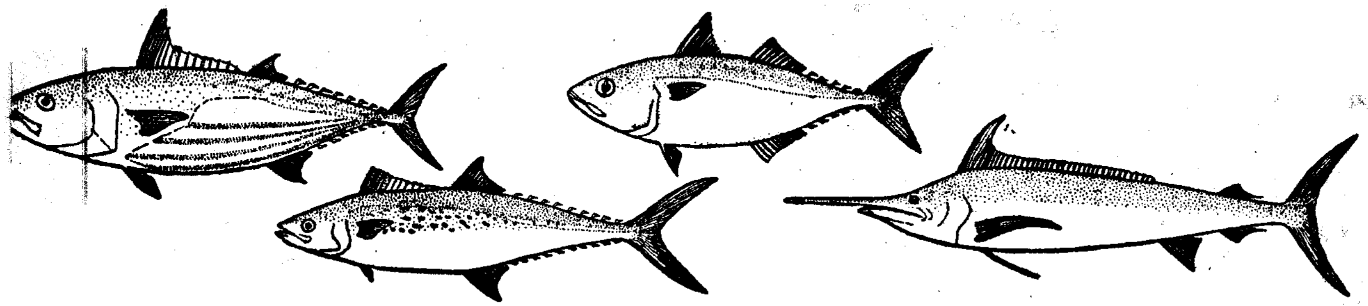


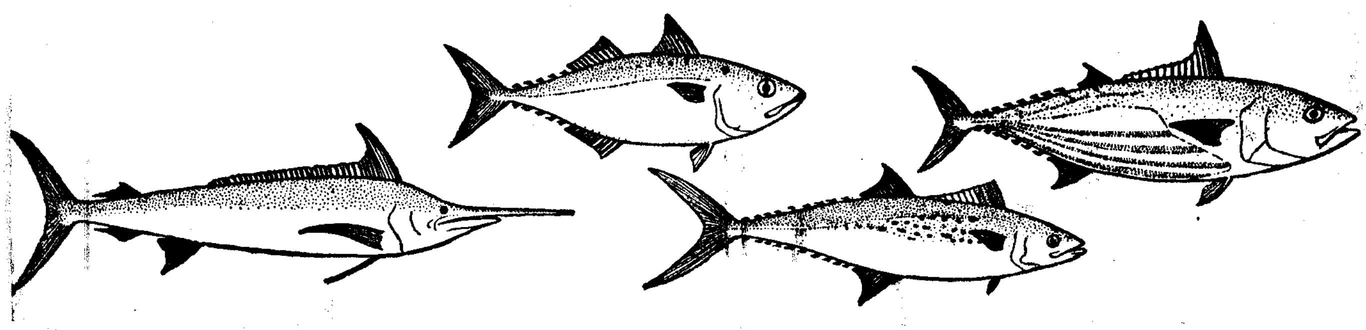
SYMPOSIUM ON SCOMBROID FISHES

PART II

MARINE BIOLOGICAL ASSOCIATION OF INDIA

MANDAPAM CAMP

S. INDIA



PROCEEDINGS OF THE

SYMPOSIUM ON SCOMBROID FISHES

HELD AT MANDAPAM CAMP FROM JAN. 12-15, 1962

PART II

SYMPOSIUM SERIES I

MARINE BIOLOGICAL ASSOCIATION OF INDIA

MANDAPAM CAMP

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OBSERVATIONS ON THE FOOD AND FEEDING HABITS OF THE OCEANIC SKIPJACK, *KATSUWONUS PELAMIS* (LINNAEUS) OF THE LACCADIVE SEA DURING THE YEARS 1958-59*

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INTRODUCTION

THE oceanic skipjack, *Katsuwonus pelamis* (Linnaeus) which is widely distributed in most tropical and subtropical seas, plays a principal role in the Minicoy tuna fishing industry bringing an annual income of over Rs. 50,000 to the islanders (Jones, 1958) in recent years, through the export of dried tuna sticks called '*mass min*'. The importance of the study of the biology of this fish in exploiting them wisely and effectively hardly needs emphasis.

Practically there is no information on the food of the skipjack from Indian waters and even the available information from the Pacific is mostly fragmentary and consists of casual observations. Through the observations of Okamura and Marukawa (1909), Kishinouye (1923), Delsman and Hardenberg (1934), Suyehiro (1936 & 1938), Walford (1937), Hatai *et al.* (1941), Clemens and Wilby (1946), Hildebrand (1946), Shapiro (1948), Yabe and Mori (1948), Eckles (1949), Imamura (1949), Kuronuma *et al.* (1949), Ronquillo (1953) and Yabe *et al.* (1953), we have gained a fair idea of the organisms constituting the food of the skipjack in the Pacific. Hotta and Ogawa (1955) elaborately studied the stomach contents of 2,900 skipjack from the surrounding seas of Japan and made a comparison of the seasonal and geographical variations in the composition of the food of this species. Detailed results of the recent studies of the stomach contents of 2317 skipjack from Eastern Pacific by the Inter-American Tropical Tuna Commission (Schaefer 1961) are awaiting publication.

An understanding of the behaviour patterns of the skipjack towards their food may indicate how best these resources could be tapped by other methods of fishing in Indian waters. In addition the food studies may reveal the existence of the correlation between the distribution of the food elements and the congregation of skipjack schools and thus may aid in locating the unexploited skipjack areas which are said to be vast encompassing the other Laccadive group of islands. The results of the preliminary study on the food and feeding habits of the oceanic skipjack from the Laccadive Sea around Minicoy Island are processed in this paper.

MATERIAL AND METHODS

A total of 2609 specimens of skipjack were examined for this study from bi-weekly samples obtained from pole and line fishing with live baits, operated at a distance of about 4-6 miles around the island between 7 a.m. and 2 p.m. during the period May 1958 to April 1959.

The specimens of skipjack landed at Minicoy by the pole and line fishery were found to have in their stomachs a very great proportion of the bait fishes employed to catch them. Those organisms that were not observed among the bait samples, but encountered in the stomach contents of skipjack were considered to represent the natural food items of these fishes. The relative importance of the food elements other than the bait, viz., natural food, is likely to be obscured if the bait fishes

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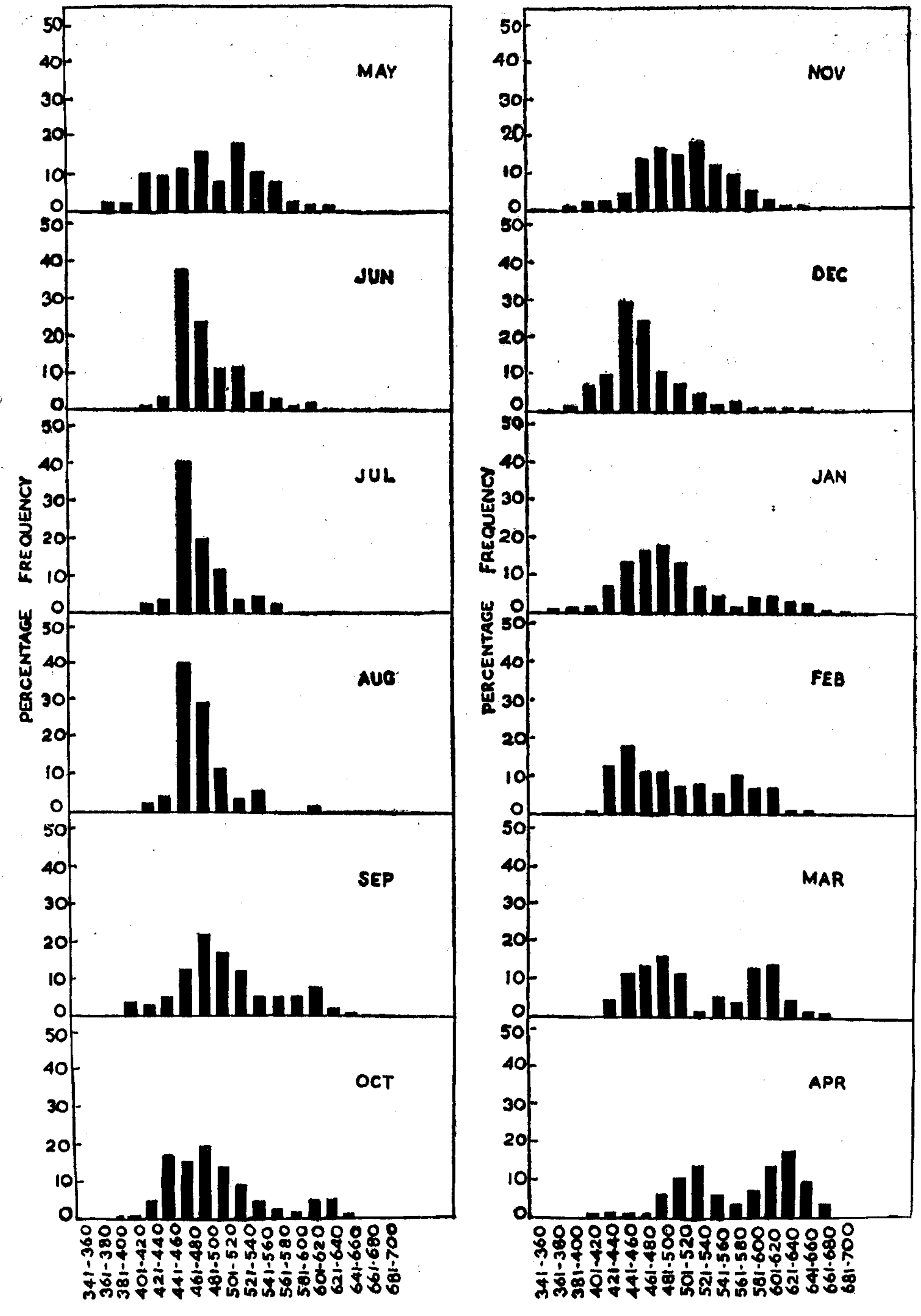

Fig. 1. Monthwise percentage frequency distribution of the size groups (total length) of skipjack sampled at random from the pole and line fishery at Minicoy during the period May 1958—April 1959.

and the so-called natural food are analysed together. A quantitative estimation of the bait also was found to be unreliable as some of the skipjack were found to regurgitate some portions of the food, mostly the bait as they were caught or soon after that. If those organisms of the natural food are assumed to have been eaten prior to taking the bait, they can be expected to lie below the bait in the stomach and thereby may not be much affected by regurgitation. In addition, the study of the natural food was found to be more important to start with and as these natural food elements were found mostly in traces, it necessitated the sampling of quite a large number of specimens for the study. Therefore, it was not possible to record the length, the weight and the gonadial condition of each specimen examined for food. A random sample of skipjack was drawn twice a week and their stomach contents analysed. The live bait fishery of Minicoy was found to be very selective with the size ordinarily ranging from 350 to 650 mm. in total length. The length frequency distribution of the random samples of skipjack was analysed for each month. The monthly frequency of the length groups landed for the period of observation is shown in Fig. 1.

The degree of distension of the stomach was recorded for all the stomachs examined under any one of the following categories, (1) empty, (2) traces, (3) half full, (4) three-fourth full, and (5) full and gorged. The average volumes of the food including the bait of each of the five categories were estimated for every month for ten specimens, for comparing the relative proportions of the bait with natural food.

In order to understand the relationship between the size of the fish and the average volume, variations if any, in the composition of the food of various size groups, feeding in relation to maturity etc., 103 specimens were examined for the total length, body weight, sex and gonad stage. As the specimens below 330 mm. and above 700 mm. in total length were very rare in the landings, whenever such specimens occurred they were selected and studied.

The viscera was pulled out of the body by slitting the gill membrane along the line of attachment with the cleithrum posterior to the fourth gill arch and the stomach removed from it. The stomach was cut open and the gut contents washed in a finger bowl for quantitative analysis. The analysis of the stomach contents was done either in the field in fresh condition or in the laboratory after preserving them in 5% formalin.

The food contents in this study were analysed by three general systems of analysis viz., Volumetric, Numerical and Occurrence. The Volumetric method in which each item of food is expressed as percentage of the total volume of the stomach contents examined, gives a better picture of the relative importance of various individual food items by taking into consideration the volume of the organisms. By the Numerical method of occurrence the number of different organisms constituting the food is expressed as percentage of total number of each food item. This was calculated to compare it with that of the Volumetric method. The prevalence of each item of food and consequently the preference and availability of the organisms as food was calculated by the Occurrence method in which each food item occurring is expressed as percentage of the total number of specimens examined. As food items of varying sizes were encountered in the stomachs of skipjack, the Numerical method in addition to placing undue emphasis on food organisms with resistant parts was found to convey very little of the relative importance of the separate components in terms of bulk.

Results of the Observations

Seasonal variation in food

The stomach contents of 2506 specimens of skipjack analysed by the above three methods (Fig. 2 A, B & C) show that they consist mainly of crustaceans, cephalopods and juvenile fishes. The seasonal fluctuations of the different food items during different months are represented in Fig. 3.

CRUSTACEANS :

Crustaceans formed the dominant food elements of skipjack during the period of investigation, their volumetric percentage, percentage of prevalence and numerical percentage being 58.6, 76.0 and 91.9 respectively. The crustaceans consisted of stomatopod larvae, megalopa larvae, mysids, euphausids and *Acetes indicus*.

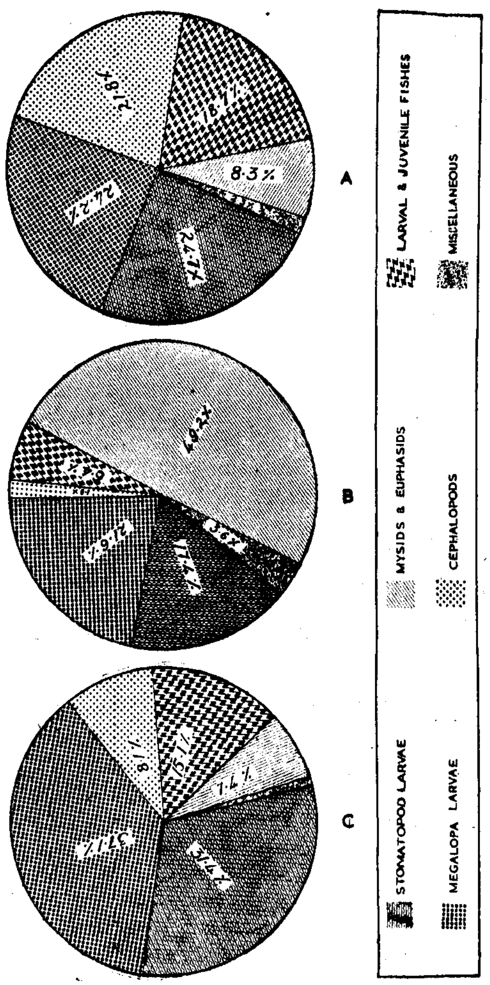

Fig. 2

The comparative VOLUMETRIC importance of the major food items for the 2,506 skipjack sampled at random from the pole and line fishery at Minicoy Island during the period, May 1958—April 1959.

The comparative NUMERICAL importance of the major food items for the 2506 skipjack sampled at random from the pole and line fishery at Minicoy during the above period.

The comparative importance of the OCCURRENCE of the major food items among the 2506 skipjack sampled at random from the pole and line fishery at Minicoy Island during the above period.

The actual total occurrence of different kinds of food organisms of skipjack encountered in the present study was recorded in 1625 stomachs and this is treated as the total percentage of the occurrence of different food items in this figure.

STOMATOPODS :

It is interesting to note that either the larvae or the juveniles alone were encountered but not the adults in the stomach contents of the skipjack examined. The stomatopod larvae and juveniles rank very high amongst the main food organisms and they were present throughout the year. Its percentage volume for the whole period of study was 24.7. The high consumption of the larvae occurred during the months May and June during which the volume percentage composition was as high as 57.9 and 52.0 respectively. Its value was very low during August but gradually increasing during successive months to 38.1 in November. From December to March it ranged from 22.0 to 27.8 with another fall in April (Table 1). The percentage of occurrence showed high values during May (38.0) and July (25.8). Its lowest values were during August (8.7), April (5.9) and June (7.2). During the remainder of the period the percentage ranged from 16.9 to 24.5 (Table 2). The numerical percentage was highest in May (58.2) and lowest in June (2.2). It ranged during other

TABLE 1

The percentage of occurrence of different food organisms in 2506 stomachs of skipjack of Minicoy during the period May 1958 to April 1959.

(The actual numbers of stomachs examined are indicated in brackets)

	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April
Mysids ..	—	12.0 (33)	—	0.8 (1)	4.3 (14)	0.5 (1)	4.7 (14)	1.3 (2)	—	12.7 (18)	—	—
Stomatopod larvae ..	38.0 (122)	7.2 (20)	25.8 (16)	8.7 (11)	21.6 (70)	22.1 (47)	24.5 (74)	23.2 (36)	21.9 (40)	16.9 (24)	21.6 (27)	5.9 (14)
Euphausids ..	—	—	—	—	0.3 (1)	—	2.3 (7)	—	—	7.0 (10)	—	—
Phyllosoma larvae ..	—	—	—	—	—	—	—	1.3 (2)	—	—	3.2 (4)	—
Megalopa larvae ..	24.8 (88)	26.8 (74)	33.9 (21)	16.5 (21)	23.8 (87)	29.1 (62)	19.5 (59)	44.5 (69)	22.4 (50)	7.7 (11)	7.2 (9)	22.5 (53)
Acetes indicus	—	—	—	—	—	5.6 (12)	—	—	—	1.4 (2)	—	—
Squids ..	2.8 (9)	2.9 (8)	—	19.7 (25)	3.7 (12)	13.1 (28)	2.3 (7)	9.7 (14)	3.1 (7)	4.2 (6)	—	1.7 (4)
Octopodids ..	—	—	—	—	—	—	—	—	1.8 (4)	2.1 (3)	—	2.1 (5)
Syngnathids ..	—	—	—	—	—	—	—	7.1 (11)	17.0 (38)	—	12.0 (15)	13.6 (32)
Sphyraena sp.	—	—	—	—	—	—	—	—	—	—	—	0.8 (2)
Larvae of *Dactyloptena*	—	—	—	—	—	—	—	—	—	3.5 (5)	2.4 (3)	2.1 (5)
Carangids ..	—	—	—	—	1.2 (4)	—	—	0.7 (1)	—	—	—	0.8 (2)
Monocanthids	—	—	3.1 (2)	—	—	—	—	—	0.9 (2)	—	3.2 (4)	—
Balistids ..	—	—	11.1 (7)	—	4.6 (15)	—	6.3 (19)	—	6.7 (15)	—	10.4 (13)	13.1 (31)
Triacanthids	—	—	—	—	0.6 (2)	—	1.7 (5)	—	—	—	—	—
Ostraciodontids	—	—	—	—	—	—	—	—	—	1.4 (2)	—	—
Tetradontids ..	—	—	—	—	—	0.5 (1)	0.9 (3)	—	—	1.4 (2)	—	—
Antennarius sp.	—	—	—	—	—	—	—	—	—	0.7 (1)	—	—
Unidentified fish remains	2.8 (9)	0.7 (2)	17.7 (11)	10.8 (1)	3.1 (10)	1.8 (4)	0.4 (1)	1.9 (3)	—	—	0.8 (1)	0.8 (2)
Miscellaneous items	0.6 (2)	—	—	1.6 (2)	—	—	—	—	—	—	—	3.8 (9)

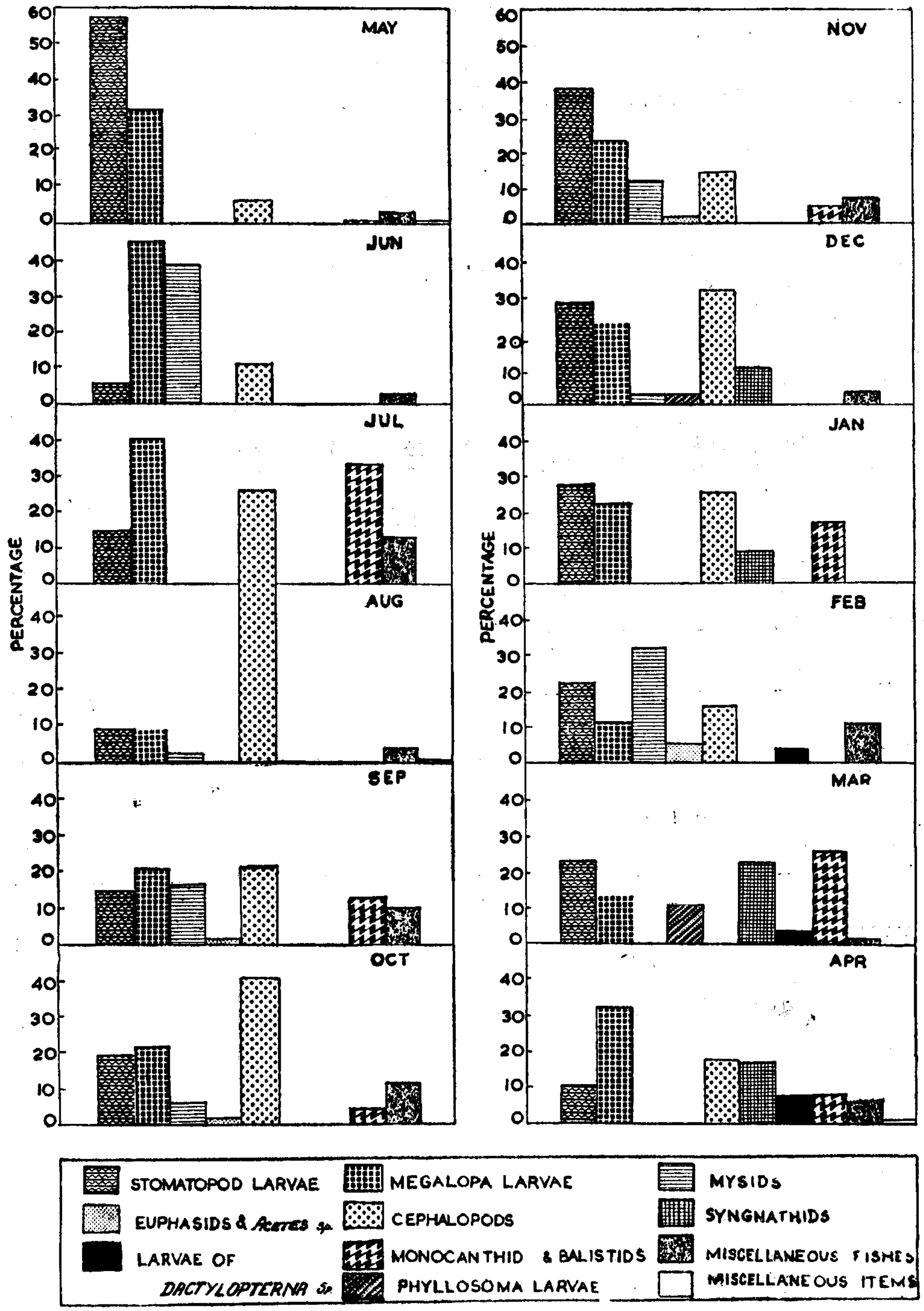

Fig. 3. Monthly fluctuations in the composition by volume of the important food elements of 2506 skipjack, observed from the random samples landed by pole and line fishery at Minicoy during the period May 1958—April 1959.

months from 5.0 to 37.5 (Table 3). The following species were identified ; as common in the stomach contents of skipjack at Minicoy : *Gonodactylus demani*, *Squilla* (*alima*) *hyalina*, and *Squilla* (*alima*) *hieroglyphica*, *Lysiosquilla sulcirotris*, *Squilla wood-masoni*, *Squilla fasciata*.

TABLE 2.

The numerical percentage of the different food organisms in stomachs of 2506 skipjack of Minicoy during the period May 1958—April 1959

	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
Mysids ..	—	83.1	—	35.2	59.6	43.8	63.1	24.5	—	81.3	—	—
Stomatopod larvae	58.2	2.2	18.6	17.0	7.0	18.2	17.3	37.5	29.0	5.0	24.5	11.2
Euphausids ..	—	—	—	—	6.4	—	3.9	—	—	8.5	—	—
Phyllosoma .. larvae	—	—	—	—	—	—	—	1.5	—	—	6.0	—
Megalopa larvae	38.0	13.9	66.0	19.4	22.0	28.2	13.5	26.0	46.0	1.5	24.6	43.6
Acetes indicus	—	—	—	—	—	3.3	—	—	—	1.2	—	—
Squids ..	1.3	0.5	—	23.2	1.0	3.3	0.3	2.0	1.8	0.3	—	0.8
Octopodids ..	—	—	—	—	—	—	—	—	1.2	0.3	—	2.2
Syngnathids	—	—	—	—	—	—	—	7.0	14.0	—	25.0	14.9
Sphyraena sp.	—	—	—	—	—	—	—	—	—	—	—	0.5
Larvae of *Dactyloptena*	—	—	—	—	—	—	—	—	—	1.0	5.5	4.3
Carangids ..	—	—	—	—	0.4	—	—	0.4	—	—	—	1.7
Monocanthids	—	—	2.9	—	—	—	—	—	1.0	—	3.2	—
Balistids	—	—	6.1	—	2.0	—	0.5	—	7.0	0.2	10.2	17.4
Triacanthids	—	—	—	—	0.2	—	0.8	—	—	—	—	—
Ostraciodontids	—	—	—	—	—	—	—	—	—	0.3	—	—
Tetradontids ..	—	—	—	—	—	1.1	0.4	—	—	0.2	—	—
Antennarius sp.	—	—	—	—	—	—	—	—	—	0.1	—	—
Unidentified fish remains	2.1	0.3	6.4	2.8	1.4	2.1	0.2	1.1	—	0.1	1.0	—
Miscellaneous items	0.4	—	—	2.4	—	—	—	—	—	—	—	3.4

Megalopa larvae :

Megalopa larva which ranked next in importance to stomatopoda with a total percentage volume composition of 24.2 was present in the stomach contents of skipjack practically throughout the year. Its high percentage of volume during June (44.4), July (39.5) and May (31.1) corresponds with its fairly high percentages of prevalence 26.8 ; 33.9 and 24.8 respectively. But its highest and lowest percentages of prevalence were observed during December (44.5) and March

(7.2). Low percentage volumes 9.1 and 11.0 were noted in August and February respectively. During the other months it showed a fairly appreciable percentage composition varying between 13.0 and 32.7. The numerical percentages also showed high values in July (66.0) and May (38.0) but its high value of 46.0 in January does not correspond either with its percentage volume or with its percentage prevalence. The lowest value was in February being 1.5.

TABLE 3.

The average volume (cc) *of different food organisms in* 2506 *skipjack of Minicoy during the period May* 1958—*April* 1959.

	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
Mysids ..	—	0.311	—	0.051	0.051	0.094	0.121	0.052	—	0.581	—	—
Stomatopod .. larvae	0.792	0.043	0.516	0.190	0.142	0.274	0.377	0.52	0.401	0.412	0.440	0.118
Euphausids ..	—	—	—	—	0.012	—	0.011	—	—	0.067	—	—
Phyllosoma larvae	—	—	—	—	—	—	—	0.045	—	—	0.215	—
Megalopa larvae	0.431	0.365	1.435	0.188	0.194	0.310	0.230	0.420	0.334	0.204	0.256	0.354
Acetes indicus	—	—	—	—	—	0.007	—	—	—	0.014	—	—
Squids ..	0.087	0.083	—	1.567	0.203	0.582	0.137	0.597	0.246	0.246	—	0.136
Octopodids ..	—	—	—	—	—	—	—	—	0.134	0.031	—	0.049
Syngnathids ..	—	—	—	—	—	—	—	0.190	0.134	—	0.444	0.189
Sphyraena sp.	—	—	—	—	—	—	—	—	—	—	—	0.026
Larvae of *Dactyloptena*	—	—	—	—	—	—	—	—	—	0.067	0.062	0.081
Carangids ..	—	—	—	—	0.031	—	—	0.026	—	—	—	0.040
Monocanthids	0.006	—	0.326	—	—	—	—	—	0.223	—	0.392	0.081
Balistids ..	—	—	0.870	—	0.123	—	0.045	—	0.020	—	0.136	—
Triacanthids	—	—	—	—	0.011	—	0.034	—	—	—	—	—
Ostraciodontids	—	—	—	—	—	—	—	—	—	0.060	—	—
Tetradontids ..	—	—	—	—	—	0.026	0.018	—	—	0.060	—	—
Antennarius sp.	—	—	—	—	—	—	—	—	—	0.017	—	—
Unidentified .. fish remains	0.047	0.018	0.470	0.075	0.057	0.039	0.075	0.038	—	0.070	0.018	—
Miscellaneous items	0.016	—	—	0.012	—	—	—	—	—	—	—	0.014

Mysids :

Mysids were observed as forming the constituents of food of the skipjack during the months June, August, December and February. They constitute 8.3% of the total volume of the food. The highest percentage composition of 38.0 and 31.5 were observed during June and February whereas its percentage of occurrence during these two months were only 12.0 and 12.7 respectively, thereby indicating that this item though found in few stomachs was consumed enormously. This was found to be true in actual observations in that only few stomachs were gorged with them. During other months their volume percentage ranged from 2.4 to 16.6 with the complete absence during May, July, March and April. Because of their small size and incidence in stomachs in greater numbers, their numerical percentages were very high; June (83.1), February (81.3), November (63.1), September (59.6). The percentage of occurrence during the months August to December ranged from 0.5 to 4.7.

Euphausids :

Euphausids were observed during three months in the following percentages of volume : February (3.7), September (1.4) and November (1.4). Their percentage of occurrence was very low being 3.9 to 8.5.

Mysids and euphausids were often difficult to be separated because of their small size and superficial resemblance. Therefore a small sub-sample from each stomach was taken and their relative proportions estimated. Likewise in determining their number, the number of organisms in one c.c. was counted and this was multiplied by its total volume.

Acetes indicus :

Acetes indicus was found to occur in the stomachs of skipjack in October and February. The percentage volume was very low being 0.8 and 2.5 respectively.

Phyllosoma larvae :

Phyllosoma larvae were observed during December and March with 2.5 and 11. 4 percentage of volumes respectively. Giant phyllosoma larvae belonging to *Palinurus* sp. (Prasad & Tampi 1959) were found in 3.2 percent of the stomachs examined in March.

Molluscs :

Molluscs mainly represented by cephalopods and occasionally by pteropods, *Cavolinia* sp. constituted an important item of food with their percentage volume of 21.8 of the total volume of the food of skipjack examined during the period.

Cephalopods :

Juvenile and adult cephalopods were observed in substantial quantities in the stomach contents practically throughout the period except in the months of March and July. Though their numerical percentage ranging from 0.3 to 23.2 and percentage of occurrence ranging from 2.3 to 19.7 were comparatively low, their percentage volumes of 6.1 to 40.6 were high. Their highest percentage volume of 75.1 during the month of August exceeded the percentage composition by volume of any single item of food in any one of the months during the period of investigation.

The comparatively low percentage of occurrence and number indicates the occurrence of these organisms in few stomachs in small numbers and thereby it is likely to under-rate their importance as food of skipjack. But it should be remembered that soft bodied organisms with enzymes of skipjack acting on them are likely to be digested unlike the crustaceans which have a resistant exoskeleton.

As the various characteristic features used in identifying these forms like the general body shape, number of arms, arrangement and modification of the suckers, presence of tentacles etc., are structures that are susceptible to the digestive action of the enzymes these were therefore identified as squids and octopodids only.

Fishes :

The next important item of food element is contributed by the larval and juvenile fishes. They formed 18.7% by volume of the total contents of stomachs examined for the whole period.

Among the important items of fishes, balistids, monocanthids, syngnathids and larval *Dactyloptena* ranked high followed by tetradontids, carangids, triacanthids, *Sphyraena sp. Ostracian sp.* and *Antennarius sp.* of minor importance.

Balistidae and Monacanthidae :

Balistid and Monacanthid fishes occurred in the stomachs during the months of July, September, November, January, March, April and May, ranging from 4.5 to 24.2 in percentage volumes. Its percentage of occurrence ranged from 4.6 to 14.2 and numerical percentage from 0.5 to 17.4. The following species of them were identified as common in the gut contents of skipjack at Minicoy: (1) *Odonus niger* (Ruppell), (2) *Sufflamen capistratus* (Shaw), (3) *Balistes stellaris* (Bloch), (4) *Melichthys ringens* (Osbeck), (5) *Hemibalistes chrysopterus* (Bloch) and certain other unidentified *Balistes* spp. and *Monacanthus* spp.

Syngnathidae :

Herald (1949) observed pipe fishes and sea horses as food of tunas in the Pacific. In Minicoy these were found to occur during the months of December, January, March and April, with their percentage of volumes ranging from 9.0 to 22.5. Two species of pipe fishes were common ; (1) *Halicampus koilomatodon* (Bleeker), (2) *Corythoichthys fasciatus* (Gray) and the sea horse *Hippocampus kuda* (Bleeker) was encountered in one of the stomachs.

Miscellaneous fishes :

Among the other fishes recovered rarely, mention may be made of the following species : Tetradontids, *Gastrophysus lunaris* (Bloch), *Chelonodon patoca* (Hamilton Buchanan) and *Arathron immaculatus* (Bloch).

Other Miscellaneous items :

Amongst recognisable miscellaneous items mention may be made of certain animate and inanimate objects that were recorded rarely. Those were Zoea larvae, *Caprella* sp. Ascidian tadpoles, *Salpa* sp. a rubber piece and wooden pieces and parts of certain sea weeds.

Bait Fish :

A relatively great proportion of the stomach contents was contributed by the bait fish. Though no quantitative study of the bait fish recovered from them was attempted, a record of the various species of baits fishes recovered from the stomach of skipjack from time to time were kept and these were classified as, (1) principal or dominant, (2) frequent, (3) occasional and (4) rare, according to their frequency of occurrence. The following are the species of live baits fishes recorded:

Dominant *:*

Lepidozygus tapeinosoma (Lacépède)
Caesio caeruleus (Lacépède) and
Chromis caeruleus (Cuvier)

Frequent *:*

Caesio tile (Valenciennes)
Pomacentrus tripunctatus (Cuv.)
Arachamia lineolatus (Cuv.)
Apogon sureus (Lacépède) and
Apogon septemstriatus (Günther)

Occasional :

Certain species of Pomacentrids like, *Pomacentrus cyanomos* (Bleeker) *P. notopthallus* (Bleeker) and unidentified *Pomacentrus* spp.

Abudefduf spp., apogonids, labrids etc.

Rare :

In addition to the following species of fishes it included various species of pomacentrids, apogonids, labrids and atherinids mainly which could not be identified up to the species.

Anampses melengrides (Val.)

Thallosoma janseni (Blkr.)

T. cuspido bipunctatum (Vas.)

Stethojulis axillaris (Q. & G.)

Platyglossus notopsis (Val.)

Halichoeres hyrtli (Blkr.)

Pempheris vanicolensis (Cuv.)

Jones (1958) states ' that there is no selection but any fish that remains alive in the bait net is transferred to the bait well or storage basket '. Likewise while fishing for tuna with the bait fish, the bait fish are scooped and thrown out into the sea without any selection. Skipjack when they are in their frenzy of competition to get as much food as possible seem to feed on anything that is small enough to be ingested.

Variations in the Volume of Food with Fish Size

Reintjes and King (1953) in yellowfin tuna and King and Ikehara (1956) in yellowfin and big-eyed tuna in the Pacific found that there was increase in the main food volume with the increase in the fork length of the fish and decrease in the average stomach content per unit of body weight with the increase of body weight. Their findings are in agreement with the findings in skipjack from Minicoy island. (Figs. 4 & 5) The explanation advanced by Reintjes and King (*op. cit.*) on this point was that the larger fish ate organisms of greater dimension than those consumed by smaller fish but both groups fed on the same organisms such as crab and stomatopod larvae. He therefore concluded, the larger the fish the greater the range of the individual food elements and the range in volume of the stomach contents.

Variations in the Composition of Food with Fish Size

With a view to find the differences, if any, in the composition of food elements in different size groups, the samples of 103 fish were divided into four length groups ; (1) fish below 400 mm. in total length—this group is represented by the juvenile or virgin fishes with immature gonads. (2) fish between 401 mm. and 550 mm., (3) fish between 551 mm. and 700 mm. and (4) fish above 700 mm.

The observations represented in Figs. 6a, b, c and d reveal that though the chief constituents were identical, the relative proportions of different groups of organisms constituting the food of skipjack appear to vary with the size of the fish. Among the fish of the group (1), the crustaceans consisting of stomatopod larvae and megalopa larvae were found to be the most dominant item followed by juvenile fishes and other miscellaneous items of lesser importance. Cephalopods were completely absent. In group (2) though the crustaceans were still dominant, the relative proportion of the stomatopod larvae was lesser than that found in group (1) and this was compensated, to some extent, by the occurrence of mysids. Juvenile cephalopods were also present and the miscellaneous items were much less in importance. In group (3) the dominant elements were juvenile fishes followed by cephalopods. The crustaceans here assumed secondary importance and were represented equally by megalopa larvae, stomatopod larvae and Mysids. In group (4) the dominant item was cephalopods followed by fishes. This is just the reverse of what is found in group (3) but however, crustaceans did not change much in total percentage.

Sexual Development and Feeding

Schaefer & Orange (1956), Brock (1956) and June (1953) observed that various species of tunas with the approach of spawning season become rare in commercial catches, in many parts of the Pacific. One of the possible explanations offered to this was that with the approach of the spawning season they do not take the bait. In Minicoy waters also skipjack with ripe running gonads were found to be completely absent in the fishery.

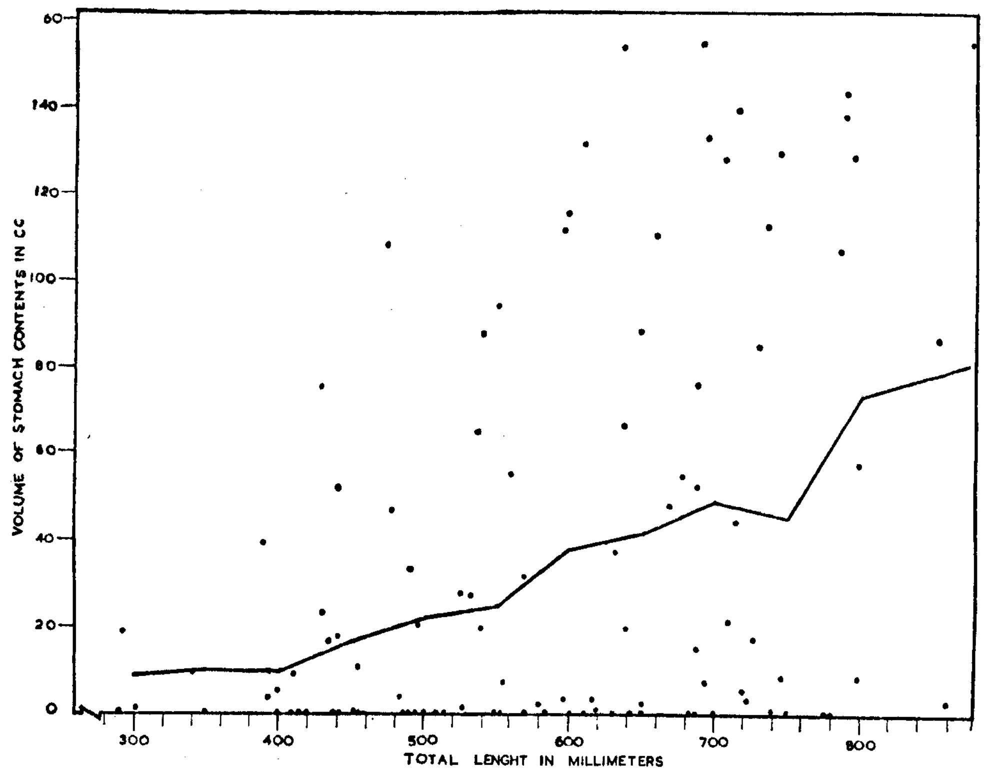

Fig. 4. Scatter diagram showing the relation between volume of food including bait, per stomach and the total length of 103 skipjack observed from the pole and line fishery at Minicoy during the period May 1958—April 1959, The mean volume (x) per stomach for 50 mm. group intervals are connected by the thick line.

Another phenomenon observed is the predominance of males in the commercial landings during the spawning season. Though in certain cases the actual milt was observed on squeezing the abdomen of the specimens, it is still questionable whether the occurrence of milt can be taken as a reliable index of the ripe stage of testes of tunas. It also remains to be studied whether males alone can take up the bait during the spawning season.

In fig. 7 wherein the average stomach contents of skipjack are represented by histograms for each month, there is a trend of steady increase in average cc. of contents per stomach from August to April. This increase may quite likely be associated with the changes in the length frequency distributions of the populations observed (Fig. 1) resulting in higher content due to greater percentage of fish in larger size groups.

Discussion

Reintjes and King (1953) from the study of the yellowfin tuna concluded that ' those food items that rank large in volume, large in number and high in frequency are important as food at the time and in the area sampled.' In the present study the crustaceans consisting mainly of larval and juvenile stomatopods and megalopa larvae and mysids ; cephalopods represented by

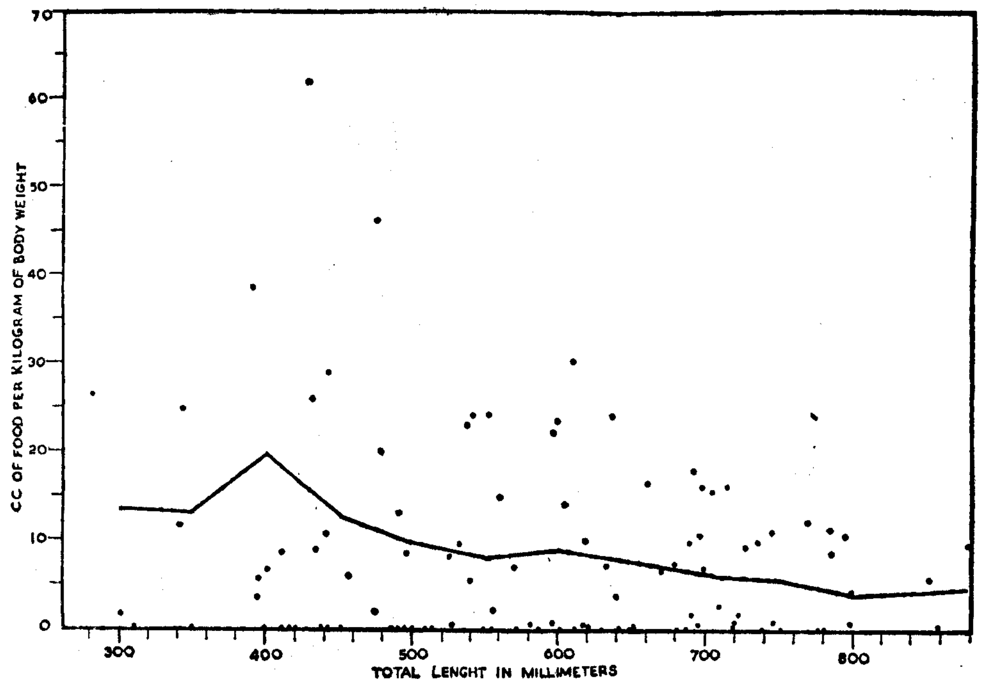

Fig. 5. Scatter diagram showing the relation between volume of food including bait per unit of body weight and total length for 103 skipjack observed from the pole and fishery at Minicoy during the period May 1958—April 1959. The mean (x) for 50 mm. group intervals are connected by the thick line.

squids and juveniles of octopodids and larval and juvenile fishes of different families fulfil the above essential requirements in being considered as important food elements of skipjack at Minicoy during the period May 1958 to April 1959.

The above statement is also in good agreement with the observations of other workers from the Pacific. Okamura and Marukawa (1909) showed from the analysis of the stomach contents collected by various fisheries stations throughout Japan, that the food of skipjack consists mainly of sardines, gastropods and large crustaceans. Kishinouye (1923) stated that the food items consist of medium sized plankton such as amphipods, heteropods, ' calamaries ' and immature and small fish. Suyehiro (1938) from the stomach contents of 220 fish showed the food to be anchovies, cuttlefish and pelagic crustaceans. Hotta and Ogawa (1955) listed crustaceans like shrimps and euphausids, cephalopods mainly constituted by squids and larval and juvenile fishes by anchovies, mackerels, flyingfishes, sigamids, holocentrids, carangids, skipjack, pufferfish and filefish. Schaefer (1960) enumerated the following items as constituting the important diet of the skipjack of the eastern Pacific in the descending order of importance. They are euphausids, *Vinciguerria lucetia*, Trichuiridae, Myctophidae, Exocoetidae and *Plueroncodes*. In most of the above studies sardines are listed as principal food but Shapiro (1948) remarked that it is highly probable that the large part of the food analysed was the bait used to catch the skipjack. Therefore it is difficult to evaluate the importance of sardines as the natural food. The absence of sardines as live bait in Minicoy is compensated for by the availability of certain

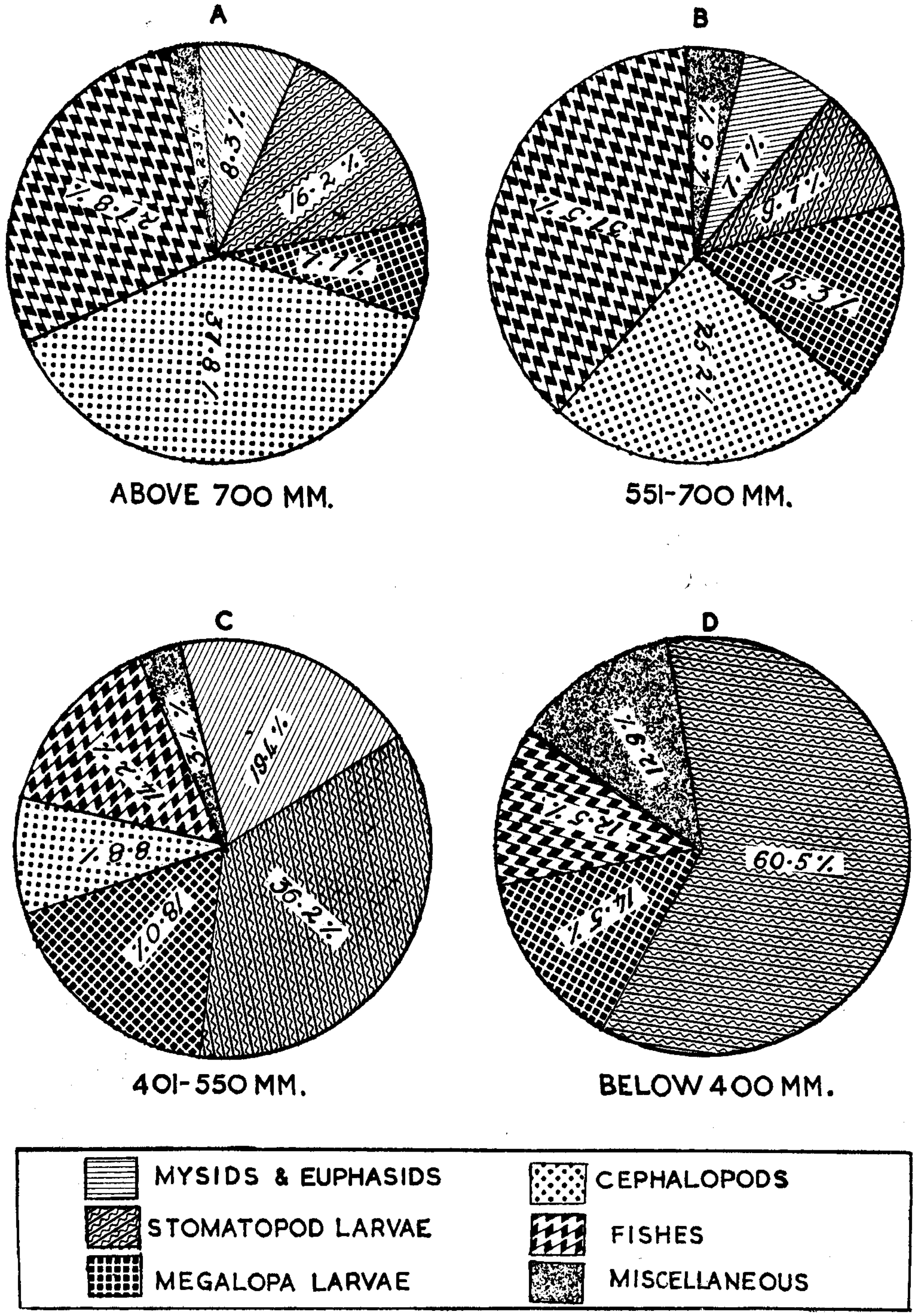

Fig. 6. Diagrams illustrating the composition by volume of the stomach contents other than the bait of 4 size groups of skipjack obtained from pole and line fishery at Minicoy during the period May 1958—April 1959.
A—Group 4 above 700 mm. in total length, B—Group 3 between 551-700 mm. in total length, C—Group 2 between 401-550 mm. in total length, D—Group 1 below 400 mm. in total length.

pomacentrid and labrid fishes as live baits which form the bulk of the stomach contents of the skipjack.

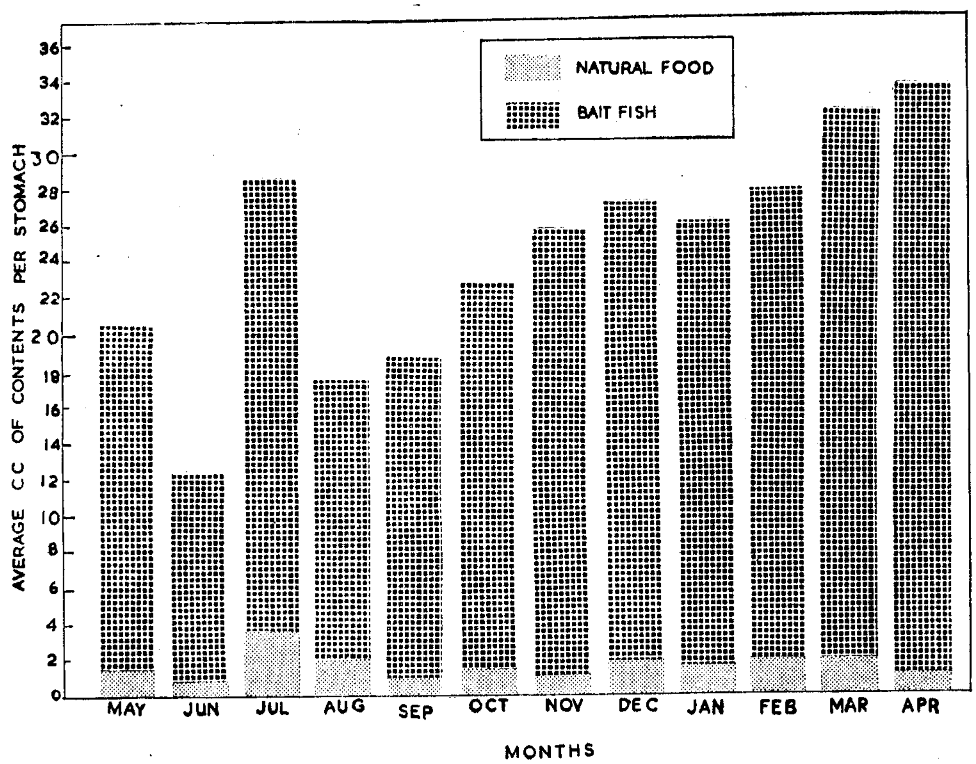

Fig. 7.—Estimated variations in the average volume per stomach of the bait and natural food of skipjack observed from the pole and line fishery at Minicoy during the period May 1958—April 1959.

Based on the above observations it can be inferred that the skipjack can accept a wide variety of food which include the reef fauna and organisms of the open sea, both nekton and plankton, within broad size limits. They appear to snap at anything that either ' wriggles ' or actively moves in the sea or tosses on its surface. Therefore it is quite likely that the congregation of this fish is influenced not so much by the specific food items but rather by the total availability of food. The occasional presence of certain inanimate objects in the stomach contents of the skipjack already mentioned, which may appear to be alive when tossing on the surface seem to support further the idea of indiscriminate feeding. The stomach contents of skipjack collected from different regions of Japan, (Hotta and Ogawa *op. cit.*) and different areas of Eastern Pacific, Schaefer (*op. cit.*) showed that those from each region had their own peculiar feature with different food items predominating. The predominance of different food items in specific localities probably does not reflect any change or preference in the feeding habits, skipjack but rather the distribution and abundance of the forage animals themselves.

Such a generalised feeding habit, appears to be true not only for skipjack but also for other species of tunas investigated from the other parts of the world as evident from the studies of King and Ikehara (1956) on the big-eyed tuna *Parathunnus sibi* (T. & S.) and yellowfin tuna, *Neothunnus macropterus* (T. & S.) Reintjes and King (1953) on the yellowfin tuna, Ronquillo (1953) on the food of Philippine tunas and dolphins, McHugh (1952) on the food of albacore (*Germo alalunga*) and Schaefer (1960 & 1961) on the food of yellowfin tuna.

Suyehiro (1938) distinguishes between the food habits of the resident and migratory skipjack. 'The resident population living in shallow and coastal places where abundant food (sardines, mackerels, horse mackerels, shrimps, amphipods, crab larvae etc.,) is available, eat almost anything and can always find food in contrast to the migratory skipjack swimming in the open oceans or deeper coastal waters generally subsistent on the crustaceans, cuttlefish, flying fish and occasional schools of sardines found in the open ocean and appear to be continually hungry since the quantity of food present in the open ocean is insufficient for the number of fish present.' Unless the stomach contents of skipjack caught far away from the land masses are available for comparison it is not possible to assign the population of skipjack studied at present to any one of the above-mentioned groups. But all that can be added is that these were caught near the land within the radius of 4 to 6 miles from the island and appear to accept anything that is available as food. These were found to be in a state of hunger and readily consumed the bait in large quantities. Majority of the bait fish used were found in association with the coral rocks either inside or outside the lagoon and the method of attracting and collecting them is described by Jones (1958). Therefore it is unlikely that these are present in such enormous numbers in the open sea as to constitute the regular natural food of the skipjack.

During the course of the present study it was observed that in addition to 11.6 to 40.5% of skipjack (Table 5) that had completely empty stomachs, 19.3 to 41.1% had bait fishes alone in their stomachs. It is rather surprising to find that in addition to the above percentages of the population of skipjack of Minicoy with natural food, 12.90 to 47.8% of the stomachs were displacing less than 0.5 c.c. by volume of the contents in this fast swimming fish with high rate of metabolism. Two possible explanations that can be offered to this are (1) the hungry fishes of the open sea in search of food migrating towards the land attracted by the inshore fauna and bait fishes, contribute to the live bait fishery of Minicoy and (2) there is perhaps a regular periodicity in the feeding behaviour of these fishes.

It is a popular belief amongst the Minicoy tuna fishermen that the skipjack schools though present in enormous numbers around Minicoy during certain seasons do not 'bite' and thereby respond very poorly to fishing by the pole and line method with live bait. If any improvement in the fishing efficiency of fisherman is to be aimed at, the factors which contribute to the variability of the response of skipjack to live bait should be ascertained. Therefore a very comprehensive study of the food and feeding habits of this fish in relation to its biting behaviour, in future is likely to unlock the mystery of this.

The necessity of such a study can very well be appreciated from the studies of Uda (1933) who stated that skipjack with stomachs between the extremes of fullness and emptiness tended to respond more poorly to fishing the less they have in their stomachs and Suyehiro (1938) observed that the skipjack which had recently fed did not bite as well as those that were hungry and skipjack feeding on pelagic forms responded to chum better than those feeding on inshore forms. But Yuen (1959) hypothesised that live bait fishing technique employed in Hawaii generally does not create a state of feeding excitement but exploits the already existing one which is apparently caused by the presence of natural food and that the state of excitement diminishes with feeding or when natural food becomes unavailable. Whereas the above cited investigations deal with the response of skipjack to physiological and psychological or psychophysiological stimulii, Tester, *et al.* (1954) experimentally studied the response of tuna to chemical and visual stimulii in the hope of utilising the information gained to develop a substitute for live bait. The results indicate that the sense of vision plays a much greater role in feeding than the sense of smell.

Yuen (1959) observed that the skipjack feeding on fast swimming fish exhibited a more favourable biting behaviour than those feeding on slow swimming fish. In the present study if the natural prey are to be classified according to their swimming abilities certain fast swimmers will include cephalopods and fishes like carangids. These were found to contribute a much greater proportion of the food of the large sized (above 700 mm. T.L.,) skipjack. But however, these were the size groups that were very poorly represented in the commercial catches of Minicoy.

However, the underwater observations of Strasburg and Yuen (1958) give a different picture of the behaviour of the large sized skipjack towards their food. According to them large skipjack appear to be almost lethargic in comparison with the smaller individuals that were found to strike at the

TABLE 4

The different degrees of distension of the stomachs, proportions of baits and natural food etc., of 2506 *skipjack observed from random samples from pole and line fishery at Minicoy during the period May* 1958—*April* 1959

Month	Total number of stomachs examined	Empty (A)	Traces ¼ full	¾ full	Full and gorged	Percentage of stomachs with bait fish only (B)	Percentage of empty stomachs plus stomachs with no natural food (A + B)	Percentage of stomachs with natural food	Estimated total volume of food including the bait of all the stomachs examined in each month	Observed total volume of natural food	Ratio between bait and natural food	Fullness of stomachs (Percentages given in brackets)
May ..	321	130 (40.5)	79 (24.6)	53 (16.6)	17 (5.3)	42 (13.0)	19.6	60.1	39.9	6548.4	442.5	13.8 : 1
June ..	276	112 (40.6)	100 (36.2)	38 (13.8)	9 (3.2)	17 (6.2)	33.0	73.6	26.4	3367.2	226.5	13.7 : 1
July ..	62	17 (27.4)	8 (12.9)	12 (19.4)	3 (4.8)	22 (35.5)	19.3	46.7	53.3	1761.8	224.0	6.9 : 1
August ..	127	49 (38.7)	34 (26.7)	20 (15.7)	11 (8.7)	13 (10.2)	30.7	69.4	30.6	2210.8	264.5	7.3 : 1
September	324	76 (23.4)	145 (44.8)	69 (21.3)	12 (3.7)	22 (6.8)	30.2	53.6	46.4	6026.4	300.0	18.0 : 1
October..	213	33 (15.5)	101 (47.4)	50 (23.4)	10 (4.7)	19 (8.9)	19.2	34.7	65.3	4813.8	305.0	14.8 : 1
November ..	302	48 (15.9)	108 (35.8)	84 (27.8)	16 (5.3)	46 (15.2)	34.1	50.0	50.0	7731.2	299.0	24.9 : 1
December ..	155	28 (18.1)	56 (36.2)	37 (23.8)	9 (5.8)	25 (16.1)	14.2	32.3	67.7	4185.0	292.5	13.4 : 1
January..	223	26 (11.6)	85 (38.1)	74 (33.2)	18 (8.1)	20 (9.0)	33.6	45.2	54.8	5775.7	333.5	16.3 : 1
February	142	23 (16.2)	57 (40.1)	39 (27.4)	12 (8.4)	11 (7.9)	34.5	50.7	49.3	3919.2	260.5	14.0 : 1
March ..	125	15 (12.0)	41 (32.8)	53 (42.4)	10 (8.0)	6 (4.8)	35.2	47.2	52.8	4000.0	244.0	15.0 : 1
April ..	236	30 (12.7)	67 (28.4)	82 (34.8)	24 (10.1)	33 (14.0)	41.1	53.8	46.2	7835.2	255.5	29.7 : 1

prey with frenzy. Tester *et al.* (1954) stress the importance of the speed or motion of the artificial lures as a prerequisite in attracting the local non-responding skipjack schools at Hawaii. Only two methods of fishing namely, pole and line method with live bait and trolling are universally so far known as very efficient methods of exploiting the surface schools of skipjack taking advantages of their feeding behaviour. If the large sized groups of skipjack are underexploited at present at

Minicoy, it remains to be studied whether the other method of fishing viz., trolling with different trolling speeds, different types of lure etc., in addition to increasing the cruising speed of the pole and line fishing boats and substituting larger hooks etc., could help in harvesting them.

SUMMARY

1. The examination of 2609 stomachs of *K. pelamis* shows that its natural food consists chiefly of crustaceans, cephalopods and larval and juvenile fishes.

2. The bait fishes recovered from the stomach contents of skipjack mainly belong to the families, Pomacentridae, Apogonidae, Labridae and Atherinidae.

3. The stomach contents of 103 skipjack ranging in size from 290-880 mm. in total length show that there is an increase in the average volume per stomach and decrease in the volume per unit weight of the body with the increase of body length.

4. The bait fishes form the dominant constituent of the gut contents ranging from 6.9-29.7 times the natural food.

5. The dominant natural food elements of the size groups 1 (below 400 mm.) and 2 (between 401-550 mm.) were crustaceans, whereas for the size groups 3 (between 551-700 mm.) and 4 (above 700 mm.) were larval and juvenile fishes and cephalopods respectively.

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