 percent), although the ratio did not deviate significantly from 1:1. This is in agreement with the sex ratio of the smaller (less than 80 to 90 pounds) fish taken by longline near the Equator, but it is in contrast to the sex ratio for the larger longline-caught fish both near the Equator and in Hawaiian waters, in which males strongly predominate (Iverson 1956). The reason for the change in sex ratio is obscure.

Dolphin

The dolphin showed a significant deviation from the 1:1 ratio, with males (28.5 percent) much less numerous than females (71.5 percent). All males were either "immature" (stage 1) or in early stages of maturing (stage 2). The females included stages ranging from "immature" to "mature" (stage 4). The fish classed as "immature" ranged from 1-1/2 to 8-1/2 pounds. Of the 12 fish classed as "mature" (but not "running ripe")

Table 9. --Sex and maturity stage of the various species

Species	Sex	Maturity stage 1 (immature)	2 (maturing)	3 (nearly mature)	4 (ripe)	5 (spent)	All
Skipjack	Males	6	43	158	2	1	210
	Females	6	18	97	10	3	134
	Undetermined	-	-	-	-	-	(3)
	Total	12	61	255	12	4	344
Little tunny	Males	3	13	24	1	4	45
	Females	11	12	17	5	3	48
	Undetermined	-	-	-	-	-	(8)
	Total	14	25	41	6	7	93
Yellowfin	Males	18	2	-	-	-	20
	Females	19	6	-	-	-	25
	Undetermined	-	-	-	-	-	(14)
	Total	37	8	-	-	-	45
Dolphin	Males	18	24	-	-	-	42
	Females	36	20	37	12	-	105
	Total	54	44	37	12	-	147
Frigate mackerel	Males	1	3	2	1	-	7
	Females	-	4	6	-	-	10
	Total	1	7	8	1	-	17
Wahoo	Males	-	5	-	-	-	5
	Females	-	1	1	1	-	3
	Total	-	6	1	1	-	8

Table 10. --Number of male and female skipjack taken during four periods of the year and the probability that the sex ratio is not significantly different from 1 : 1 as determined by a chi-square test

Sex	December-February	March-May	June-August	September-November	Total
Male	0	12	174	24	210
Female	3	13	105	13	134
Both	3	25	279	37	344
Probability		>0.05	<0.01	>0.05	<0.01

7 ranged from 5 to 8 pounds and 5 ranged from 10 to 32 pounds.

There is considerable diversity in the proportion of males and females between schools. For example, 11 females and 6 males were caught from a school of 5- to 9-pound fish on August 8, 1951. In contrast, of 31 fish taken from a school of 5- to 9-pound fish on July 12, 1954, 29 were females and only 2 were males.

Other Fish

We have few data on frigate mackerel and wahoo. It might be noted, however, that the 17 frigate mackerel, which were all about 1-1/2 pounds in weight, were mostly at stages 2 and 3, but included one male (2-1/2 pounds) classed as "mature." The 8 wahoo, which ranged from 20 to 33 pounds, were mostly at stage 2, but the largest specimen, a female, was classed as "mature."

FOOD

The results of the stomach analyses for skipjack, little tunny, yellowfin, and dolphin are presented in tables 11, 12, 13, and 14, respectively. The numbers of stomachs examined were as follows: 67 skipjack, 32 little tunny, 15 yellowfin, 52 dolphin, 3 wahoo, and 2 frigate mackerel. The stomach collections were made in 1951, 1952, and 1953.

The advantages and disadvantages of the various methods of evaluating food components have been discussed by Reintjes and King (1953). They conclude "....that those food items that rank large in number, large in volume, and high in frequency of occurrence are important foods--at the time and in the area sampled." Data for all three of these methods of analysis have been incorporated into the above-mentioned tables.

In identifying the ingested fishes, the following references proved to be helpful: Brock (1950), Jordan and Evermann (1905), and Smith (1949). The scientific names of the food fishes referred to in this report are for the most part in accordance with Brock (1950). Identification of the invertebrates was aided by reference to Berry (1914), Edmondson (1946), Hiatt (no date), and Townsley (1950).

We wish to thank Drs. A. H. Banner and D. W. Strasburg for their help in the identification of various organisms found in the stomachs.

The food of these troll-caught fishes is composed almost entirely of fishes, cephalopods, and crustaceans. This is in agreement with the results of other investigators who have noted the stomach contents of these same pelagic species in Hawaii and elsewhere (Imamura 1949, Nakamura 1949, Reintjes and King 1953, Ronquillo 1953, Shapiro 1948, Welsh 1949a, and others). A discussion of the food of each species follows.

Skipjack

For skipjack ranging in size from 40.0 to 61.1 cm. the most important food item by volume appeared to be cephalopods (squid), with fishes second in importance (table 11). Not only did squid comprise the largest volume, but the numbers found were also high, lending further support to their importance. This is in contrast to results which were obtained by Welsh (1949a) from samples collected in waters adjacent to Oahu but not confined to the area delineated in figure 1. In 21 stomachs he found fishes to be the most important food by volume. In our samples fishes did have the highest frequency of occurrence.

Of the crustaceans the stomatopod larvae comprised the largest volume and highest occurrence. Some of the skipjack were found to be gorged with stomatopods. Some were also found to be gorged with crab megalops.

Little Tunny

The results for the little tunny ranging in size from 31.2 to 66.8 cm. show that fishes comprised the greatest volume of food with crustaceans next in rank (table 12). The 196 samples examined by Welsh (1949a) for this same species showed just the opposite.

Gorging on stomatopods and crab megalops was also observed for the little tunny.

Yellowfin

In the food of yellowfin ranging in size from 47.4 to 58.9 cm., squid provided the greatest bulk (table 13). Welsh (1949a) also found that squid were important as food for yellowfin around the island of Oahu. Reintjes and King (1953) found that cephalopods were relatively unimportant in the food of yellowfin caught at the surface near land in the region of the Line and Phoenix islands.

The presence of seahorses (Syngnathidae) in the stomach contents of yellowfin in Hawaiian waters has been previously reported by Herald (1949). As seen in table 13, seahorses were

Table 11.--Stomach contents of 67 troll-caught skipjack (number of stomachs: 49 in 1951, 10 in 1952, 8 in 1953)

Food organisms	Total volume		Stomachs in which occurred		Number of organisms
	cm.^{3}	Percent	Number	Percent	
Fishes					
Exocoetidae					
Parexocoetus brachypterus	0.7	---*	1	1.5	1
Sphyraenidae					
Sphyraena helleri	6.0	0.2	1	1.5	1
Serranidae					
Unidentified sp.	13.3	0.5	2	3.0	14
Bramidae					
Collybus drachme	166.2	6.3	7	10.4	33
Carangidae					
Unidentified sp.	264.0	10.0	10	14.9	18
Chaetodontidae					
Unidentified sp.	2.3	---*	1	1.5	4
Acanthuridae					
Unidentified sp.	7.1	0.3	2	3.0	3
Unidentified fish remains	225.5	8.6	32	47.8	88
Total fishes	685.1	26.0			
Cephalopoda					
Decapoda					
Ommastrephidae					
Ommastrephes hawaiiensis	810.6	30.8	13	19.4	41
Unidentified sp.	594.9	22.6	12	17.9	33
Sepiolidae					
Heteroteuthis hawaiiensis	247.4	9.4	4	6.0	Numerous
Unidentified squid	116.0	4.4	11	16.4	22
Total decapod cephalopods	1768.9	67.2			
Crustacea					
Stomatopoda					
Unidentified larvae	161.4	6.1	25	37.3	Numerous
Decapoda					
Unidentified shrimp	0.1	---*	1	1.5	7
Unidentified anomuran	0.1	---*	1	1.5	1
Brachyuran megalopa	15.1	0.6	20	30.0	Numerous
Total crustaceans	176.7	6.7			
Grand total	2630.7				

* Less than 0.1 percent.

Table 12.--Stomach contents of 32 troll-caught little tunny (number of stomachs: 20 in 1951, 11 in 1952, 1 in 1953)

Food organisms	Total volume		Stomachs in which occurred		Number of organisms
	cm.^{3}	Percent	Number	Percent	
Fishes					
Syngnathidae					
Hippocampus sp.	1.0	---*	2	6.2	2
Serranidae					
Unidentified sp.	516.3	28.3	8	25.0	Numerous
Priacanthidae					
Priacanthus cruentatus	26.2	1.4	1	3.1	1
Unidentified sp.	121.2	6.6	1	3.1	8
Bramidae					
Collybus drachme	30.3	1.7	1	3.1	1
Carangidae					
Decapturus sp.	308.0	16.9	2	6.2	Numerous
Unidentified sp.	151.2	8.3	3	9.4	6
Ostraciidae					
Lactoria diaphanus	2.3	0.1	3	9.4	6
Pegasidae					
Pegasus papilio	0.4	---*	1	3.1	1
Unidentified fish remains	518.1	28.4	20	62.5	Numerous
Total fishes	1675.0	91.8			
Cephalopoda					
Decapoda					
Unidentified squid	1.3	---*	1	3.1	1
Total decapod cephalopods	1.3	---*			
Crustacea					
Stomatopoda					
Unidentified larvae	28.4	1.6	7	21.9	Numerous
Decapoda					
Unidentified caridean shrimp	101.0	5.5	2	6.2	Numerous
Penaeidae					
Unidentified sp.	1.0	---*	1	3.1	1
Unidentified reptantian larvae	1.8	---*	1	3.1	4
Brachyuran megalopa	16.6	0.9	5	15.6	Numerous
Total crustaceans	148.8	8.2			
Grand total	1825.1				

* Less than 0.1 percent.

Table 13.--Stomach contents of 15 troll-caught yellowfin (number of stomachs: 10 in 1951, 4 in 1952, 1 in 1953)

Food organisms	Total volume		Stomachs in which occurred		Number of organisms
	cm.^{3}	Percent	Number	Percent	
Fishes					
Syngnathidae					
Hippocampus histrix	11.3	1.6	3	20.0	10
Hippocampus sp.	29.4	4.2	5	33.3	Numerous
Bramidae					
Unidentified sp.	86.5	12.4	1	6.7	5
Blennidae					
Runula sp.	0.4	---*	1	6.7	1
Dactylopteridae					
Dactyloptena orientalis	2.3	0.3	1	6.7	1
Balistidae					
Balistapus sp.	3.5	0.5	1	6.7	1
Monacanthidae					
Unidentified sp.	4.6	0.7	1	6.7	1
Ostraciidae					
Lactoria diaphanus	9.6	1.4	3	20.0	10
Lactoria sp.	0.4	---*	1	6.7	1
Tetrodontidae					
Arothron sp.	0.2	---*	1	6.7	1
Pegasidae					
Pegasus papilio	10.9	1.6	4	26.7	14
Unidentified fish remains	40.5	5.8	9	60.0	Numerous
Total fishes	199.6	28.6			
Cephalopoda					
Decapoda					
Ommastrephidae					
Ommastrephes hawaiiensis	380.1	54.4	4	26.7	9
Unidentified squid	48.8	7.0	6	40.0	Numerous
Total decapod cephalopods	428.9	61.4			
Crustacea					
Stomatopoda					
Unidentified larvae	59.7	8.6	15	100.0	Numerous
Euphausiacea					
Euphausidae					
Unidentified sp.	0.4	---*	1	6.7	1
Decapoda					
Unidentified caridean shrimp	1.0	0.1	1	6.7	3
Palinuridae					
Panulirus japonicus	1.0	0.1	1	6.7	1
Brachyuran megalopa	7.6	1.1	6	40.0	26
Total crustaceans	69.7	10.0			
Grand total	698.2				

* Less than 0.1 percent.

the most common identifiable group of the food fishes utilized by the yellowfin in our samples.

Dolphin

An examination of the stomachs of 52 dolphin ranging in size from 41.3 to 121.0 cm. showed the importance of fish in their diet (table 14). Cephalopods and crustaceans together comprised less than 3 percent of the total volume. Flyingfishes (Exocoetidae) appeared to be particularly significant both in volume and occurrence. Welsh's study of 58 stomach samples showed almost identical results. Flyingfish have also been reported in the food of dolphin caught in North Carolina waters (Schuck 1951).

Cymothoid isopods were found in two stomachs. Members of this family are known to be parasitic on fish. It is possible that they were parasitic on the food fishes and thus incidentally ingested. One of the stomachs containing cymothoid isopods also contained a monacanthid, an exocoetid, and unidentified fish remains. The other contained exocoetids and a syngnathid in addition to the isopod.

A further item of interest was the presence of a coral rock about 1/2 $cm.^3$ in volume in one of the stomachs. The rock may have been ingested accidentally while feeding on reef-dwelling forms. Other contents of this stomach were penaeid shrimps, stomatopod larvae, a crab megalopa, remains of a fish, and remains of a squid.

Wahoo

All three of the stomachs examined contained remains of fish. One of the food fishes was identified as a carangid. The sizes of these three wahoo were 104.1, 111.1, and ca. 123 cm.

Frigate Mackerel

Of the two frigate mackerel stomachs examined, one contained numerous crab megalops and stomatopod larvae, while the other contained 8 crab megalops, numerous stomatopod larvae, 2 anomuran larvae, and a small octopus. The frigate mackerel were 33.2 and 36.6 cm. in length.

General Discussion

The relative importance by volume of the three major food categories for the skipjack, little tunny, yellowfin, and dolphin is portrayed in figure 10. The little tunny and dolphin appear to rely heavily upon fishes for food, while the skipjack and yellowfin have a more varied diet utilizing all three of the major food groups.

The similarity between the diets of skipjack and yellowfin and between little tunny and dolphin suggests the likelihood of interspecific competition. Evidence of competition for food between skipjack and yellowfin was furnished on several occasions when the *Salpa* would catch both species while trolling under a working bird flock. The occurrence of the same invertebrate organisms in the stomachs of both skipjack and yellowfin seems to attest the presence of competition, but the absence of food fish species common to both fails to support it (tables 11 and 13). Evidence for competition between the little tunny and the dolphin may be seen in the number of food fish species common to both (tables 12 and 14). The fishes most prevalent in the food of the dolphin, however, were the flyingfishes

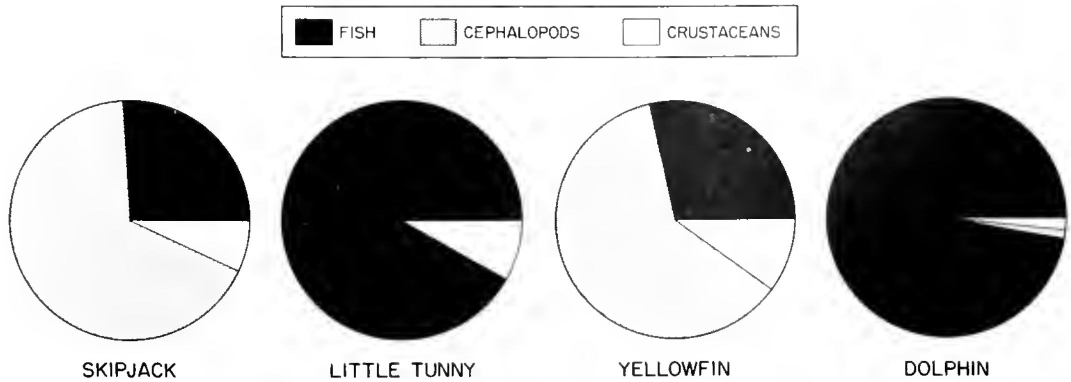

Figure 10.--Relative importance of fishes, cephalopods, and crustaceans in the diets of skipjack, little tunny, yellowfin, and dolphin.

Table 14.--Stomach contents of 52 troll-caught dolphin (number of stomachs: 53 in 1951, 5 in 1952, 14 in 1953)

Food organisms	Total volume		Stomachs in which occurred		Number of organisms
	cm.^{3}	Percent	Number	Percent	
Fishes					
Clupeidae					
Spratelloides delicatulus	3.4	---*	4	7.7	6
Synodontidae					
Synodus variegatus	0.5	---*	1	1.9	1
Belonidae					
Ablennes hians	121.0	3.4	1	1.9	1
Hemiramphidae					
Hemiramphus brasiliensis	239.2	6.7	2	3.8	2
Euleptorhamphus viridis	40.5	1.1	1	1.9	1
Exocoetidae					
Parexocoetus brachypterus	402.9	11.3	3	5.8	11
Exocoetus volitans	4.9	0.1	1	1.9	4
Cypselurus sp.	429.6	12.0	3	5.8	4
Unidentified sp.	605.8	17.0	16	30.8	Numerous
Syngnathidae					
Hippocampus histrix	8.3	0.2	4	7.7	7
Hippocampus sp.	9.0	0.3	4	7.7	8
Holocentridae					
Holocentrus sp.	3.5	---*	1	1.9	1
Serranidae					
Unidentified sp.	1.6	---*	1	1.9	1
Coryphaenidae					
Coryphaena hippurus	7.8	0.2	2	3.8	2
Mullidae					
Unidentified sp.	61.0	1.7	2	3.8	3
Carangidae					
Decapturus pinnulatus	14.4	0.4	1	1.9	1
Caranx melampygus	14.4	0.4	1	1.9	2
Unidentified sp.	32.3	0.9	2	3.8	2
Kyphosidae					
Kyphosus sp.	23.5	0.7	1	1.9	1
Chaetodontidae					
Chaetodon sp.	1.6	---*	1	1.9	4
Unidentified sp.	0.5	---*	1	1.9	1
Blenniidae					
Runula sp.	2.4	---*	4	7.7	5
Zanclidae					
Zanclus canescens	30.8	0.9	1	1.9	1
Istiophoridae					
Istiophorus orientalis	17.4	0.5	1	1.9	1
Scorpaenidae					
Taenianotus triacanthus	2.4	---*	1	1.9	1
Unidentified sp.	4.6	0.1	1	1.9	3
Scombridae					
Unidentified sp.	765.0	21.4	2	3.8	2

* Less than 0.1 percent.

Table 14.--Stomach contents of 52 troll-caught dolphin (number of stomachs: 53 in 1951, 5 in 1952, 14 in 1953) (cont'd)

Food organisms	Total volume		Stomachs in which occurred		Number of organisms
	cm.³	Percent	Number	Percent	
Monacanthidae					
Cantherines _pardalis_	10.1	0.3	2	3.8	2
Cantherines sp.	5.4	0.2	1	1.9	1
Unidentified sp.	30.4	0.9	3	5.8	4
Ostraciidae					
Lactoria _diaphanus_	20.5	0.6	11	21.2	18
Ostracion _lentiginosum_	11.3	0.3	3	5.8	3
Tetrodontidae					
Unidentified sp.	30.7	0.9	2	3.8	2
Diodontidae					
Diodon _holacanthus_	46.1	1.3	3	5.8	8
Pegasidae					
Pegasus _papilio_	1.1	---*	1	1.9	1
Unidentified fish remains	470.2	13.2	25	48.1	Numerous
Total fishes	3474.1	97.3			
Cephalopoda					
Decapoda					
Unidentified squid	40.1	1.1	4	7.7	6
Total decapod cephalopods	40.1	1.1			
Crustacea					
Isopoda					
Cymothoidae					
Unidentified sp.	3.5	---*	2	3.8	3
Stomatopoda					
Unidentified larvae	45.3	1.3	16	30.8	Numerous
Decapoda					
Penaeidae					
Unidentified sp.	5.1	0.1	5	9.6	24
Brachyuran megalopa	4.0	0.1	6	11.5	12
Total crustaceans	57.9	1.6			
Grand total	3572.1				

* Less than 0.1 percent.

(Exocoetidae), which were not found in the stomachs of the little tunny. In view of the lack of specificity in the diets, it is probable that if all four species were present in the same area at the same time, they would vie with each other for whatever food was available.

Reliance upon inshore fauna was evident in the stomach contents of all four species, but this is not surprising since all of our catches were made relatively close to land. The pelagic larval and juvenile stages of many of the food fishes were those of species which spend their adult stages among the reefs or waters close to the reefs. This holds true for some of the invertebrates also. Undoubtedly the reefs of Kaneohe Bay and adjacent areas play an important role in contributing food to the area sampled. However, the extent of this contribution is presently unknown.

SUMMARY

1. Catch, catch rate, lure preference, size frequencies, weight-length relations, sex and maturity, and food are reported for tunas and other pelagic fishes caught by trolling off Kaneohe Bay, Oahu. Trolling operations were conducted aboard the University of Hawaii's research vessel Salpa during 1951 through 1955.

2. The bulk of the catch was composed of skipjack, dolphin, little tunny, and yellowfin. The highest availability for all species combined occurred in the months of May to October. Yellowfin availability was consistently high during September and October.

3. Among the various types of lures used, no preference was found with respect to form or color of the lure.

4. Weight distribution of skipjack showed no progression of modes, indicating migration away from the fishing area as the fish grew larger. The majority of the skipjack were presumed to be "1-year-olds." Weight distribution of little tunny appeared to indicate the presence of two and possibly three age groups. Weight distribution of yellowfin indicated growth from 5 or 6 pounds in June to 10 pounds in November. Weight distribution of dolphin appeared to indicate bimodality in fish less than 10 pounds.

5. Weight-length relations were calculated for skipjack, little tunny, yellowfin, and dolphin. Beyond 68 cm. male dolphin tended to be heavier than females at a given length.

6. The sex ratio of skipjack showed a preponderance of males. Gonad examinations indicate that skipjack may mature in 1 year. The sex ratio of little tunny showed approximately an equal proportion of males and females. Gonad examinations showed the majority of little tunny in the "maturing" stages, with a few mature and spent fish. The sex ratio for yellowfin was similar to that of the little tunny. Gonad examinations revealed no mature yellowfin. The sex ratio of dolphin showed a preponderance of females, although there was considerable diversity in the sex ratio between schools. Gonad examinations revealed the presence of mature females but no mature males.

7. Food analyses showed that the diet of these pelagic fishes comprised primarily fishes, cephalopods, and crustaceans. Some evidence of interspecific competition for food was indicated. Reliance upon inshore fauna was evident in the stomach contents of all the species examined.

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