Food Acquisition Patterns in Some Demersal Teleosts

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Summary

Seven demersal teleosts inhabiting Sendai Bay, *Hexagrammos otakii*, *Liparis tanakai*, *Limanda herzensteini*, *Limanda yokohamae*, *Argyrosomus argentatus*, *Nibea mitsukurii* and *Astroconger myriaster*, were examined concerning their food acquisition patterns from the viewpoint of the changes in the composition, size, number and weight of food organisms with growth and development. As a result of the analysis of food acquisition pattern, the following three food selection types are suggested :

1. Number selection type : food organisms are small irrespective of fish size and their number increases with growth of fish to meet the rising food requirements. Example : *Nibea mitsukurii*.
2. Size selection type : food organisms get larger with growth of fish. Example : *Astroconger myriaster*.
3. Transformation type : "number selection" is converted to "size selection" on the way of growth and development of fish. This type is divided into two sub-types. One is sub-type I in which transformation occurs in a short period. *Hexagrammos otakii* and *Liparis tanakai* are examples. The other is sub-type II, in which transformation proceeds gradually. *Limanda herzensteini*, *L. yokohamae* and *Argyrosomus argentatus* are examples.

These differences in the food acquisition patterns are probably caused by interrelation among the foraging ability, tactics, food demand and niche of each species including food procurability in the environment. The selection for food acquisition pattern to cope with the changes in the ability, demand and niche augments the efficiency of foraging activity, which is a means to survive.

Many studies on feeding habits of fishes have been carried out, but the food acquisition pattern of fish under natural conditions has not been worked on comprehensively. In the present study, optimal foraging measures in marine teleosts such as selecting and searching for food are examined, and the central purpose is to establish the food selection type adopted by a species as the optimal strategy through the process of development of life history.

Accordingly, I took up seven demersal teleosts examining the pattern of food acquisition in fish from the viewpoint of the changes in the composition, size, number and quantity of food with growth and development. The species treated are as follows:

1. Fat greenling, *Hexagrammos otakii* JORDAN et STARKS
2. Snailfish, *Liparis tanakai* (GILBERT et BURKE)
3. Brown sole, *Limanda herzensteini* JORDAN et SNYDER
4. Marbled sole, *Limanda yokohamae* (GÜNTHER)
5. White croaker, *Argyrosomus argentatus* (HOUTTUYN)
6. Nibe croaker, *Nibea mitsukurii* (JORDAN et SNYDER)
7. Common Japanese conger, *Astroconger myriaster* (BREVOORT)

Materials and Methods

Samples were obtained in Sendai Bay north of 37°50′N by trawling and gill-netting by RV Suiko of Tohoku University and at Haragama Fish Market, Fukushima, 1980-1981.

Materials were preserved in 10 per cent formalin solution. A number of body parts and stomach contents were measured (Table 1). Taxon compositions of food ingested in every 50 or 100 mm length* interval of fish are shown in weight percentages.

According to Tyler (1) and Omori (2), prey items for demersal fishes are divided into three faunae: 1. nekton (Osteichthyes, Euphausiacea, Mysidacea and

TABLE 1. *Items of Measurement*

	Morphological Characteristics
Motion Apparatus:	Body Length (BL), Body Depth (BD), Body Width (BWi), Pectoral Fin Length (PFL), Ventral Fin Length (VFL), Caudal Peduncle Length (CPL), Caudal Peduncle Height (CPH)
Orientation Apparatus:	Eye Diameter (ED), Snout Length (SnL)
Working Apparatus:	Number of Teeth (Premaxilla, Dentary, Pharyngeal) Number of Gill Rakers Width of Gape (GWi) Stomach Length (StL), Intestine Length (IL)
Stomach Contents:	Stomach Content Weight Food Items Number of Individuals, Body Length, Body Weight, Body Depth and Body Width of Each Food Item
Unit of Length: mm Unit of Weight: g	

*Body length is the distance from the tip of the snout to the hindermost part of the caudal fin.

Cephalopoda), 2. epi-fauna (Macrura, Anomura, Brachyura and Isopoda) and 3. in-fauna (Polychaeta, Sipunculoidae, Amphipoda, Bivalvia, Actiniaria and *Ammodytes personatus*).

The changes in average number and weight of food organisms in the stomach with growth and development of fish were examined.

Results and Discussion

The results are arranged in Table 2 showing the morphological characteristics, relation between sizes of prey and predator, major food items, trend of changes in the number and weight of food with growth and development and food selection types. Food selection types will be explained later.

Categorizing Food Selection Pattern

The developmental stages of fish investigated in the present study were mostly preadult and adult. From the relative growth of the organs in charge of food acquisition (Appendix Tables 1-7), it is supposed that the capacity to acquire food increases with growth and development, resulting in a large ability to handle a larger amount of food. The demand for food increases exponentially with fish size (Appendix Figs. 1-13 and Honda *in* Kawasaki *et al.* (1983) (3)). Thus, both the extent of food demand and ability for food acquisition rise with growth and development. Moreover, from the composition of food organisms taken through the demand and ability of fish at different stages of growth and development, the pattern of food acquisition changes (Appendix Figs. 14-17, Honda *in* Kawasaki *et al.* (1983) (3) and Honda *and* Kawasaki (1983) (4)). This implies that changes in the composition and life form of food organisms occur. Here, I intend to take "feeding" as an activity of energy acquisition, and to discuss what means is adopted by predators for food selection to maximize the energy intake.

From the foregoing I propose two directions of food selection which are defined by the number and size of food organisms : one is that the amount of food required is maintained by increasing the number of food organisms ; the other is that the requirement for food is met by enlarging the size of food organisms instead of increasing the number. For the seven species treated, it is considered that there are generally three types of food selection. The first is a type in which the prey animals taken remain smaller in size, while their number increases with growth and development. This type is named "number selection type", nibe croaker is an example (Appendix Fig. 18). The second one is "size selection type" as exemplified by the common Japanese conger (Appendix Fig. 19). In this type, the prey becomes larger with increasing predator size, while the number of prey stays very small. The third one is "transformation type", in which the pattern of food selection is transformed from "number selection" in which food requirement

TABLE 2. *Characteristics Concerning*

Species	Morphological Characteristics			Prey Size versus Predator Size
	Motion Apparatus	Orientation Apparatus	Working Apparatus	
N. mitsukurii	Rather developed	Rather developed sense of sight	Wide gape, pointed canine teeth	Small ratio (*a*)
A. myriaster	Comparatively underdeveloped	Well-developed olfactory sense	Wide gape, no gill raker	Small ratio, large absolute prey size
H. otakii	Rather developed	Rather developed	Wide gape, dull canine teeth	Comparatively large ratio
L. tanakai	Underdeveloped	Comparatively well-developed olfactory sense	Wide gape, rasp-like teeth	Large ratio
L. herzensteini	Comparatively developed	Comparatively developed sense of sight	Well-developed incisors on the blind side	Small ratio
L. yokohamae	Comparatively developed	Comparatively developed sense of sight	Well-developed incisors on the blind side	Small ratio
A. argentatus	Rather developed	Rather developed sense of sight	Wide gape, pointed canine teeth	Comparatively large ratio

is provided by a large number of food organisms to "size selection" in which the requirement is provided by fewer large food organisms, through the life time of the predator. The "transformation type" may be divided into two sub-types. One is sub-type I in which the transformation of food selection types occurs in a short period. The other is sub-type II in which the transformation proceeds slowly. The snailfish and fat greenling belong to sub-type I (Appendix Fig. 20 and Honda *in* Kawasaki *et al.* (1983) (3)). The brown sole, marbled sole and white croaker belong to sub-type II (Appendix Figs. 21–23). These differences in food selection type are probably caused by the interrelation among feeding ability, demand for food and food niche of each species and food procurability in its environment. A food selection type corresponding to the changes of feeding ability and demand for food with growth and development leads to an effective feeding in order that a species might survive. Then, for such fishes as take food by the "locate-and-seize" method like the demersal fishes treated in the present study, "size selection" is essentially purposive, because taking a prey of size optimal for the size and feeding ability of a predator is selected in this type. Taking the energy efficiency

Food Acquisition by Species

Major Food Items	Trend of Changes in Food Number and Weight with Growth and Development	Food Selection Type
Small Crustacea (Mysidacea & Macrura)	A large number of small crustaceans are taken	Number selection
Fishes	A small number of large fishes are taken	Size selection
Epi-benthic Crustacea (Macrura & Anomura)	Number: rising trend is converted to a falling beyond 250 mm in length Weight: notable increase is observed beyond 350 mm	Transformation sub-type I
Major foods converted from Crustacea to sandeel	Shift from "number selection" to "size selection"	Transformation sub-type I
In-fauna (Bivalvia & Crustacea)	Number : decreases slowly Weight : increases slowly	Transformation sub-type II
Small in-fauna (Polychaeta & Bivalvia)	Number: small as a whole Weight: light in average but rising trend beyond 250 mm in length is accelerated	Transformation sub-type II
Fish & Macrura	Number: small as a whole Weight: heavy in average	Transformation sub-type II

in feeding into consideration, one effective feeding strategy is to select the prey size optimal for the size of the predator and to maximize the net energy intake. Thus, the size of food may increase with the increasing ability to acquire food. For species such as the brown and marbled soles, in which the extent of change of the niche and that of the kind and life form of food organisms are relatively small, the food procurability may become unchangeable. Therefore, it would be essentially effective for a predator to procure a prey as large as possible, matching its feeding ability. In the case of snailfish which shifts its food niche to a higher level with growth and development, the procurability of food changes considerably. In this case, the energy efficiency would increase by an adaptation in the feeding behavior: if the "sit-and-wait tactic" (Pianka(1978) (5)) is adopted instead of the pursuing and "widely-foraging tactic" (Pianka(1978) (5)), even a dull predator may capture large, active prey at small cost. However, the "sit-and-wait tactic" is a foraging behavior that is negative as well as passive and will decrease the probability of coming across food. Consequently, large-size prey are to be required to compensate for fewer chances to take food. Thus, the size is selected by the predators to satisfy their demand and make best use of their foraging tactic.

The difference between advantage and disadvantage in a foraging tactic is one of the factors promoting the transformation of food selection type. If energy lost in motion and metabolism exceeds that gained by number-selection-type foraging, the food selection must be transformed to an alternative tactic in which a predator can take larger prey to meet its demand. In sub-type I, the transformation occurs in a short time and the food niche is rapidly shifted to a higher level. A generalist (Hyatt(1979) (6)) tends to assume this feeding type. Sub-type II, that of gradual transformation, is probably taken by a specialist (Hyatt(1979) (6)). Thus, it turns out that the size selection type tends to be assumed by the forms occupying higher food niches. On the contrary, the number selection type seems not to be advantageous to the demersal, "locate-and-seize" forms, resulting in low food niches. In the case of demersal fishes, the density-dependent relations in the animal community, as well as the food procurability and environmental factors, influence the foraging strategy considerably. These factors influence the food niche, and eventually the interspecific relation among predators, of which the intraspecific relation among life historical stages and the predator-prey relation are composed. It seems that the diversity of food acquisition patterns has been produced in this way.

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Appendix

APPENDIX TABLE 1. *Allometric Formula of the Length of a Particular Part on Body Length, the Length of a Particular Part as a Ratio of Body Length, the Number of Teeth, Gill Rakers and Tubes of Pyloric Caecum for Fat Greenling*

Hexagrammos otakii (BL: 54-474 mm, N=194)

Allometry ($y=bx^a$)	BD	$=2.790\times10^{-1}$ $BL^{0.950}$	r; 0.988
	BWi	$=1.156\times10^{-1}$ $BL^{1.030}$	r; 0.981
	PFL	$=2.867\times10^{-1}$ $BL^{0.914}$	r; 0.992
	CPL	$=1.825\times10^{-1}$ $BL^{0.920}$	r; 0.977
	CPH	$=1.145\times10^{-1}$ $BL^{0.932}$	r; 0.979
	ED	$=2.030\times10^{-1}$ $BL^{0.733}$	r; 0.964
	SnL	$=7.622\times10^{-2}$ $BL^{0.972}$	r; 0.969
	GWi	$=1.657\times10^{-2}$ $BL^{1.284}$	r; 0.975
	IL	$=1.926\times10^{-1}$ $BL^{1.293}$	r; 0.921
Ratio*1	BD/BL	$=0.2164\pm0.0343$	
	BWi/BL	$=0.1346\pm0.0245$	
	PFL/BL	$=0.1839\pm0.0286$	
	CPL/BL	$=0.1211\pm0.0244$	
	CPH/BL	$=0.0803\pm0.0117$	
	ED/BL	$=0.0508\pm0.0150$	
	SnL/BL	$=0.0668\pm0.0190$	
Number of Teeth*2	Premaxilla	154 ± 74	
	Dentary	52 ± 10	
	Total	206 ± 77	
	Pharyngeal	251 ± 135	
Number of Gill-rakers*2		17.3 ± 1.7	
Number of Pyloric-caeca*2		30.6 ± 11.4	

*1: Mean Ratio ± 95% confidence interval
*2: Mean Number ± 95% confidence interval

APPENDIX TABLE 2. *Allometric Formula of the Length of a Particular Part on Body Length, the Length of a Particular Part as a Ratio of Body Length, the Number of Tubes of Pyloric Caecum for Snailfish*

Liparis tanakai (BL: 60-492 mm, N=326)

Allometry ($y=bx^a$)	BD $=1.741\times10^{-1}$ $BL^{1.001}$	r; 0.967
	BWi $=1.927\times10^{-1}$ $BL^{0.962}$	r; 0.968
	PFL $=2.502\times10^{-1}$ $BL^{1.007}$	r; 0.969
	VFL $=1.268\times10^{-1}$ $BL^{0.930}$	r; 0.984
	ED $=2.517\times10^{-1}$ $BL^{0.598}$	r; 0.932
	SnL $=1.395\times10^{-1}$ $BL^{0.896}$	r; 0.965
	GWi $=6.529\times10^{-2}$ $BL^{1.110}$	r; 0.986
	IL $=4.910\times10^{-1}$ $BL^{1.056}$	r; 0.945
Ratio	BD/BL $=0.1785\pm0.0521$	
	BWi/BL $=0.1579\pm0.0520$	
	PFL/BL $=0.2270\pm0.0951$	
	VFL/BL $=0.0872\pm0.0154$	
	ED/BL $=0.0314\pm0.0148$	
	SnL/BL $=0.0816\pm0.0222$	
	GWi/BL $=0.1195\pm0.0326$	
	IL/BL $=0.6764\pm0.3236$	
Number of Pyloric-caeca	81.4 ±27.9	

APPENDIX TABLE 3. *Allometric Formula of the Length of a Particular Part on Body Length, the Length of a Particular Part as a Ratio of Body Length, the Number of Teeth, Gill Rakers and Tubes of Pyloric Caecum for Brown Sole*

Limanda herzensteini (BL: 96-398 mm, N=148)

Allometry ($y=bx^a$)	BD	$=1.717\times10^{-1}$ $BL^{1.129}$	r; 0.995
	BWi	$=5.902\times10^{-2}$ $BL^{1.038}$	r; 0.957
	PFL	$=8.636\times10^{-2}$ $BL^{1.065}$	r; 0.982
	CPL	$=3.335\times10^{-2}$ $BL^{1.124}$	r; 0.950
	CPH	$=7.903\times10^{-2}$ $BL^{1.011}$	r; 0.989
	ED	$=2.484\times10^{-1}$ $BL^{0.694}$	r; 0.966
	SnL	$=3.331\times10^{-2}$ $BL^{0.988}$	r; 0.989
	GWi	$=9.429\times10^{-3}$ $BL^{1.284}$	r; 0.980
	IL	$=2.656\times10^{-1}$ $BL^{1.237}$	r; 0.956
Ratio	BD/BL	$=0.3421\pm0.0475$	
	BWi/BL	$=0.0735\pm0.0017$	
	PFL/BL	$=0.1228\pm0.0192$	
	CPL/BL	$=0.0649\pm0.0190$	
	CPH/BL	$=0.0835\pm0.0096$	
	ED/BL	$=0.0496\pm0.0143$	
	SnL/BL	$=0.0308\pm0.0067$	
	GWi/BL	$=0.0432\pm0.0122$	
	IL/BL	$=0.9638\pm0.3116$	
Number of Teeth	Eyed Side	Premaxilla	0.15 ± 0.75
		Dentary	4.85 ± 2.72
	Blind Side	Premaxilla	20.30 ± 4.30
		Dentary	22.30 ± 4.00
	Total		47.60 ± 8.30
	Pharyngeal		90.70 ± 19.10
Number of Gill-rakers			9.77 ± 1.37
Number of Pyloric-caeca			3.94 ± 0.79

APPENDIX TABLE 4. *Allometric Formula of the Length of a Particular Part on Body Length, the Length of a Particular Part as a Ratio of Body Length, the Number of Teeth, Gill Rakers and Tubes of Pyloric Caecum for Marbled Sole*

Limanda yokohamae (BL: 87-313 mm, N=107)

Allometry ($y=bx^a$)	BD	$=2.477\times10^{-1}$ $BL^{1.065}$		r; 0.992	
	BWi	$=4.682\times10^{-2}$ $BL^{1.089}$		r; 0.964	
	PFL	$=8.920\times10^{-2}$ $BL^{1.046}$		r; 0.976	
	CPL	$=2.302\times10^{-2}$ $BL^{1.182}$		r; 0.927	
	CPH	$=8.804\times10^{-2}$ $BL^{1.011}$		r; 0.983	
	ED	$=1.486\times10^{-1}$ $BL^{0.775}$		r; 0.956	
	SnL	$=4.011\times10^{-2}$ $BL^{0.937}$		r; 0.907	
	GWi	$=1.566\times10^{-2}$ $BL^{1.169}$		r; 0.947	
	IL	$=6.483\times10^{-2}$ $BL^{1.536}$		r; 0.880	
Ratio	BD/BL	$=0.3517\pm0.0289$			
	BWi/BL	$=0.0760\pm0.0132$			
	PFL/BL	$=0.1142\pm0.0172$			
	CPL/BL	$=0.0604\pm0.0186$			
	CPH/BL	$=0.0935\pm0.0097$			
	ED/BL	$=0.0440\pm0.0114$			
	SnL/BL	$=0.0283\pm0.0071$			
	GWi/BL	$=1.0393\pm0.0142$			
	IL/BL	$=0.2090\pm0.6048$			
Number of Teeth				130 mm $\leq$ BL	< 130 mm
	Eyed Side	Premaxilla		0.041 ± 0.408	0
		Dentary		1.750 ± 1.220	4.80 ± 1.67
	Blind Side	Premaxilla		12.400 ± 2.420	20.4 ± 4.15
		Dentary		14.600 ± 3.480	22.4 ± 6.87
	Total			82.400 ± 14.130	99.6 ± 17.70
Number of Gill-rakers		9.79 ± 1.57			
Number of Pyloric-caeca		7.66 ± 3.60			

APPENDIX TABLE 5. *Allometric Formula of the Length of a Particular Part on Body Length, the Length of a Particular Part as a Ratio of Body Length, the Number of Teeth, Gill Rakers and Tubes of Pyloric Caecum for White Croaker*

Argyrosomus argentatus (BL: 165-327 mm, N=71)

Allometry ($y=bx^a$)	BD $=1.262\times10^{-1}$ BL$^{1.116}$	r; 0.960
	BWi $=1.681\times10^{-2}$ BL$^{1.381}$	r; 0.949
	PFL $=3.576\times10^{-1}$ BL$^{0.898}$	r; 0.850
	CPL $=2.804\times10^{-1}$ BL$^{0.931}$	r; 0.900
	CPH $=3.646\times10^{-2}$ BL$^{1.136}$	r; 0.911
	ED $=2.104\times10^{-1}$ BL$^{0.752}$	r; 0.907
	SnL $=1.173\times10^{-1}$ BL$^{0.873}$	r; 0.779
	GWi $=9.855\times10^{-2}$ BL$^{1.011}$	r; 0.683
	IL $=2.140\times10^{-1}$ BL$^{1.242}$	r; 0.696
Ratio	BD/BL $=0.2316\pm0.0200$	
	BWi/BL $=0.1244\pm0.0180$	
	PFL/BL $=0.2103\pm0.0220$	
	CPL/BL $=0.1937\pm0.0245$	
	CPH/BL $=0.0738\pm0.0202$	
	ED/BL $=0.0567\pm0.0064$	
	SnL/BL $=0.0597\pm0.0137$	
	GWi/BL $=0.1044\pm0.0290$	
	IL/BL $=0.7542\pm0.2516$	
Number of Teeth	Premaxilla	20.3 ± 6.35
	Dentary	33.9 ± 8.12
	Total	54.4 ± 12.40
Number of Gill-rakers		20.8 ± 1.52
Number of Pyloric-caeca		9.20 ± 3.37

APPENDIX TABLE 6. *Allometric Formula of the Length of a Particular Part on Body Length, the Length of a Particular Part as a Ratio of Body Length, the Number of Teeth, Gill Rakers and Tubes of Pyloric Caecum for Nibe Croaker*

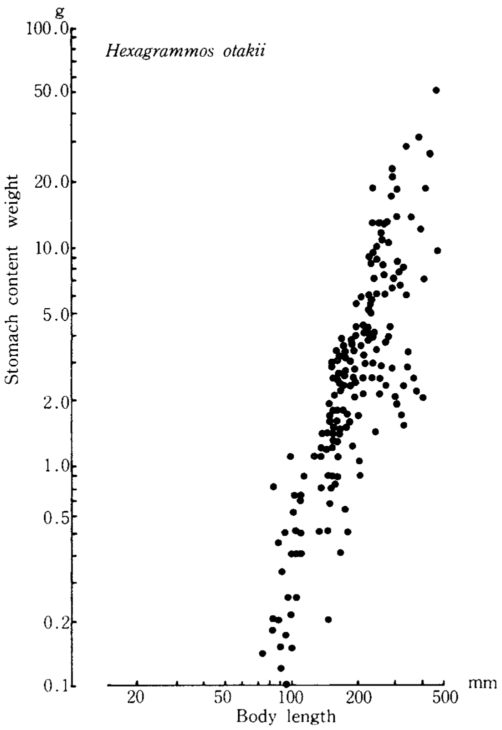
Nibea mitsukurii (BL: 169-338 mm, N=58)

Allometry ($y=bx^a$)	BD $=6.905\times10^{-1}$ $BL^{0.793}$	r; 0.936
	BWi $=5.922\times10^{-1}$ $BL^{0.712}$	r; 0.854
	PFL $=2.320\times10^{-1}$ $BL^{0.950}$	r; 0.935
	CPL $=1.075\times10^{-1}$ $BL^{1.112}$	r; 0.981
	CPH $=2.742\times10^{-1}$ $BL^{0.766}$	r; 0.913
	ED $=7.771\times10^{-2}$ $BL^{0.914}$	r; 0.944
	SnL $=5.206\times10^{-3}$ $BL^{1.392}$	r; 0.937
	GWi $=1.603\times10^{-2}$ $BL^{1.351}$	r; 0.953
	IL $=9.929\times BL^{0.561}$	r; 0.534
Ratio	BD/BL $=0.2235\pm0.0300$	
	BWi/BL $=0.1240\pm0.0222$	
	PFL/BL $=0.1768\pm0.0198$	
	CPL/BL $=0.1988\pm0.0172$	
	CPH/BL $=0.0765\pm0.0120$	
	ED/BL $=0.0484\pm0.0060$	
	SnL/BL $=0.0443\pm0.0099$	
	GWi/BL $=0.1102\pm0.0200$	
	IL/BL $=0.9095\pm0.3344$	
Number of Teeth	Premaxilla	39.4± 4.61
	Dentary	73.9±17.4
	Total	113 ±16.0
Number of Gill-rakers		24.7 ±3.10
Number of Pyloric-caeca		7.56±1.57

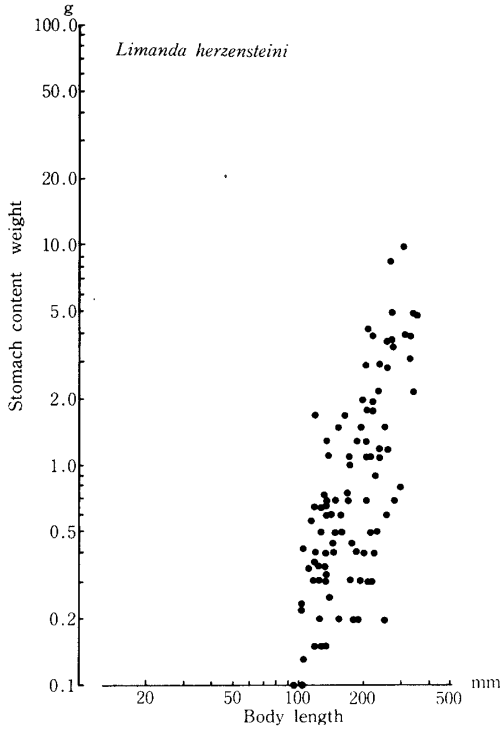
APPENDIX TABLE 7. *Allometric Formula of the Length of a Particular Part on Body Length, the Length of a Particular Part as a Ratio of Body Length, the Number of Teeth, Gill Rakers and Tubes of Pyloric Caecum for Common Japanese Conger*

Astroconger myriaster (BL : 363-605 mm, N=61)

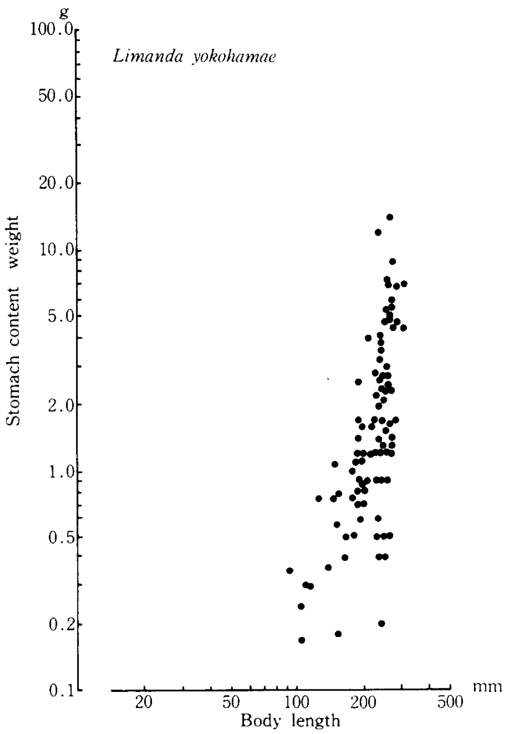
Allometry ($y=bx^a$)	BD $=6.783\times10^{-3}$ $BL^{1.358}$	r ; 0.828
	BWi $=4.220\times10^{-2}$ $BL^{1.051}$	r ; 0.983
	PFL $=2.125\times10^{-1}$ $BL^{0.778}$	r ; 0.814
	ED $=2.442\times10^{-1}$ $BL^{0.568}$	r ; 0.721
	SnL $=8.818\times10^{-2}$ $BL^{0.831}$	r ; 0.831
	GWi $=1.210\times10^{-2}$ $BL^{1.183}$	r ; 0.802
	StL $=5.339\times10^{-2}$ $BL^{1.229}$	r ; 0.716
	IL $=5.080\times10^{-3}$ $BL^{1.695}$	r ; 0.668
Ratio	BD/BL $=0.0613\pm0.0144$	
	BWi/BL $=0.0579\pm0.0116$	
	PFL/BL $=0.0547\pm0.0094$	
	ED/BL $=0.0168\pm0.0032$	
	SnL/BL $=0.0309\pm0.0047$	
	GWi/BL $=0.0376\pm0.0086$	
	StL/BL $=0.2200\pm0.0792$	
	IL/BL $=0.2361\pm0.1136$	
Number of Teeth	Premaxilla	131 ± 45.6
	Dentary	117 ± 41.5
	Total	244 ± 80.2
Number of Gill-rakers		0
Number of Pyloric-caeca		0



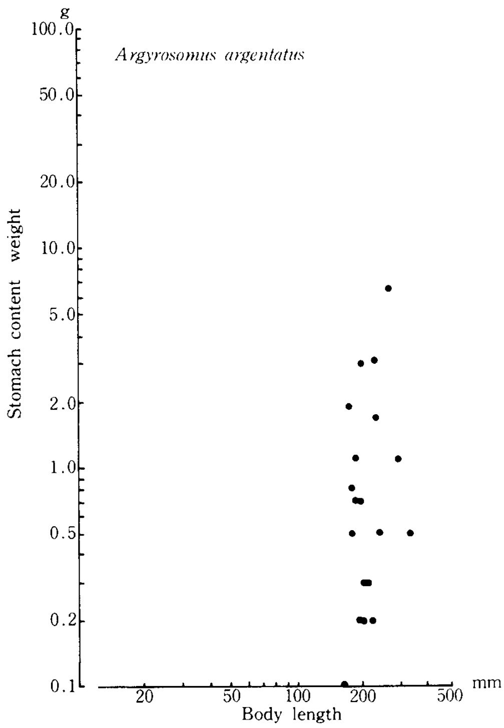
APPENDIX FIG. 1. Relation of weight of food in stomach to body length in logarithmic scale.



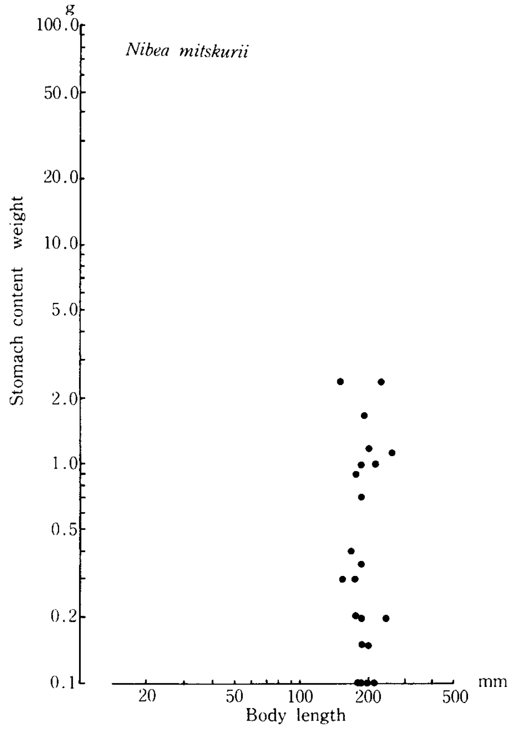
APPENDIX FIG. 2. Relation of weight of food in stomach to body length in logarithmic scale.



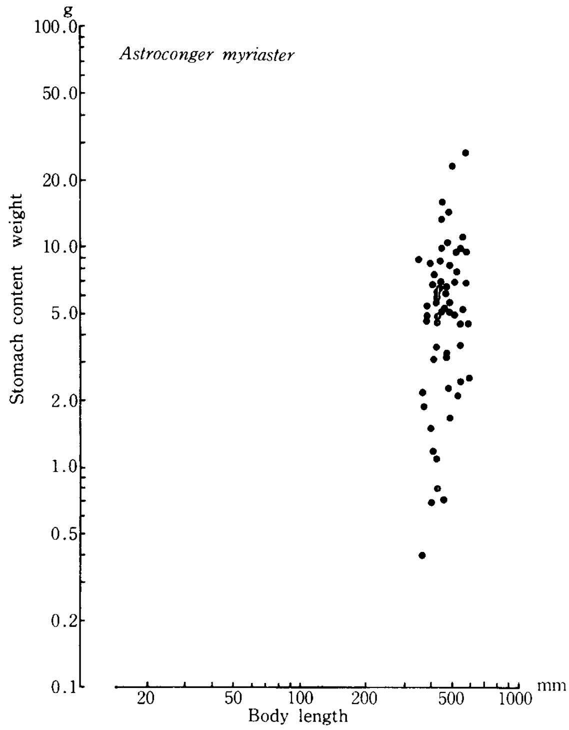
APPENDIX FIG. 3. Relation of weight of food in stomach to body length in logarithmic scale.



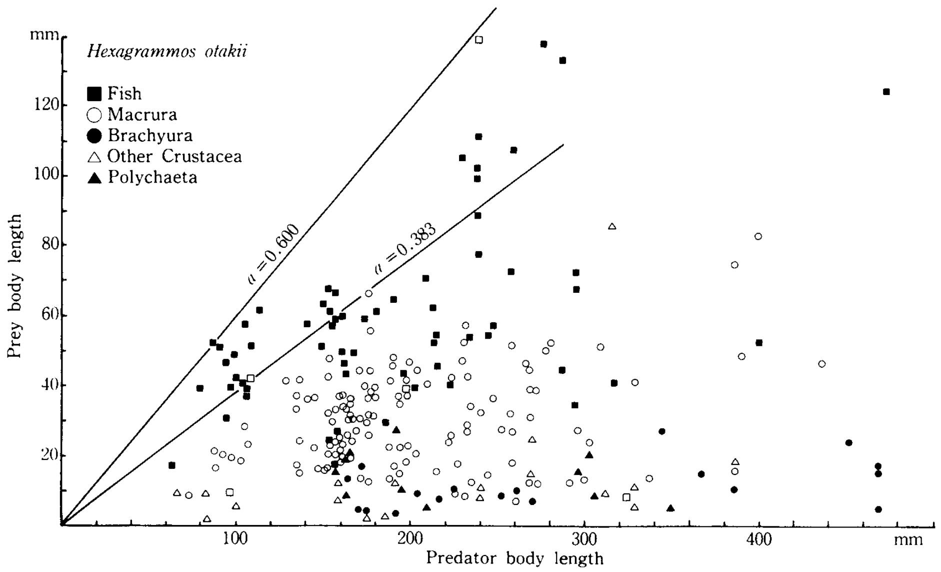
APPENDIX FIG. 4. Relation of weight of food in stomach to body length in logarithmic scale.



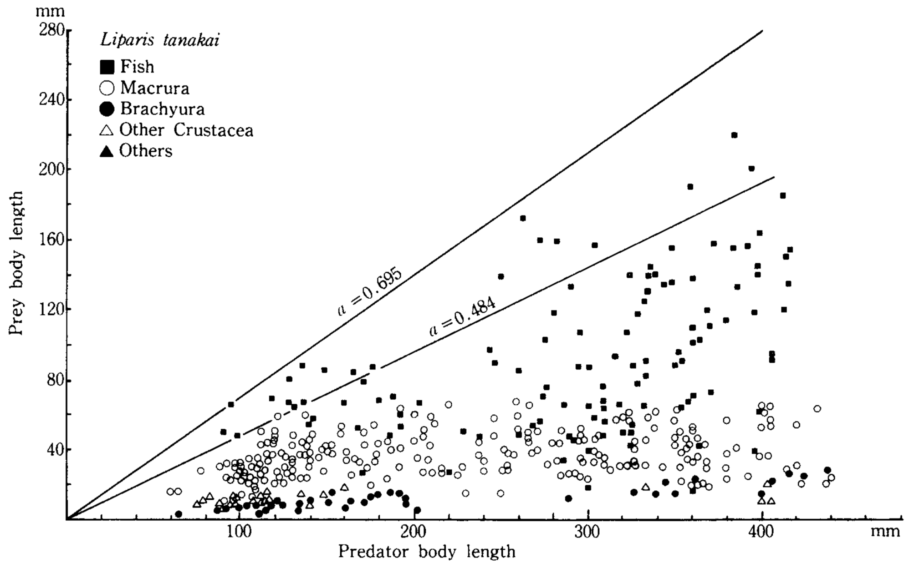
Appendix Fig. 5. Relation of weight of food in stomach to body length in logarithmic scale.



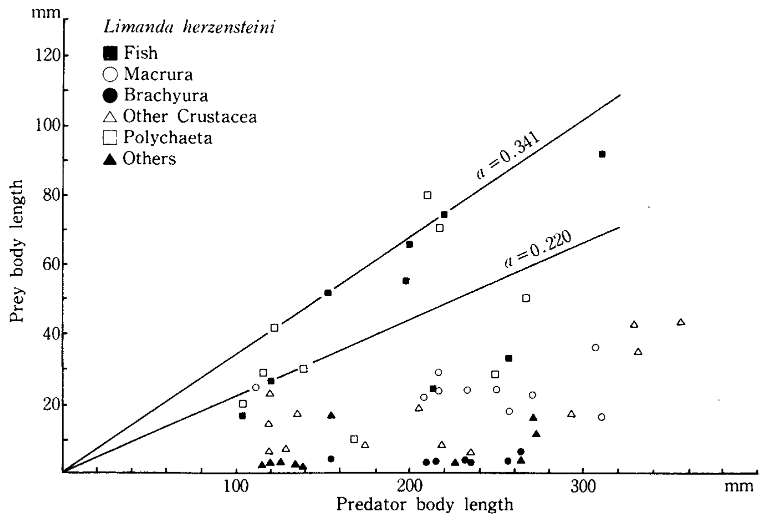
Appendix Fig. 6. Relation of weight of food in stomach to body length in logarithmic scale.



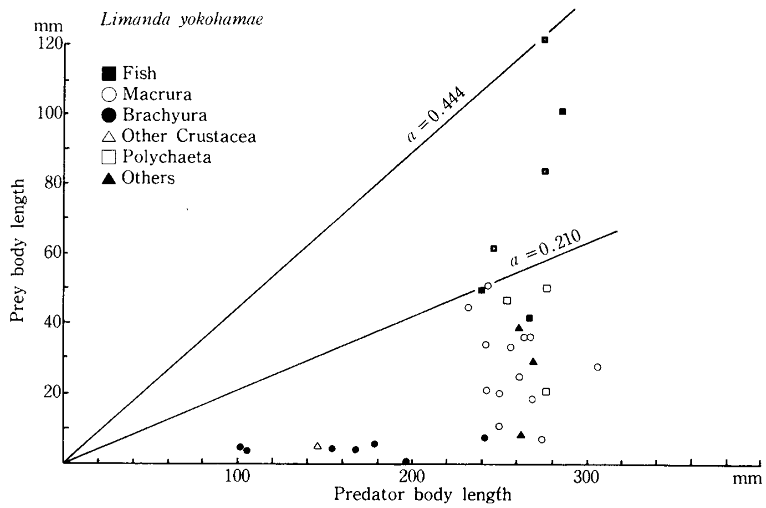
Appendix Fig. 7. Relation between body length of prey and that of predator. The maximum ratio of prey body length to that of predator, a, is indicated.



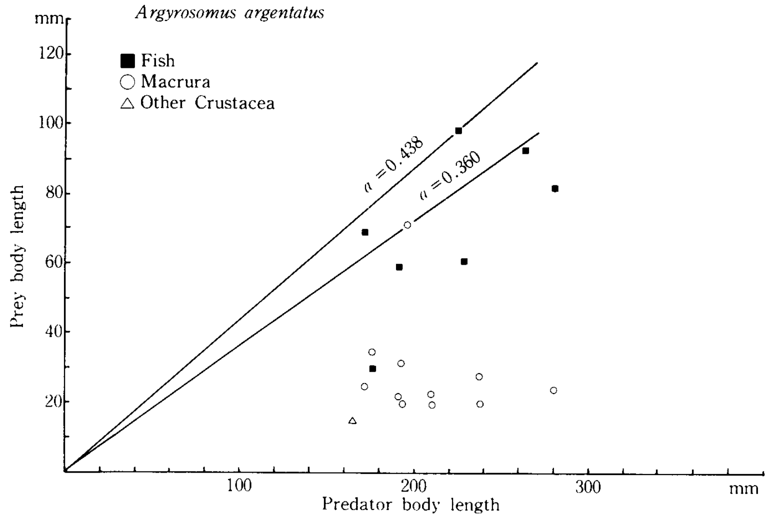
APPENDIX FIG. 8. Relation between body length of prey and that of predator. The maximum ratio of prey body length to that of predator, *a*, is indicated.



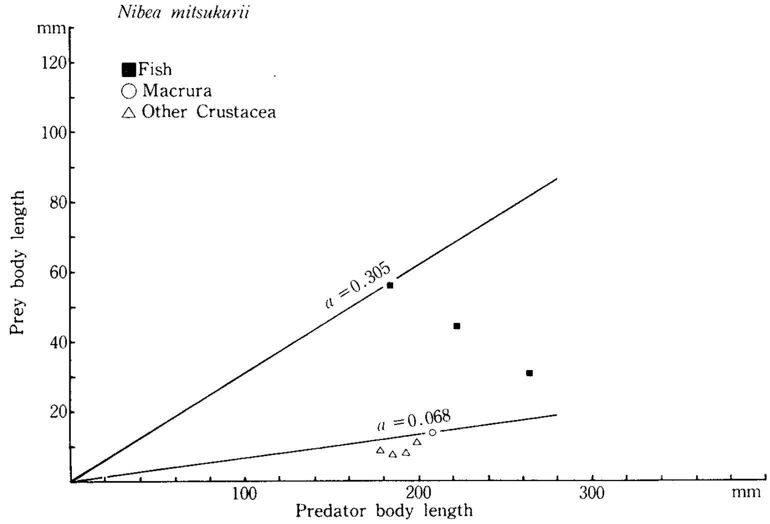
APPENDIX FIG. 9. Relation between body length of prey and that of predator. The maximum ratio of prey body length to that of predator, *a*, is indicated.



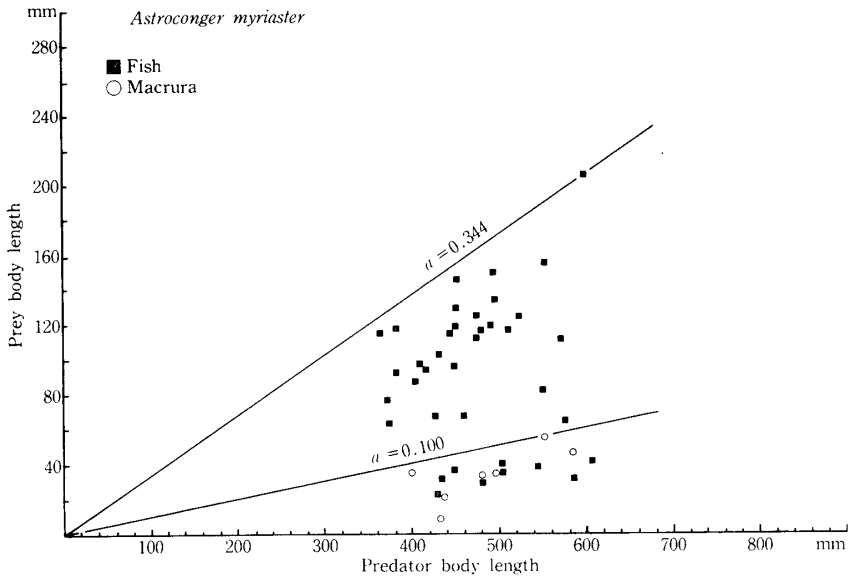
APPENDIX FIG. 10. Relation between body length of prey and that of predator. The maximum ratio of prey body length to that of predator, a, is indicated.



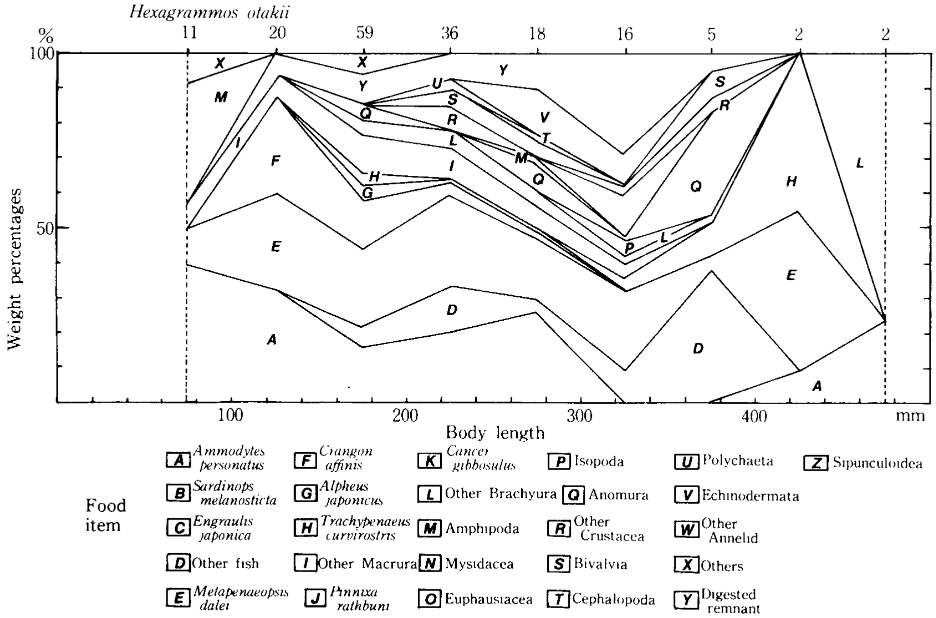
APPENDIX FIG. 11. Relation between body length of prey and that of predator. The maximum ratio of prey body length to that of predator, a, is indicated.



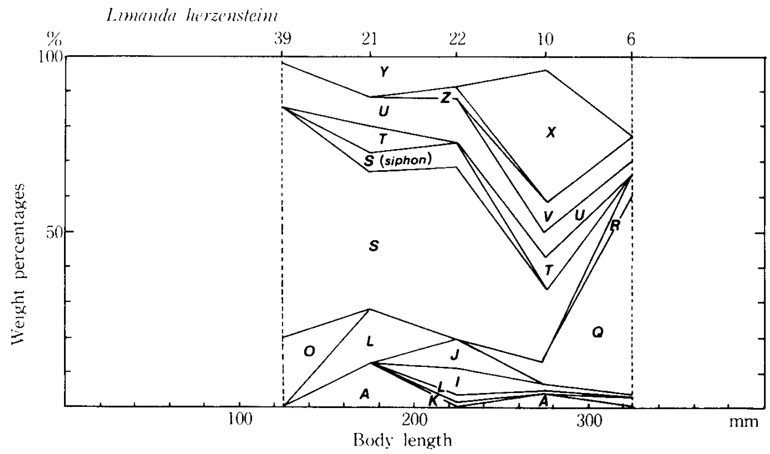
APPENDIX FIG. 12. Relation between body length of prey and that of predator. The maximum ratio of prey body length to that of predator, a, is indicated.



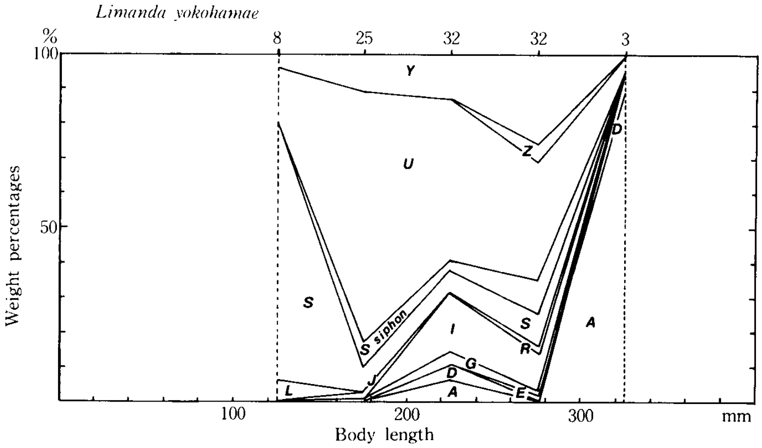
APPENDIX FIG. 13. Relation between body length of prey and that of predator. The maximum ratio of prey body length to that of predator, a, is indicated.



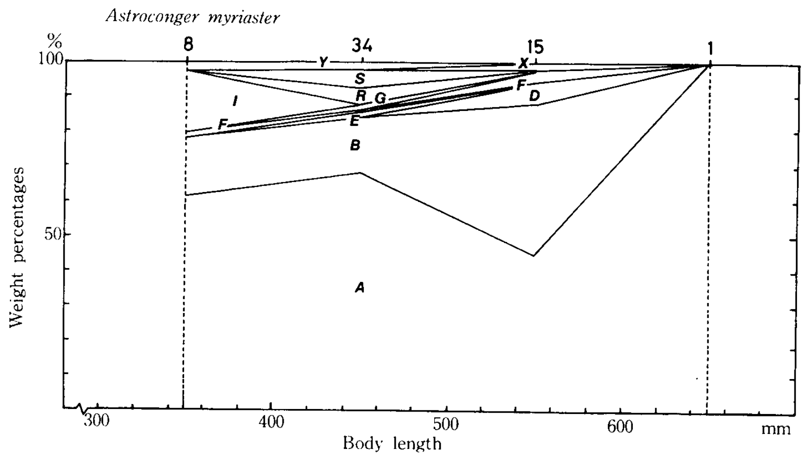
APPENDIX FIG. 14. Food composition in weight percentages in 50 mm length intervals. Along the top horizontal line the number of stomachs investigated is indicated.



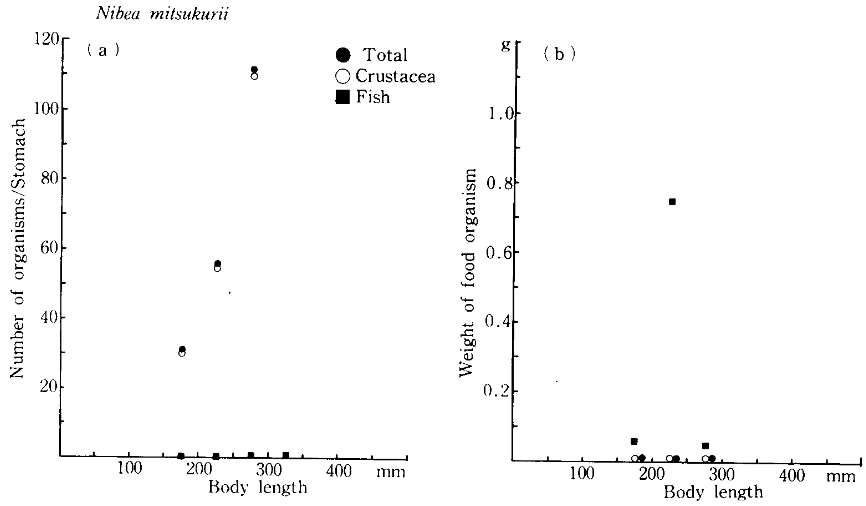
APPENDIX FIG. 15. Food composition in weight percentages in 50 mm length intervals. Along the top horizontal line the number of stomachs investigated is indicated.



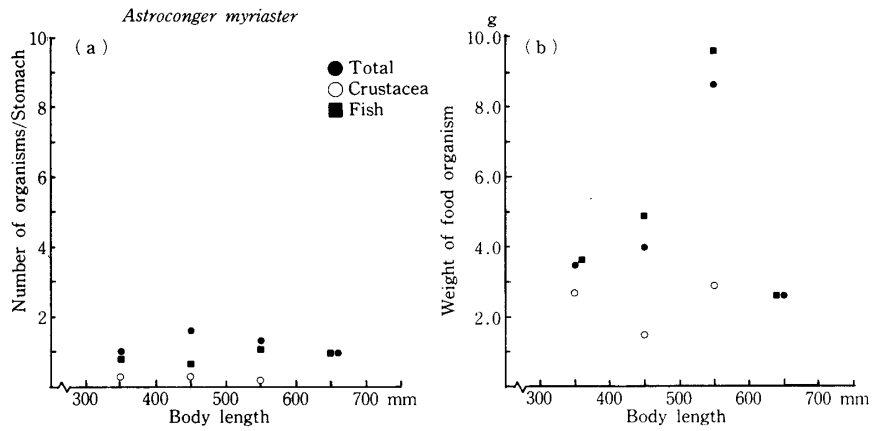
Appendix Fig. 16. Food composition in weight percentages in 50 mm length intervals. Along the top horizontal line the number of stomachs investigated is indicated.



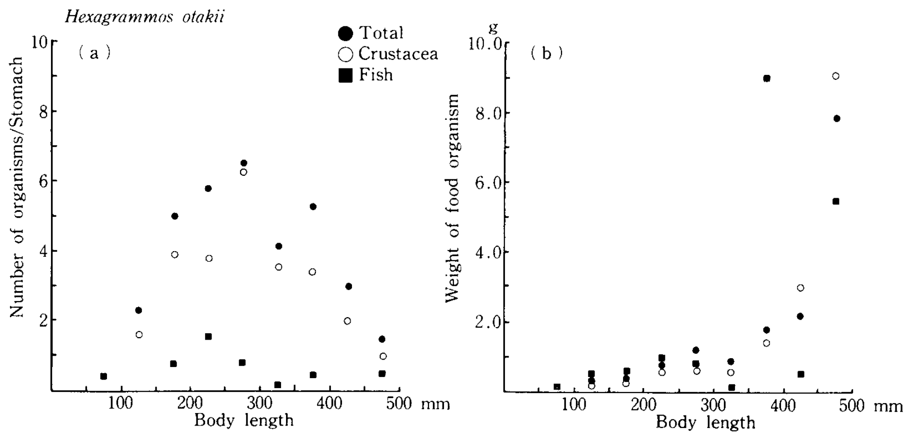
Appendix Fig. 17. Food composition in weight percentages in 100 mm length intervals. Along the top horizontal line the number of stomachs investigated is indicated.



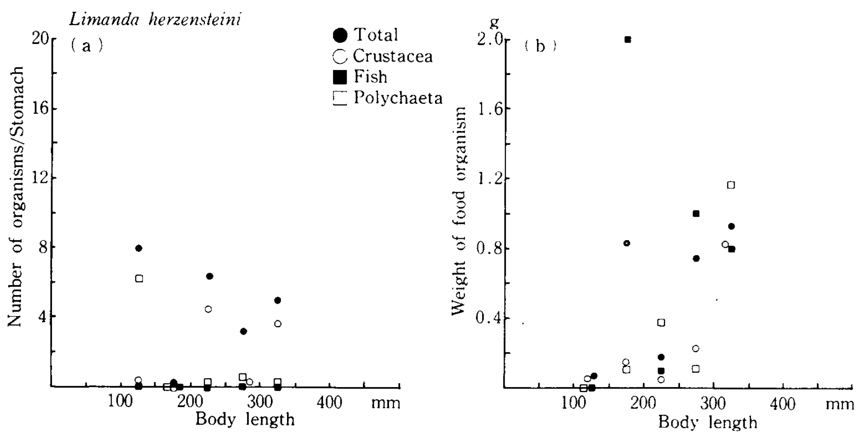
Appendix Fig. 18. Changes in average number (a) and weight (b) of organisms in a stomach with growth of fish.



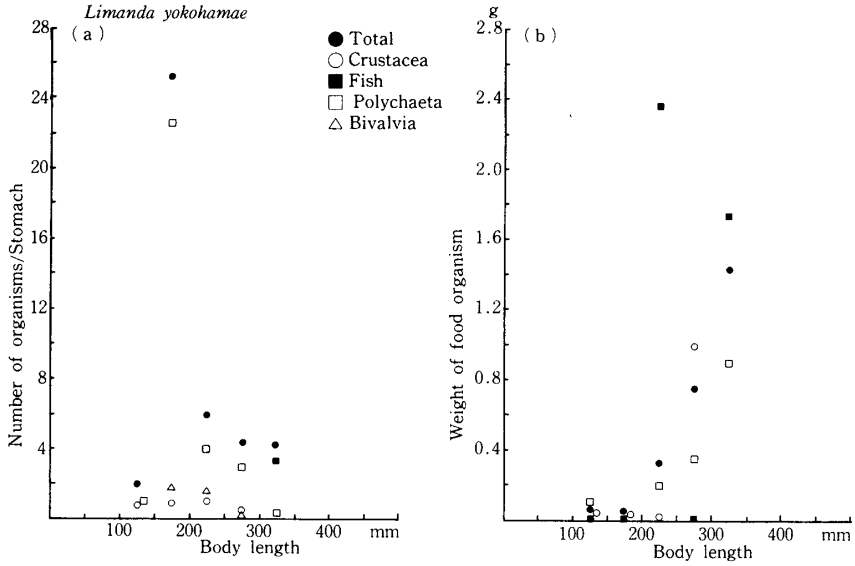
APPENDIX FIG. 19. Changes in average number (a) and weight (b) of organisms in a stomach with growth of fish.



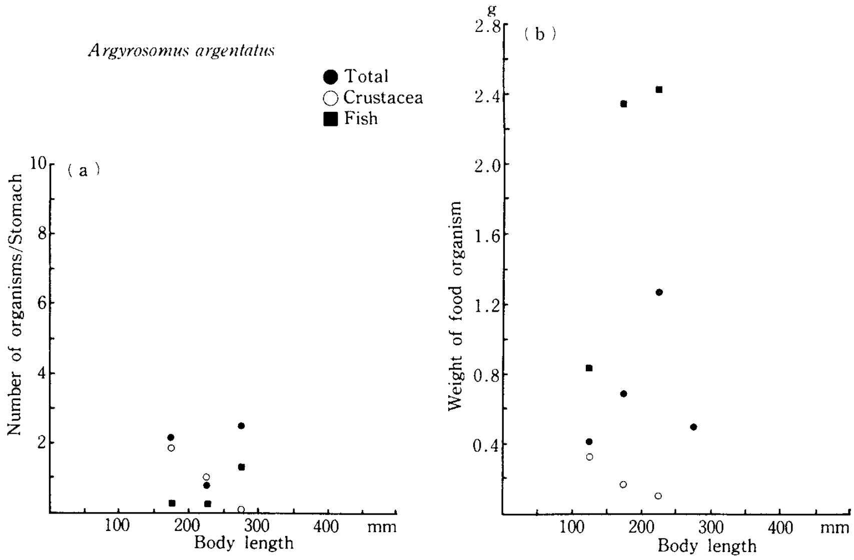
APPENDIX FIG. 20. Changes in average number (a) and weight (b) of organisms in a stomach with growth of fish.



APPENDIX FIG. 21. Changes in average number (a) and weight (b) of organisms in a stomach with growth of fish.



APPENDIX FIG. 22. Changes in average number (a) and weight (b) of organisms in a stomach with growth of fish.



APPENDIX FIG. 23. Changes in average number (a) and weight (b) of organisms in a stomach with growth of fish.