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FEEDING HABITS OF FRIGATE MACKEREL (*AUXIS TAPEINOSOMA*) IN THE NORTHEASTERN WATER OF TAIWAN

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ABSTRACT

K. H. Chang and S. C. Lee (1971) *Feeding habits of frigate mackerel* (Auxis tapeinosoma) *in the northeastern waters of Taiwan*. Bull. Inst. Zool., Academia Sinica **10**(2): 47-57. Stomach contents were examined from 352 frigate mackerel (*Auxis tapeinosoma*) caught by handline fishing in waters off Nanfanao from August, 1970 to May 1971. Stomach contents weight indices (SCWI) increased from August, September to October, then dropped down and became flattened from November to next May. Frigate mackerel fed mainly on crustaceans, fishes and mollusks. There are no food selectivity could be considered. The principal crustacean food consisted of euphasiids, copepods, amphipods, megalops, alima larvae and shrimps, while the main molluscan items were squids, pteropods and gastropod shells. The major fish items were Gympelidae, Trichiuridae, Nemichthyidae, Scorpaenidae, Synodontidae and apodal leptocephalus. Gill rakers, gill sieves and bristles on each side of gill rakers form a gill mesh to asses filtering foods from sea water. Numerous gill rakers of frigate mackerel is similar to that of plankton feeder while the shorter intestine is close to that of carnivorous fish. The feeding patterns appeared in the mackerel is in bell-shaped as an omnivorous fish.

The frigate mackerel, *Auxis tapeinosoma* (Bleeker), which distributes from north Japan, Taiwan, Philippines and southward to Indonesia, is one of the commercially important mackerels in the waters of Taiwan. It has long been used as materials of fish cans and also as baits of long line fishing. Its fishing ground covers almost of the eastern waters of Taiwan, but it is very abundant in northeastern waters during the period extending from May to August. The result of the concentrating of the fishes may conerns its feeding habits.

The present work is carried out with an attempt to find out the feeding habits of the frigate mackerel, and then in search of the mechanisms of its schooling behavior.

MATERIALS AND METHODS

Three hundred and fifty two (157 males and 195 females) frigate mackerels caught by hand linear purchased from Nanfanao fish market at monthly intervals from August 1970 to May 1971 were used in the study (Table 1). The fishing ground was restricted to the sea not far from the coast off Nanfanao,

TABLE 1.

List of frigate mackerels collected from northeastern sea of Taiwan

Month	Sex	Male Sample size	Male Fork length (mm)	Female Sample size	Female Fork length (mm)
1970	Aug.	21	252-304	33	248-320
	Sep.	25	208-247	24	215-244
	Oct.	8	231-266	20	233-267
	Nov.	10	231-261	15	230-257
	Dec.	23	232-272	26	241-263
1971	Jan.	22	252-296	18	253-306
	Mar.	10	272-311	12	278-313
	Apr.	17	286-335	19	278-316
	May	21	260-294	28	260-303

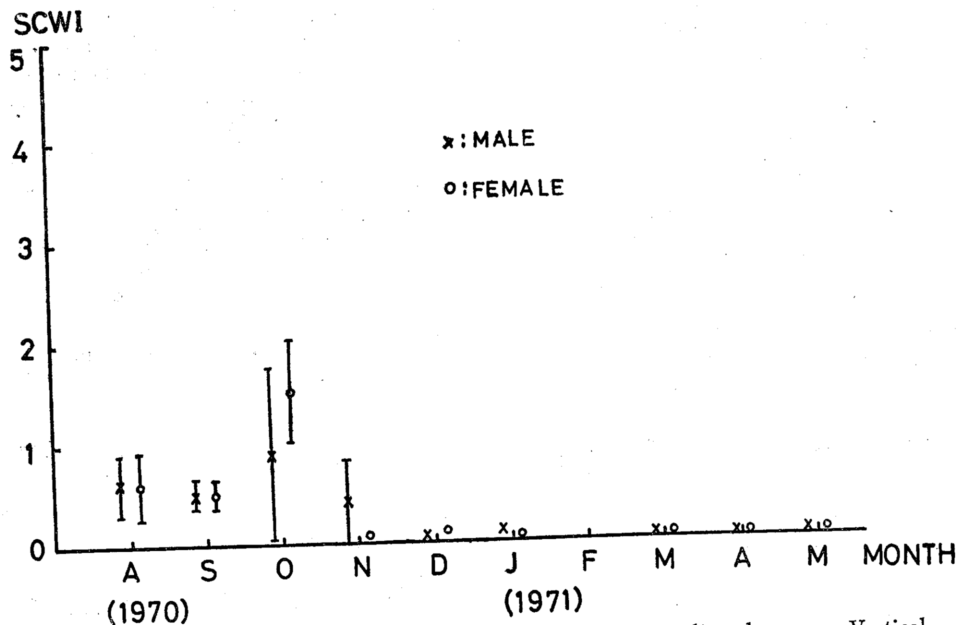

Fig. 1. Monthly fluctuation of stomach contents weight indices by sexes. Vertical bars indicate twice of standard error.

Sampling was made within the time from evening till dawn.

The specimens were injected with 10% formalin into their abdominal cavities to preserve stomach contents in perfect condition. Then the specimens were preserved for a suitable period in the same formalin solution. Afterwards the body weight, fork length, mouth cleft, mouth breadth, gill raker counting, length of longest gill raker, width of gill-raker intervals, length of stomach and intestine were measured. When stomachs

TABLE 2.

Occurrence of food organisms in stomachs of frigate mackerels

Month	Occurrence of food organisms (%)									
	(1970) Aug.	Sep.	Oct.	Nov.	Dec.	(1971) Jan.	Mar.	Apr.	May	Total
No. of stomachs	54	49	28	25	49	40	22	36	49	352
Coelenterata		4	4			5			2	2
Medusae		4	4			5			2	2
Mollusca	15	33	50	8	8	5	5	3	6	15
Pteropoda		16		4		3				5
Squids	15	14	50	4	2		5	3		9
Gastropoda		14			6	3			6	4
Annelida	4									*
Polychaeta	4									*
Crustacea	74	92	75	44	24	55	32	31	29	52
Copepoda	6	82	46	4	14	28	14		16	24
Amphipoda	19	23	21	12	8	25	18	25	10	18
Euphasia	41	92	75	16	8	15	9	8	8	32
Shrimp	4	14			2	3				3
Shrimp larvae				4	4					1
Megalop larvae	33	10		16	4	10	14	3	4	11
Anomura larvae	6					3				1
Squillidae	4		4							1
Gonodactylidae			4	4						*
Alima larvae	41	10	4	12	2	3	9	14	2	12
Scyllaridae larvae	30					3				5
Other decapod larvae				4						*
Fish	48	37	79	48	2	15	5	11		26
Engraulidae	2									*
Carangidae	4									*
Gympelidae			7							*
Trichiuridae			7	4						1
Apogonidae			4							*
Antigonidae				2	2					*
Scorpaenidae				8						*
Juvenile eels	2									*
Leptocephalus	2	2					5			1
Nemichtbyidae			11							1
Other apodes			4							*
Synodontidae			7							*
Diaphus				2	2					*
Bregmaceromatidae			11							1
Holocentridae	2									*
Triacanthidae	2									*
Balistidae						3				*
Unidentified fish	33	23	29	36		10		11		15
Unrecognized material				8	4	18	14	11	6	5

*: Below 1%

were dissected, the contents were weighed by using Ishida's balance, and the stomach content weight indices (SCWI) was calculated by $\frac{\text{stomach contents weight}}{\text{Body weight}} \times 100$

Then, the food organisms eaten by the fish were sorted and the frequency of occurrence of food organisms was conducted by the formula:

$$\frac{\text{No. fish feeding on particular food organisms}}{\text{No. surveyed fish}}$$

×100

The maximum size of total length and minimum size of the other body parts (body depth or body width) of the undamaged food organisms were measured.

RESULTS

I. Quantitative analysis of stomach contents

As shown in Fig. 1, the mean values of stomach content weight indices (SCWI) were completed. There were no difference existed between sexes in any month and it showed that the SCWI increased from August, September to October, then dropped down and became flattened from November to next May. The relationship between SCWI and fork length was also obtained but because of the limited range of the body length (208–335 mm) of the examined fish, no linear relationship between SCWI and fork length could be found out.

II. Qualitative analysis of stomach contents

1. *Diet composition*: Parasitic nematopods were occasionally found in the stomachs but they were excluded because they weren't considered to be fed by frigate mackerel. As shown in table 2, crustaceans were the major foods of frigate mackerel in this area, fishes and mollusks were of the secondary important food categories. Coelenterats and annelids were scarcely found. Phytoplanktons and protozoans were not found in the stomachs of frigate mackerel. Among crustaceans, euphasiids were the major ones in the list of diets and then followed by copepods and amphipods. The common copepods were Calanidae, while the common amphipods were *Cxycephalus*, *Rhabdosoma*, Hyperidae, Phrosinidae and Vibiliidae. Larvae of stomatopods, anomura, crabs and *Ibacus* were also found frequently. Shrimps and adult stomatopods belonging to Squillidae and Gonodactylidae were also contented. Fishes eaten by frigate mackerel were juveniles and most of them were difficult to identify species because of digestion, yet part of them listed as follows could be easily recognized: Apodal leptocephalus, *Nemichthys*, *Holocentrus*, *G. tapeinosoma* (Gympellidae), Trichiuridae, Bregmacerotidae, Apogonidae, Synodontidae, *Engraulis*, Carangidae, *Sebastiscus* (Scorpaenidae), *Diaphus*, Antigonidae and Balistidae. Among Mollusks mainly consisted of pteropods, squids and gastropod shells.

2. *Monthly fluctuation of diet composition*: From table 2, copepods found in the stomachs of frigate mackerel were comparatively abundant in September and October, Euphasiids were very abundant during the months of August, September and October. Other crustacean larvae were mainly found in August. Fishes eaten by frigate mackerel were frequently found during the period extending from August to November. Other diet categories showed no regular tendency.

TABLE 3.
Frequency of occurrence of the main foods in relation to the body size of frigate mackerel (%)

Size group (mm) / No. exam. / Food items %	201-250	251-300	301-350
No. exam.	91	227	34
Crustacea	73	45	50
Copepoda	56	14	9
Amphipoda	18	13	27
Euphasia	63	19	21
Megalopa	9	11	15
Alima	9	12	12
Mollusca	26	11	9
Squid	13	8	9
Pteropoda	10	—	—
Fish	43	19	24

3. *Comparison of the occurence of food organisms with different size of frigate mackerel*: In table 3 and Fig. 2 showed that frigate

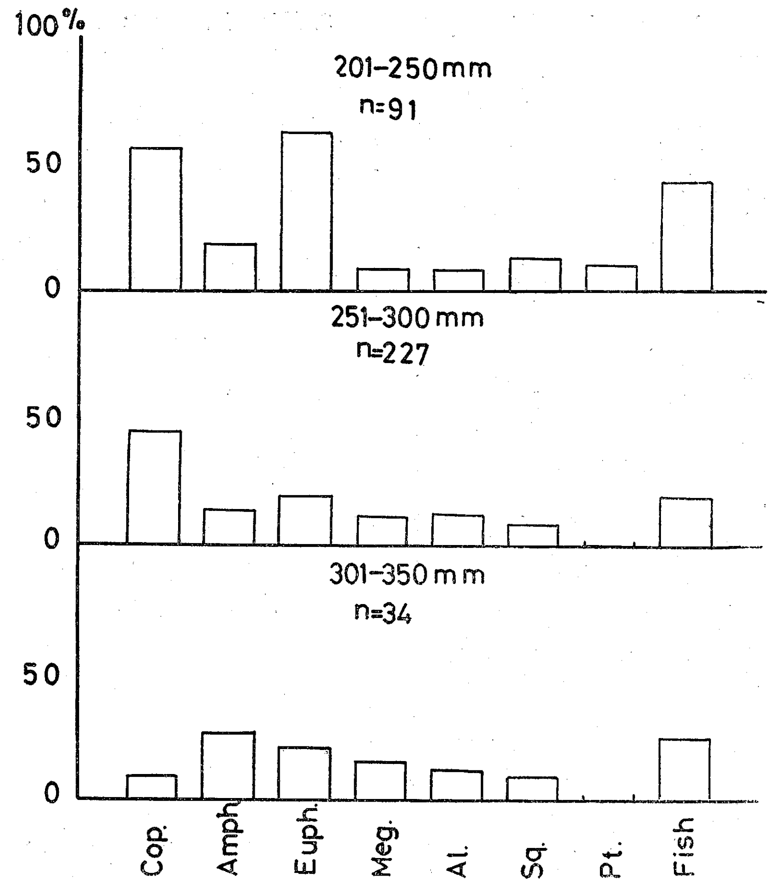

Fig. 2. Frequency of occurrence of the main foods in the stomach contents of frigate mackerels in each size group. (Cop., Copepoda; Amph., Amphipoda; Euph., Euphasiacea; Meg., Megalopa; Al., Alima; Sq., Squid; Pt., Pteropoda).

mackerel fed mainly on crustaceans when the fish were under 250 mm in length, but the amount of crustaceans decreased gradually when the fish grew over 250 mm. Mollusks and fishes preyed upon by frigate mackerels also indicated the similar tendency as that of the crustaceans. Of the crustaceans, copepods and euphasiids had been eaten with higher frequency by the smaller frigate mackerel of 201-250 mm but reduced in larger fish. Amphipods and other crustacean larvae eaten by frigate mackerel did not show any obvious difference in different size of the mackerels.

III. Feeding mechanism

1. *Mouth structure*: Teeth in jaws are canine-like but small and feeble, vomer and palatine are toothless. Therefore, when preys are larger than the mouth, they are difficult to pass through the mouth cavity. It can only catch preys in sea water by filtering them. Yasuda (9) pointed out that the size of mouth cleft and that of the mouth breadth are important factors to feeding mechanism

of the fish. The size of mouth cleft determines the trapping mechanism or action and the mouth breadth controls the size of prey. In Fig. 3, both maximum size and minimum size of the preys and in relation to mouth breadth were plotted. It clearly indicated their overlapping situation, this result is in agreement with that of Yasuda's work. The relationship of mouth cleft and fork length as well as which of mouth breadth and fork length has linear correlation as shown in Fig. 4 and Fig. 5 respectively. The formula is Y=0.85+0.08X (r=0.94) and the latter is Y=−2.28+0.05X (r=0.89), where Y=mouth cleft or mouth breadth, X=fork length.

2. *Gill structure*: There are two important functions in gills, they are respiration and filting. The respiration is played by gill filaments, while the filtering function is carried out by gill rakers. Gill rakers of frigate mackerel are slender and pointed, the longest one is about 3.61-4.11 (3.90%) of fork length, the regression of the longest gill-raker length on fork length is Y=1.46+0.03X (r=0.81), which is shown in Fig. 6. Gill rakers with number of about 42-49 (Fig. 7) on the first left gill arch, each one furnishes with many bristles on each side. The intervals between gill rakers ranging 0.4-1.0 mm is quite narrow. Gill sieves are situated at bases of gill rakers. The minimum preys ranging 0.7-5.0 mm filtered by gill rakers is in comparison with intervals of gill rakers are listed in table 4. Most of them are larger than the widest gill-raker interval, they can be kept in mouth cavity by gill sieves and the bristles on each side of gill rakers. Gill rakers, gill sieves and bristles form a gill mesh to carry out the feeding mechanism. Morphologically, undamaged gill rakers of frigate mackerel are closely related to the typical form of plankton feeder and it is quite different from that of carnivorous fishes which could be found with many damaged gill rakers.

3. *Digestive tract*: Following by mouth cavity, there lies the pharynx which is indistinct but with bristle-like teeth. Esophagus is short with thick and rough wall. "Y" shaped stomach includes cardiac end, blind sac and pyloric end. Cardiac end is distinctly short, blind sac is elongated and pyloric end is bulb-like. Longitudinal mucous folds on the inner lining of stomach is present. When the stomoch is empty or only with few food, the mucous folds is very clearly visible, when the stomach has great amount of food, the inner lining of stomach is nearly smooth. Much mucous can be found in the stomach and digestive secretion can also induced into stomachs to asses the digestion of the preys eaten by them. The comparison of stomach length including empty stomachs and those with contents with fork length of the fish is also made by obtaining the linear rgeression relationship. The result is Y=15.6 +0.22X, in which Y=stomach length, X=fork length, the coefficient of correlation (r) is 0.40. But when the length of empty stomachs only was used to compare with fork length, the relationship obtained was Y=0.16+0.26X and r=0.66. This result is considered to be quite acceptable (Fig. 8). Intestine is followed by the end of pyloric stomach and extending to anus. According to 36 specimens, the length of intestine is measured to have a proportion of about 1.73-2.05 (1.85) in fork length. It indicates, the intestine of frigate mackerel is quite shorter than that of the plankton feeder's.

DISCUSSION

From the results of stomach examination of frigate mackerel, we can easily find out that frigate mackerel usually feed on any kinds of food organisms such as planktonic crustaceans, benthic shrimps and stomatopods, fishes and mollusks they encountered. It can't be considered that they have any selectivity in feeding. Otherwise, the numerous gill

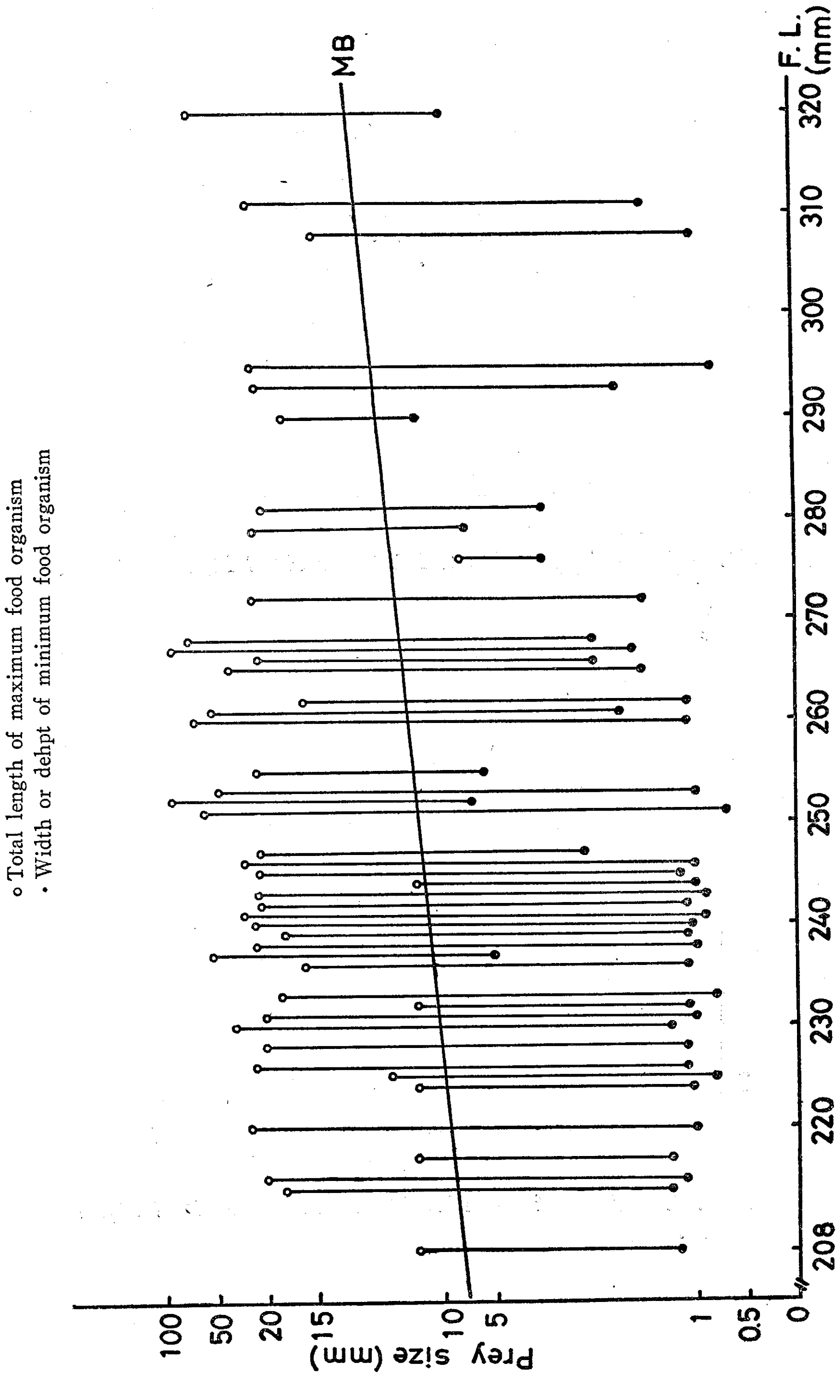

Fig. 3. Size of food organisms and mouth breadth.

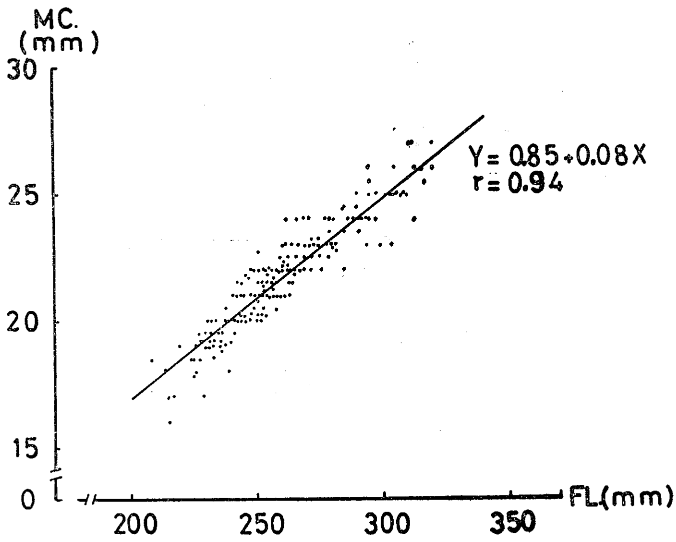

Fig. 4. Relation of mouth cleft to fork length of 267 frigate mackerels.

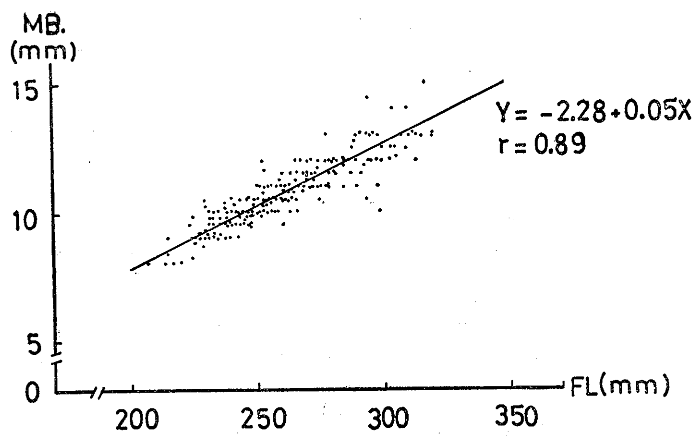

Fig. 5. Relation of mouth breadth to fork length of 267 frigate mackerels.

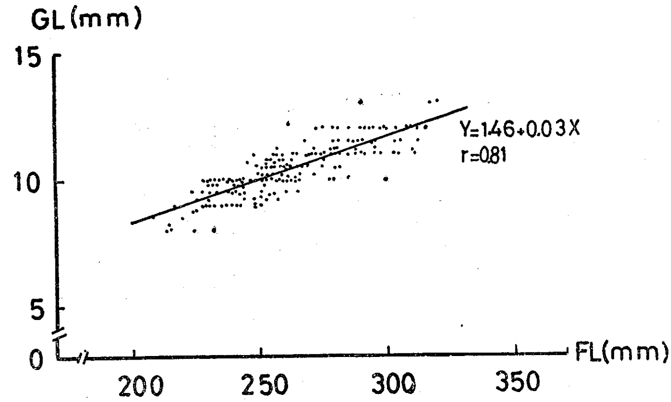

Fig. 6. Relation of the longest gill raker to fork length of 267 frigate mackerels.

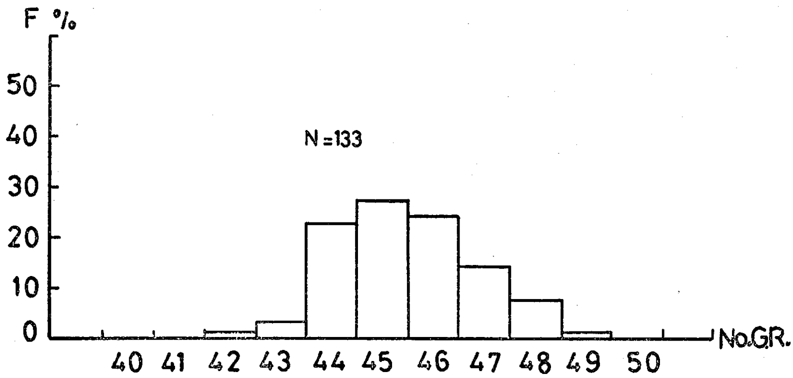

Fig. 7. Frequency of number of gill rakers of first left arch in frigate mackerel.

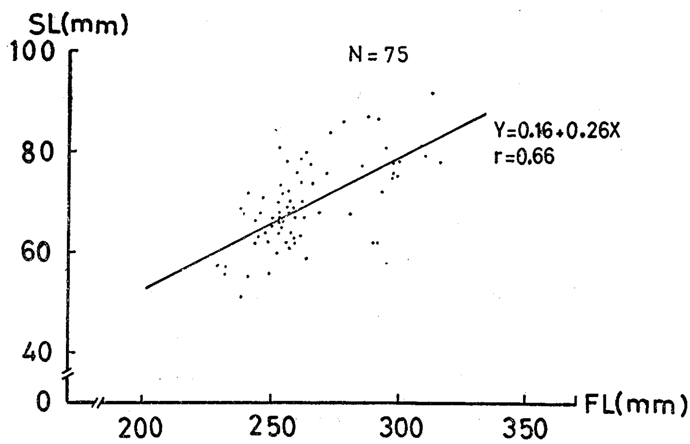

Fig. 8. Relation of the length of empty stomachs to fork length of 75 frigate mackerels.

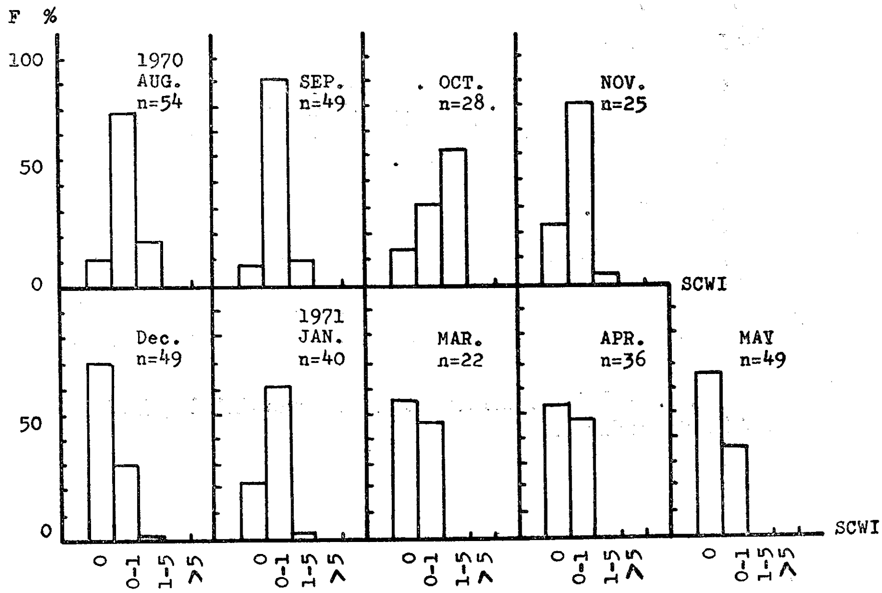

Fig. 9a. Feeding patterns of frigate mackerel by month.

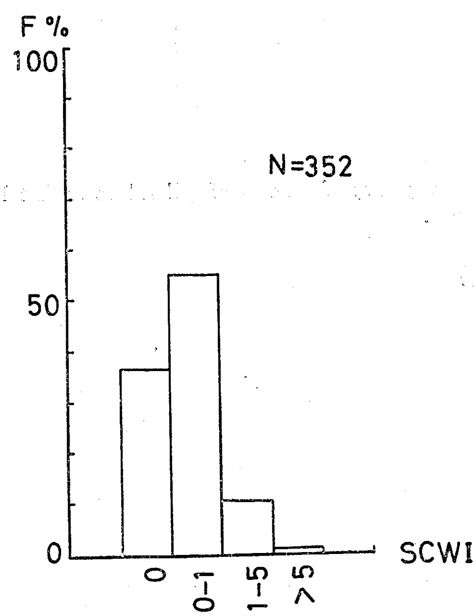

Fig. 9b. Feeding patterns of 267 frigate mackerels from August, 1970 to March, 1971.

TABLE 4.
Interval of gill raker and minimum size of food organism

Fork length (mm)	Interval of gill raker (mm)	Minimum size of food organism (mm)
231	0.5	1.0
233	0.6	0.8
235	0.6	4.5
237	0.6	5.0
238	0.5	1.0
238	0.6	1.0
241	0.6	0.9
242	0.5	1.2
243	0.4	1.2
243	0.5	1.0
246	0.4	4.0
246	0.8	1.0
251	0.5	2.8
251	0.5	0.7
252	0.7	7.0
253	0.6	1.5
253	0.6	1.0
253	0.8	1.2
258	0.8	1.0
260	0.8	1.1
261	0.5	2.5
261	0.8	2.0
262	0.5	1.1
263	0.9	3.0
266	0.8	3.0
267	0.5	1.5
272	0.7	2.0
275	1.0	2.0
275	1.0	1.7
285	1.0	1.1
293	0.9	2.5
295	0.8	0.8
306	0.9	1.8
308	1.0	1.0
311	1.0	2.0
313	1.0	1.2

rakers of frigate mackerel is similar to that of plankton feeder, while the shorter intestine is close to that of carnivorous fishes. From Fig. 9a-b, the distributions of SCWI was generally in bell-shaped, it is quite similar to those of results obtained in spotted mackerel (1) and we may consider that frigate mackerel is an omnivorous fish on the basis of the above mentioned reasons.

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