INTER-SPECIFIC RELATIONS CONCERNING THE PREDACIOLTS HABITS AMONG THE BENTHIC FISH

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By

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The food relationships or predacious habits among fish are important factors, operating to mould the character of a fish community, when they have the same habit. The inter-specific relations among the benthic fish living together, paticularly their feeding habits have been studied in this report. The kinds of benthic fish taken by middle-sized trawlers from Sendai Bay throughout the year of 1952 can be judged from the records (Table 1) of the monthly commercial landings at the Fish Market of Yuriage. The sampling locality was fixed within a 4 square miles area in the northern part of Sendai Bay, where the depths were between 30 and 50 m. The investigations were carried out once or twice each month during the period from June to December in 1952, with the addition of several occasions in 1953, when collections were made aboard the fishing boat "Daishin-Maru". The fish caught during a voyage from the above locality were divided and weighed by species for a unit haul. Body length measurements and detailed observations on the stomach contents were executed in the laboratory on 10 to 20 specimens of different size and species taken from each catch at eight opportunities. The fish examined include seven species of flat fish and one species of gurnard, amounting to 928 individuals in total.

We should like to express our hearty thanks to the members of Fish Market of Yuriage Fisheries Cooperative Association and also to the members of the "Daishin-Maru", for their kind cooperation in collecting the materials. We are also indbebted to Messrs. S. Yamato and K. Abe for their assistances given during the investgations. The expense of this study was partly defrayed by a grant from the Ministry of Education.

1. Types in the predacious habits

The dates of collections, the amount of catch per unit haul and the size range

Table 1. Records of the commercial landings of benthic fish at the Fish Market of Yuriage in 1952 (in tons)

Species Name	Limanda herzensteini	Paralichthys olivaceus	Limanda yokohamae	Lepidotrigla microptera	Kareius bicoloratus	Microstomus achne	Pleuronichthys cornutus
Jan.	41.13	29.04	7.35	5.12	9.49	4.82	2.07
Feb.	35.79	30.09	12.36	3.47	8.11	5.91	4.27
Mar.	20.85	20.64	6.39	3.61	0.80	8.12	2.11
Apr.	12.78	11.20	7.67	3.96	0.66	5.21	0.53
May	33.95	26.99	20.94	4.08	8.10	10.21	3.39
June	14.52	20.91	14.93	18.81	3.88	0.68	0.56
July	11.08	12.90	5.73	3.56	3.08	0.50	0.15
Aug.	55.04	6.68	6.22	4.21	2.73	4.34	0.17
Sep.	119.85	23.86	26.63	13.37	7.73	7.01	4.22
Oct.	48.71	62.22	12.29	10.36	8.01	1.16	3.56
Nov.	46.41	18.04	13.55	10.28	4.26	3.47	2.69
Dec.	50.06	78.43	21.23	15.34	24.10	4.14	7.06
Total	490.54	373.88	155.30	96.17	80.95	55.56	31.56

for each species are given in Table 2. Fish less than 5 cm or exceeding 65 cm in length were not obtained in this area. The stomach contents of each specimen were classified into five items, namely annelid worms, small crustaceans, large crustaceans, molluscs and fish. The average weight of each food item in the stomach are shown in Table 3, for the species, and for the size-groups according to the season of collection. As seen from this table, the kinds of food taken by the fish do not vary fundamentally with seasons, except for the collection on July, 1st. In this occasion, juvenile fish of the sand-launce (*Ammodytes personatus*) were found for the first time in the stomachs of *Kareius bicoloratus*, *Limanda herzensteini*, and *Eopsetta grigorjewi*. In this season of the year abundant juvenile fish of the sand-launce can usually be found in Sendai Bay (1).

As the seasonal variations of food are not conspicuous, the food items for each species were investigated throughout the period of collection, by means of the percentages of weights separately for the size groups in five cm interval of body length (Table 4). The size groups containing less than five specimens were omitted from comparison. From this table the staple food of various sizes of each species can be known.

Microstomus achne :– Annelid worms predominate for all size-groups. Small crustaceans for the size-group between 10 and 14 cm, and large crustaceans for 15–19 cm group are next to the annelids in frequency. Molluscs and fish were not found in the diets.

Table 2. Collections of the benthic fish in the northern part of Sendai Bay in 1952, with informations bearing on the catch per haul and the size range of each species

No.	Dates of Collect. / Species Name	Catch per haul in kg VI-10	VII-1	VII-24	VIII-14	VIII-29	IX-26	XII-5	XII-24	Size range in cm
1	L. herzensteini	0.3	1.5	0	20.2	12.2	4.8	5.6	0.2	10.4～25.8
2	P. olivaceus	12.7	7.5	11.3	3.0	0.3	16.0	23.6	16.7	10.5～65.1
3	L. yokohamae	8.0	1.7	14.5	2.3	1.8	0	5.2	6.3	9.2～35.2
4	L. microptera	4.2	5.5	0	0.7	1.0	0	0	1.4	10.4～25.4
5	K. bicoloratus	0	0	0.7	0	0	0	0	0	5.7～14.9
6	〃	7.6	0.03	1.1	0.8	0.6	0	0.5	8.8	15.0～21.9
7	〃	1.0	0.07	0.3	0.7	0.5	0	3.9	1.2	22.0～49.1
8	M. achne	0	1.2	0	1.4	3.8	0	0.7	0	11.8～26.5
9	P. cornutus	0	0	1.6	0.6	0.4	1.3	0	0.4	8.3～17.6
10	E. grigorjewi	1.0	0.7	2.2	11.2	4.5	0.4	0.7	0.7	9.7～23.9

Table 3. The average weight (in gr) of each food item in the stomach, for the species and for the size-groups according to the season of collection

Season of Collection	June ～ July						Sept. ～ Oct.					Dec.				
Size range in cm	5～9	10～14	15～19	20～24	25～29	30～	10～14	15～19	20～24	25～29	30～	10～14	15～19	20～24	25～29	30～
Microstomus achne																
Annelids	0.1	6.3	3.2				17.0	7.5				0.7				
Small crustaceans		3.3	0.1													
Large crustaceans			0.2					0.6								
Molluscs																
Fishes																
Unident. fragments		1.9					2.3	1.3				0.1				
Pleuronichthys cornutus																
Annelids	0.6	1.0					3.1					1.7	5.0			
Small crustaceans	0.5	1·0														
Large crustaceans																
Molluscs												0.3	0.3			
Fishes																
Unident. fragments		1.2					0.6					0.7				
Limanda yokohamae																
Annelids	0.4	8.6	4.8	3.2				32.4				2.3	7.1	3.9	0.3	
Small crustaceans		0.2	0.4													
Large crustaceans		0.9						3.9					1.2			
Molluscs		0.6	1.9	0.1				0.8		0.2			2.1	0.8		
Fishes																
Unident. fragments		1.5	2.5	1.6				4.2		0.1			0.4	0.5	2.6	

Limanda herzensteini

Annelids	1.2 2.3 5.3	11.7 2.0 0.4	8.7 4.5 1.7
Small crustaceans	1.2 0.5		
Large crustaceans	0.9 3.2 3.9	1.6	
Molluscs	0.7 0.4 1.0	0.1	0.1
Fishes	5.7 2.8		
Unident. fragments	3.7 1.7 0.8	0.8 0.6	0.4

Kareius bicoloratus

Annelids	0.4 2.5 0.1	0.1 1.0	
Small crustaceans	0.2 0.1 0.1	0.1	
Large crustaceans	7.3 0.5	0.6	1.4 1.2
Molluscs	3.8		
Fishes	1.3 14.7		
Unident. fragments	0.1 2.6 0.6	0.1 0.4	

Eopsetta grigorjewi

Annelids	0.1		
Small crustaceans	3.1 4.0 0.8	1.9 0.5	
Large crustaceans	2.3 5.8 3.4	1.6 0.5	1.5 13.7
Molluscs	0.2		
Fishes	3.6 4.3		
Unident. fragments			

Lepidotrigla microptera

Annelids			
Small crustaceans	0.5	3.7 0.3	
Large crustaceans	0.4 1.7 2.5	4.1	1.4
Molluscs	0.2	0.3	
Fishes			
Unident. fragments			

Paralichthys olivaceus

Annelids			
Small crustaceans	0.2 1.4 3.6		0.2
Large crustaceans	0.1	0.3	2.3 0.5 3.6
Molluscs	2.5 7.1		7.4
Fishes	1.5 1.7 5.3 6.3 14.9	2.1 3.0 1.1	2.5 3.6 13.5
Unident. fragments			

Pleuronichthys cornutus : – Annelid worms are dominant for all size-groups, followed by small crustaceans for the size-groups of 5–9 cm and 10–14 cm, and molluscs for 15–19 cm group. Large crustaceans and fish were not found.

Limanda yokohamae : – Annelid worms are also predominant for all size-groups, large crustaceans for the size-groups of 10–14 cm and 15–19 cm, followed by the molluscs for the group of 20–24 cm. Fish were not found.

Limanda herzensteini : – Annelid worms are dominant for all size-groups, large crustaceans and fish succeed the size-groups of 15–19 cm and 20–24 cm. Food items show a rather wide range of animals.

Kareius bicoloratus : – Change of food with growth is most obvious. For the size-group of 10–14 cm, annelid worms are most prominent, followed by small crustaceans, but neither large crustaceans, molluscs nor fish occur. For the size-group of 15–19 cm, large crustaceans dominate, followed by various kinds

Table 4. The percentage composition of the food items in weight for each species, throughout the period of collections

Species name	Class	size range in cm	Annelids	Small crustaceans	Large crustaceans	Molluscs	Fishes	unidentif. fragments
M. achne	1	10~14	87.9	12.1				4.3
	2	15~19	92.2	1.0	6.8			1.3
P. cornutus	3	10~14	81.6	13.1		5.3		
	4	15~19	94.3			5.7		
L. yokohamae	5	10~14	86.5	1.5	7.1	4.9		1.5
	6	15~19	81.1	0.9	9.3	8.7		7.1
	7	20~24	87.1		1.5	11.4		2.1
L. herzensteini	8	10~14	91.6	5.0	1.7	1.7		4.9
	9	15~19	43.5	2.4	23.7	2.2	28.2	2.3
	10	20~24	49.0		25.8	7.5	18.5	0.8
K. bicoloratus	11	10~14	71.4	28.6				0.2
	12	15~19	20.5	0.5	48.8	22.3	7.9	3.0
	13	20~24	0.7		10.3		89.0	0.6
E. grigorjewi	14	10~14	1.1	54.3	42.3	2.3		
	15	15~19		28.3	49.0		22.7	
L. microptera	16	10~14		48.2	51.8			
	17	15~19		7.8	79.4	12.8		
P. olivaceus	18	10~14		11.2			88.8	
	19	15~19		14.1	9.9		76.0	
	20	20~24		0.2	15.4		84.4	
	21	25~29			2.2		97.8	
	22	30~			14.2		85.8	

of molluscs, annelids and fish in the order named. For the size-group of 20–24 cm, small fish are predominant, followed by large crustaceans, but neither small crustaceans nor molluscs occur.

Eopsetta grigorjewi : – Change of food with growth is fairly marked. For the size-group of 10–14 cm, small crustaceans take first place, followed by large crustaceans but no fish. For the size-group of 15–19 cm, large crustaceans predominate, followed by small crustaceans and fish, but neither annelids nor molluscs occur. For the size-group of 20–24 cm, large crustaceans are likwise predominant, followed by fish and small crustaceans, but neither annelids nor molluscs occurr.

Lepidotrigla microptera : – Large crustaceans are dominant for all size-groups, followed by small crustaceans and molluscs, but neither annelid nor fish occur.

Paralichthys olivaceus : – Fish are predominant as food for all size-groups. Small crustaceans succeed for the size-groups of 10–14 cm and 15–19 cm, and large crustaceans for all sizes exceeding 20 cm upwards. Neither annelids nor molluscs were found.

In short, the main food items are quite definite for each species regardless of their growth within the size range of this study, except for the case of *K. bicoloratus*.

All of the specimens were divided with five cm interval of body length, and each division independent of species were separated into twenty-two classes. Then the correlation coefficients between each two classes taking into consideration the percentage composition of the weight of food items were calculated after Motomura's method (2). Thus, the reciprocal relation of the composition of each class was represented by twenty-two series of correlation coefficients (Fig. 1). The series were classified by their form into three types, each of which represents a characteristic habit.

Type A (The staple food of this type is annelids) : – To this type belong all the series of *M. achne*. *P. cornutus*, *L. herzensteini* and a series which corresponds to the size-group between 10 and 14 cm length of *K. bicoloratus*.

Type B (The staple food of this type is crustaceans) : – To this type belong all the series of *E. grigorjewi*, *L. microptera* and a series of the size-group between 15 and 19 cm length of *K. bicoloratus*.

Type C (The staple food of this type is small fish) : – To this type belong all the series of *P. olivaceus* and a series of the size-group between 20 and 24 cm of *K. bicoloratus*.

A sharp line of demarcation can not always be drawn between the different types, as for instance, one of the series of *L. herzensteini* is intermediate between types A and B. The food of *K. bicoloratus* varies from A-type through B-type to C-type as the fish grow larger.

In short, it is obvious that the benthic fish examined here can be classified into three types, based on their staple food, namely annelid, crustacean and fish eaters.

2. Predacious habits and structures

Some morphological characters closely connected with food-hunting and digestion were measured to find their relations with predacious habits. The length of the maxillary, jaw teeth, pharyngeal teeth, gill-rakers and intestinal loop were compared respectively with each other among the eight species of the benthic fish whose types of diets had been classified. The variations in each structure of the different species are well adapted to their specific habits.

2. 1. Length of maxillary

The length of the maxillary or mouth size were measured separately for the right and the left sides, and the regression lines between the length and body length are shown in Fig. 2, respectively for the seven species of flat-fish. The length of the maxillary on the side with the eyes is usually longer than the side without eyes. This structure may be convenient for the bottom feeder to hunt the prey. That the structure of the fish-eater, *P. olivaceus*, is likewise similar

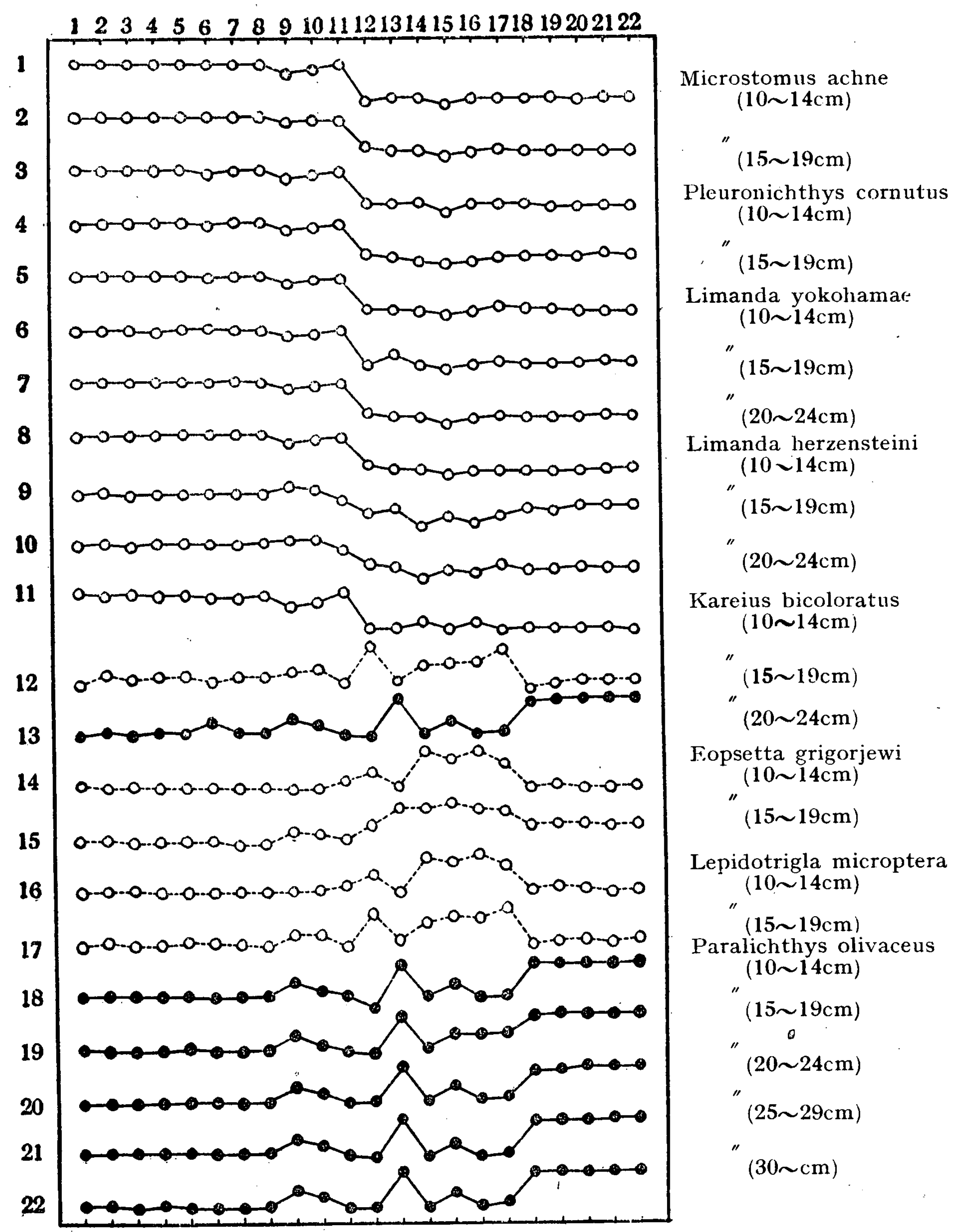


Fig. 1. Recpirocal relation between the compositions of food items in the stomach contents of the respective size groups of each species represented by correlation coefficients.

to that of the other bottom feeders, may account for its feeding on the burrowing fish such as the sand-launce.

There is an order in the arrangement of the mouth size against the body length that the mouth becomes larger with the change of the predacious habits from

A-type through B-type to C-type. The mouth sizes are larger in the cases of *P. olivaceus*, *E. grigorjewi* and *K. bicoloratus* whose diets are mainly fish or crustaceans, than in the cases of *L. herzensteini*, *L. yokohamae*, *M. achne* and *P. cornutus*, preying mainly on annelids. A large mouth may be convenient for the predater to catch fish quick in action or to filtrate the planktonic crustaceans, while a small mouth is more suitable to prey upon tubicolous polychaetes which form the bulk of annelid worms.

2. 2. Jaw teeth and pharyngeal teeth

P. cornutus : – Minute teeth in the anterior part of each jaw on the right side are arranged in 3 or 4 rows, making up a band of teeth, but there become fewer posteriorly and in the outermost there is only 1 row. No tooth are found on the

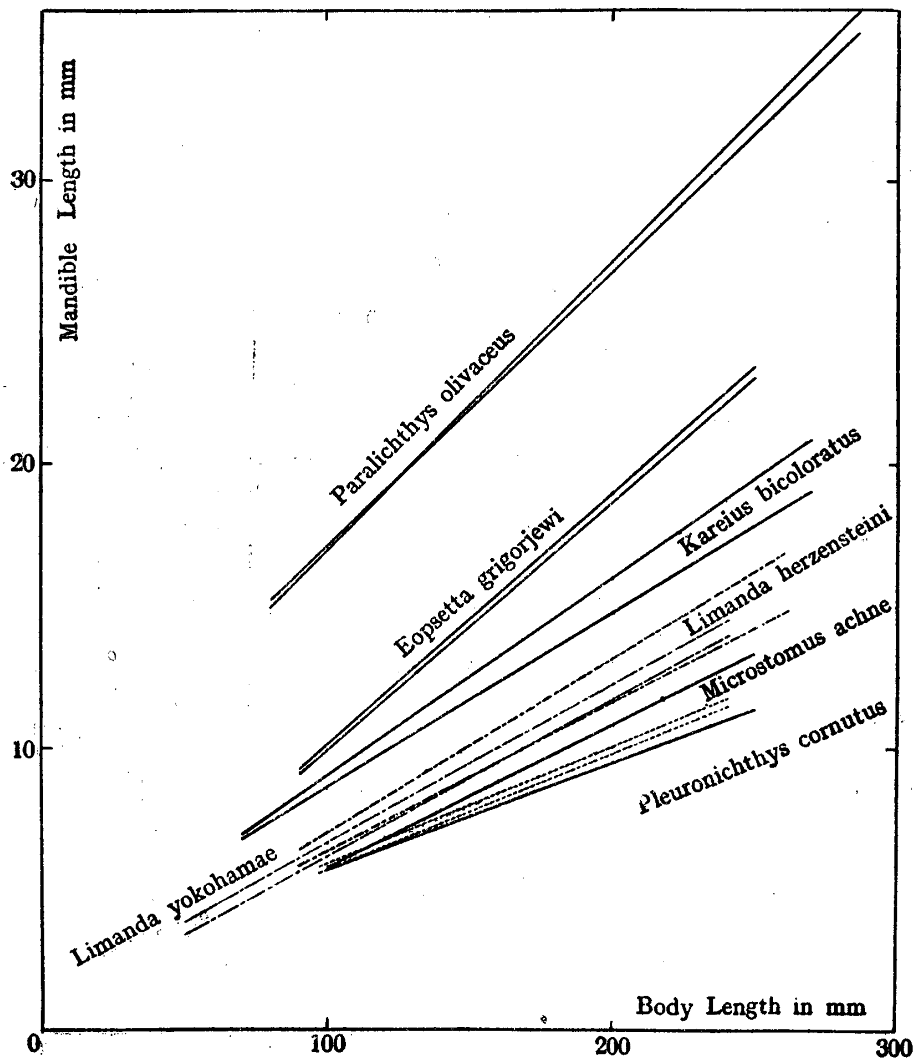


Fig. 2. The relation betwcen the maxillary length and the body length, respectivety for the seven species of flat-fish.

left side. Unsuitable for preying on fish or large crustaceans.

L. herzensteini and *L. yokohamae* : – Both species have broad incisors arranged in 1 row in each jaw on the left side. On the right side, there is no tooth in the upper jaw and only a few occur in the lower jaw. Suited to seize animals burrowing on the bottom.

M. achne : – Broad incisors are arranged in 1 row in each jaw on both sides. Each incisor on the right side is smaller than that on the left side.

K. bicoloratus : – Incisors are arranged in 1 row in each jaw on both sides. Suited to bite the prey. The pharyngeal teeth are granular in shape and well developed for grinding food.

E. grigorjewi : – Small canine teeth are arranged in 2 rows in the upper jaw and 1 row in the lower jaw on both sides. The frontal teeth in the upper jaw are larger but less close-set than those in the lower jaw.

P. olivaceus : – Large and sharp teeth arranged in 1 row, separated from each other, in each jaw on both sides ; those in the anterior part are large but become smaller posteriorly. Suited to seize small fish quick in action. Upper pharyngeal teeth conical and better developed than lower ones.

L. microptera : – For comparison, a gurnard was taken. Very small teeth are arranged in a broad band in each jaw on both sides.

The fish-eater, *P. olivaceus*, has characteristic canine teeth differing from the other flat-fish. *E. grigorjewi* has the most similar structure. Annelid-eaters such as *L. yokohamae, M. achne* and *P. cornutus* have no or very poorly developed teeth on the side with eyes. *K. bicoloratus* has an intermediate structure between the former and the latter. Pharyngeal teeth are not developed except for in *P. olivaceus* and *K. bicoloratus*.

2. 3. Gill-rakers (Fig. 3)

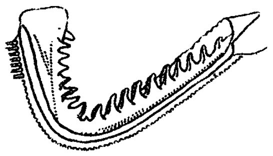
The gill-rakers of *M. achne, P. cornutus, L. herzensteini* and *K. bicoloratus* have in general in a simple structure of tubercular processes separately arranged. Among them, those of *L. herzensteini* and *K. bicoloratus* are larger in size but fewer in number, hence the space between each raker is broad, corresponding to their diets which lack small crustaceans. Those of *M. achne* and *P. cornutus* are smaller and numerous, hence the space are narrow. The gill-rakers of *L. yokohamae* show an intermediate structure between the former and the latter. On the contrary, the gill-rakers of *P. olivaceus*, *E. grigorjewi* and *L. microptera* are covered thickly by long and slender rakers with numerous spines. As the function of the gill-rakers are related to filtration of food, the space between each gill-raker will control the minimum size of the prey.

2. 4. Length of intestine

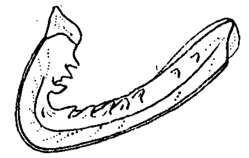
Dissecting the peritoneal wall of the left side of the body, the intestinal loop was exposed, thus its length was measured by integrating the partial components of straight length. The ratios of the intestinal length against the body

Fig. 3. Gill-rakers of each of the 7 species of flatfish and 1 species of gurnard.

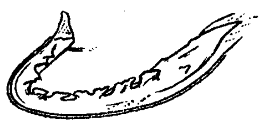
M. achne B.L. 130mm



P. cornutus B.L. 114mm



L. yokohamae B.L. 115mm

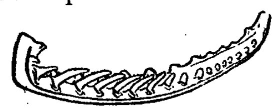


L. herzensteini B.L. 126mm

K. bicoloratus B.L. 141mm

E. grigorjewi B.L. 134mm

L. microptera B.L. 215uum



P. olivaceus B.L. 280mm

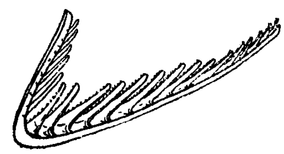
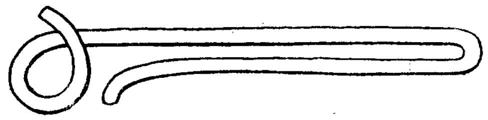
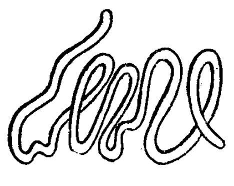


Fig. 4 Diagramatic illustration of the intestinal loop of each of the 7 species of flatfish.

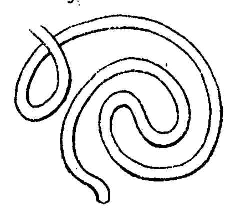
M. achne



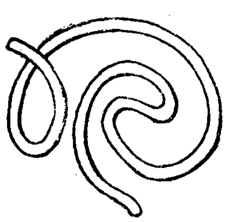
P. cornutus



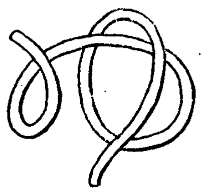
L. yokohamae



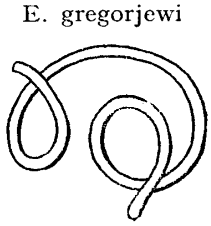
L. herzensteini



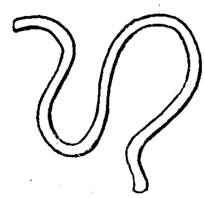
K. bicoloratus



E. gregorjewi



P. olivaceus



length of each specimen were calculated and comparison was made between the different species. Within a species the ratios are almost unchanged with growth. They were compared by the mean value of each species (Table 5).

Table 5. The mean values of the intestinal length against the body length of each of the 7 species of flatfish

Species name	Number of fish examined	The means
P. cornutus	58	1.55
L. yokohamae	104	1.06
L. herzensteini	59	1.01
M. achne	48	0.99
K. bicoloratus	43	0.81
E. grigorjewi	48	0.46
P. olivaceus	13	0.37

Annelid-eaters such as *P. cornutus, L. yokohamae, L. herzensteini* and *M. achne* have a long intestine, whereas they are very short in the fish-eaters and crustacean-eaters, such as *P. olivaceus* and *E. grigorjewi*. *K. bicoloratus* changes its food with growth, but the ratios of the intestinal length to body length show no marked difference in sizes. The length of the intestine is rather long and nearer to that of the annelid-eaters. The parallelism betwen the intestinal length and the predacious habits may perhaps be due to the various degrees of digestion and absorption among the different foods.

2. 5. Intestinal loop

The shapes of the intestinal loop of each species are diagramatically shown in Fig. 4. A serial order existing in the various shapes from the most complex one of *P. cornutus* to the simplest of *P. olivaceus* is comparable to the rank of the intestinal length. The intestinal loop of *M. achne* is elongated posteriorly to beyond the body cavity as far as to the point near three-fourth of the body length and then turns anteriorly.

In general, the series of each morphological structures related to food-hunting and digestions of the eight species show sometimes a gradient and at other times two or three classes, but all of the series confirm with the three types existing in the predacious habits. It is clear that these structures effect directly upon determining the kinds of food for the fish.

3. Composition of the catch and predacious habits

The species composition of the catches are shown in Fig. 5, in which is also given the average weight per haul respectively for each voyage. It can be seen from this figure that the fish caught at the same time in the same ground usually include the three types of predacious habits. Namely, the three types of predacious habits among the benthic fish are due not simply by chance of finding the prey, but from the selectivity of food by their own habits.

Provided the compositions of the catches represent those of a community of benthic fish, the predacious habits are always different between the two dominant species among them. In other words, the two species whose predacious habits belong to the same category can not live together as a most abundant group in the same ground at the same time. The variations in weight of each species

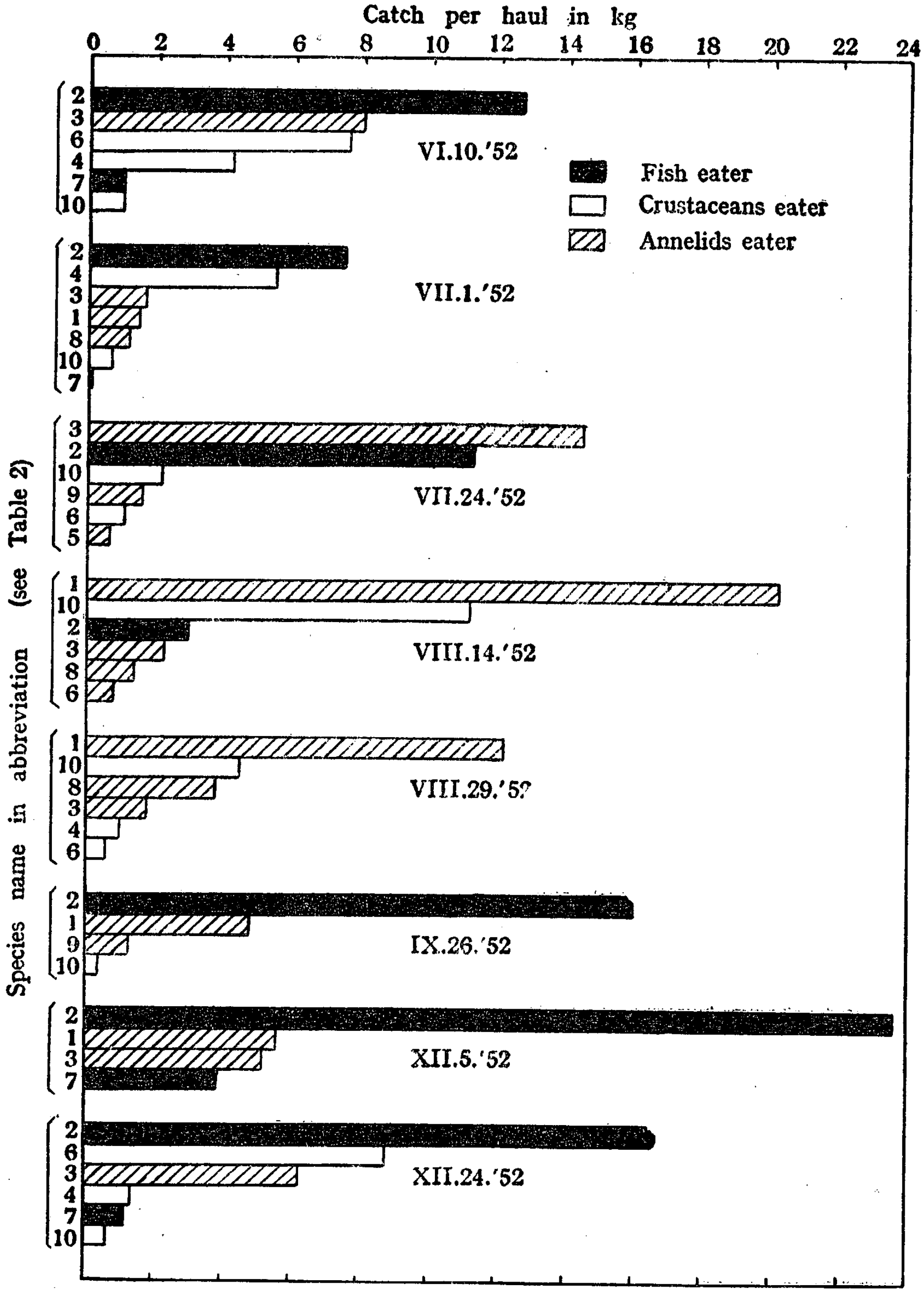


Fig. 5. Catch per haul in kg of each species, classified with the types of feeding habits, separately for the time of collection. On the abbreviation of the species name see Table 2.

may be better treated by grouping the fish with the type of predacious habits.

References

1) Hatanaka, M. and R. Okamoto (1950). Tohoku Jour. Agri. Res., **1**, No. 2, pp. 57-67.
2) Motomura, I. (1935). Ecol. Rev., **1**, pp. 339-342.
3) Motomura, I. (1932). Zool. Mag. (Japan), **44**, pp. 379-383.
4) Kawasaki, T. and M. Hatanaka (1951). Tohoku Jour. Agri. Res., **2**, No. 1, pp. 85-106.
5) Hatanaka, M., K. Sekino and A. Otsuka (1952). Tohoku Jour. Agri. Res., 2, No. **2**, pp. 25-32.
6) Hatanaka, M. and S. Iwahashi (1953). Tohoku Jour. Agri. Res., **3**, No. 2, pp. 303-309.
7) Suehiro, Y. (1942). Jap. Jour. Zool., **10**, pp. 1-303.
8) Ricker, W. E. (1946). Ecol. Monog., **16**, pp. 373-391.
9) Steven, G. A. (1930). Jour. Mar. Biol. Assoc., **16**, p. p. 677-706.