Food-relations among the Fish Caught by the Set-nets along the Arikawa Bay (at the Middle of the Goto Islands) during the Period from Late Autumn to Early Winter※

By

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Group of the fish caught by the set-nets is, to see ecologically, consisted of not only the pelagic fish but also the demersal ones of various species distributed almost all over the possible types of food-habits to be observable in the studied area, and there are some algaevora such as *Girella punctata* and other piscivora of very high trophic levels, perhaps the end predators of this water, such as the sharks and the marlins. The catch by the set-net is, therefore, thought to be one of the most desirable materials for finding out an outline of the food-relations to be found among the fish inhabiting an area. Since we planned to find out the food-relations observable among the fish caught in an area under the strong influence of the Tsushima Current during the period from its seasonal change, the study was carried out during the period from Oct. 21 to Dec. 17 in 1956 on the catch by a group of the set-nets along the coast of the Arikawa Bay in the Goto Islands. This area is one of the most prevalent fishing ground for set-net under strong influence of the Tsushima Current without any other fishery of importance and is one of the commercial centers of these detached islands with little higher consumption of fish in the town; these made it very easy to get many facilities for the work from the staffs of the fishery cooperative society, which gratefully brought us to save much expenses to collect the stomach samples of some predators of high trophic levels and some demersal fish of high commercial value without any afraid of the possibility to sampling wrongly those from the other areas. These were the reasons why this area was selected for the study.

In this report, the records of catch compositions were first classified into 11 types by the abundant species and whether hauled up in the morning or in the evening taking the location of net and the season into consideration. Then, examining on the stomach contents of each member fish, we analyzed the food-relations found during the stay of each type of catch and found that the anchovy (*Engraulis japonica*)

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was of most ecological importance on which the arrows showing the predatory relations were concentrated. And some considerations were given to the problem what influence was led by the replacement of a certain member caught abundantly by other species of similar food-habits with similar life-form and to the prcblem what influence was led by a sudden appearance or disappearance including abrupt increase or decrease of one of the members to the food-relations of the members of the rest of it.

We are grateful to Mr. T. KAWASAKI and any other staffs of the Arikawa Fishery Cooperative Society, fishermen and fishmongers in this town for their kindness offered us carrying out this work.

Material and Method

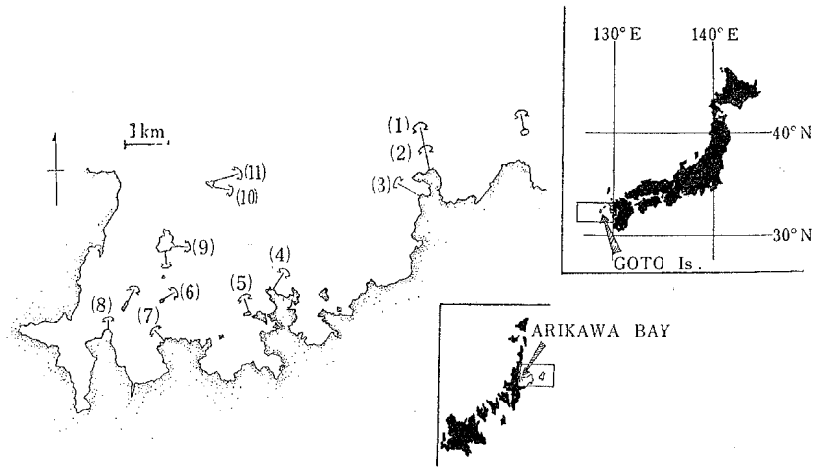

Fig. 1. Sketch chart of the Arikawa Bay.
Note : Number in parentheses indicates the net number.

There were 11 sets of the nets along the coast of the Arikawa Bay. The fish entered the nets at night were gathered at 7～9 in the morning and those entered during the daytime were hauled up at 3～5.30 in the evening. The materials used this study were collected at each haul of the nets. The fish samples of seven species of low economic value such as the round herring (*Etrumeus micropus*), *Spratelloides japonicus*, the sardine (*Sardinops melanosticta*), the anchovy (*Engraulis japonica*), the atherine fish (*Allanetta bleekeri*), the jack mackerel (*Trachurus japonicus*) and *Apogon semilineatus* were collected at fish market attaching to the cooperative society. And those hauled up in the morning (entered at night) were examined within the day, while those brought back to the market in the evening (entered during the daytime) were stored in 10 percent formalin solution and examined in the next day. For other species of high economic value, only their body sizes were measured at the

market before the auction and their stomach samples were gathered from the fishmongers twice a day, usually about 13.00 and 19.00. Then, the kinds and the weight of the organisms contained in each sample thus collected were examined; if possible in count, the individual numbers of some organisms also were included.

Results

1. Outline of the change in the catch of several fish of importance (Preliminary step to the classification of the type of catch)

As a preliminary step to this study, we intended to classify the samples into several groups according to the type of the catch compositions. It was one of the most remarkable characteristics of the catch that we could get better catch of richer species at night (hauled up in the morning) than in the daytime (hauled up in the evening). Among 41 species hauled up in the morning and 37 at night, most of the abundant species were the pelagic fish; consequently, the type of catch was strongly governed by the transit of some pelagic fish. And the summarized characteristics of the change in the catch of some abundant members are shown in the below, for reference' sake.

1) The most common and rather domestic surface swimmers around the Goto Islands and their adjucent waters : The sardines and the jack mackerel were the members of this group. These were hauled up abundantly in the morning especially at the opening part of the bay. Three species of the sardines of importance (the anchovy, the sardine and the round herring) more or less segregated their fishing ground each other and the anchovy was hauled up abundantly at the inner part while the sardine and the round herring were the characteristics of the opening part. The jack mackerel caught at the inner part and those near the opening were more or less different in size and larger individuals were inclined to be caught near the opening of the bay, while smaller ones apt to be caught at the inner part.

2) The surface swimmers with strong ability of seasonal migration : The flying fishes and the saury (*Cololabis saira*) were also the surface swimmers caught abundantly but they differed from the members of the former group in their strong ability of seasonal migration. The flying fishes are thought to be rather warmer species and visit this water in summer season. They were caught abundantly in the daytime (hauled up in the evening) during the period from before the beginning of the study to Oct. 31, and they disappeared earlier at the opening part of the bay, while stayed longer at the innermost part. The saury is known as one of the colder water inhabitants and also thought to be the fish ecologically corresponding to the flying fishes in the warmer waters in respect to their strong phototaxis, food-habits and many other habits of importance. But it passed as long as 20 days from the end of the good catch of the flying fishes to the beginning of that of the saury, moreover the saury was chiefly caught by the nets set near the opening of the bay at night in contrast with the fact that the flying fishes were caught throughout the bay and

were assumed to enter the net during the daytime. Another member of this group usually inhabiting rather colder waters was the squid (chiefly *Ommastrephes sloani pacificus*). This was caught during the latter half of the studied period chiefly near the opening part and hauled up in the morning.

3) The surface swimmers of higher trophic levels caught abundantly : The dolphin fish (*Coryphaena hippurus*) and the bonitos (*Auxis thazard, Sarda orientalis* and *Euthynnus affinis yaito*) were the members of this group. The dolphin fish was chiefly caught near the opening till November and did not show any markedly daily-rhythmic change in the catch. The good catch of the bonitos began a little before the end of that in the dolphin fish; and these fish were caught chiefly at the middle

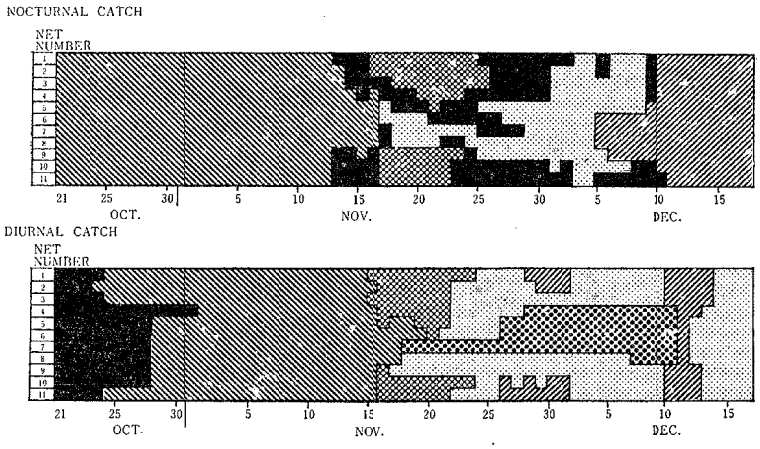

Fig. 2. Schematical representation of the change in the type of the catch compositions at each net with the days passing.

Nocturnal catch (hauled up in the morning)

- The dolphin fish type
- The saury, the squid and the jack mackerel type
- The dolphin fish, the bonito, the saury, the squid and the jack mackerel type
- The type of miscellaneous catch at night
- The saury, the squid and the jack mackerel type with the bonitos

Diurnal catch (hauled up in the evening)

- The flying fish type
- The dolphin fish type in the diurnal catch
- The dolphin fish, the bonito and the saury type
- The *Girella punctata* type
- The type of miscellaneous catch in the daytime
- The juvenile tuna and the bonito type

For net number, refer Fig. 1.

of the bay in the daytime.

4) The demersal fish of importance : *Girella punctata* was the demersal fish of importance, but this was caught mostly in the daytime at the innermost part of the bay.

5) Temporary visitors of high trophic levels : Few individuals of large fish of high trophic levels such as the juvenile individuals of the bluefin tuna (*Thunnus thynnus*), the marlins and the sharks were occasionally caught near the opening of the bay. Catch of the bluefin did not show any markedly daily-rhythmic change. Here, the marlin caught during the beginning half of the studied period was chiefly the striped marlin (*Makaira mitsukurii*) but this was changed into the black marlin (*Makaira mazara*) and the sailfish (*Histiophorus orientalis*) in the latter half. The shark, chiefly the hammer-head shark (*Sphyrna zygaena*), was also caught near the opening.

In consequence, the catch composition by each net during the studied period was changed considerably by the transit of the above-mentioned abundant members and the outline of the change in the catch compositions is schematically represented in Fig. 2.

2. Food-relations found in each type of the catch composition

We examined on the stomach contents of each member fish semi-quantitatively and some examples of the results are shown in Tables 1 and 2. From these tables, we will easily find, as already recorded in the introduction, that the food-habits of the members vary considerably and are distributed almost all over the possible types to be found in this water; and there are some algaevora and other piscivora, perhaps the end predators of that water. And another result of the examination on the stomach contents of worth while to be described is high rate of the occurrence of the individuals with empty stomach; but this may not mean at all that most of the individuals swimming freely have empty stomach but may well be thought to be the consequence of the vomiting due to the struggling during the hauling of the net; this prevented us very much from telling the food-habits of small fish such as the saury, the jack mackerel, the round herring, the sardine, the anchovy and *Apogon*, despite of the fact that we examined hundreds of stomach samples of each species.

Basing on the results of the examination on the stomach contents, then, we drew the schema representing the food-relations of the members in each type of the catch compositions.

Nocturnal catch (hauled up in the morning)

1) The dolphin fish type : This type of catch was characterized by a good catch of the dolphin fish and was found during the period from before the beginning of the study to mid-November, while this type was changed into the next one earlier at the opening of the bay but later at the innermost part.

Some attention should be paid to the following facts: (1) some fish of similar size to the dolphin fish with similar swimming ability such as the Spanish mackerel (*Scombermorus niphonius*) or the yellowtail (*Seriola quinqueradiata*) were the

Table 1. Stomach contents of each member fish caught during the stay of the dolphin fish type at night.

Stomach contents / Fish	Spanish mackerel	Yellowtail	Skipjack	Barracuda	*Ablennes anastomella*	Rizardfish	Goatfish	Puffers	*Girella punctata* (juv.)	Jack mackerel	Squids (juv.)
Sharks	1 (1000.0)		1 (19.0)	1 (200.0)					1 (240.0)		
Striped marlin		1 (6000.0)									
Sailfish								2 (140.0)			
Dolphin fish				2 (15.7)	2 (100.0)					1 (18.0)	3 (50.5)
Scombrops boops						3 (26.3)				1 (5.0)	
Barracuda										1 (1.5)	
Parapristipoma trilineatum Bastard halibut											
Red sea bream											
Hairtail											
Rizardfish											
Mackerel										1 (1.5)	
Caranx equula										1 (1.5)	
Girella punctata											
Flying fish											
Jack mackerel						5 (10.6)				1 (0.3)	4 (0.8)
Apogon semilineatus						1 (1.5)					5 (1.1)
Round herring											1 (0.2)
Spratelloides japonicus Atherine fish											

Besides, the stomach samples of the following species were examined, but we could not find any organism or its fragment contained in them :
saury (73 specimens), *Sarda orientalis* (22), *Ablennes anastomella* (21), *Formio niger* (9), scad (4), rabbitfish (3), *Auxis thazard* (2), butterfish (2), *Rachycentron canadum* (2), yellowtail (1) and filefish (1).

Bregmaceros japonicus	Round herring	Saury	Flying fishes	Anchovy	*Spratelloides japonicus*	Fish meat	Schizopod	Isopod	*Caprella*	Euphausiid	Zooplankton	Saury eggs	Seaweeds	Empty stomach	Number of individuals examined
	1 (150.0)	1 (20.0)												4	10
														1	2
		2 (220.0)												3	7
	3 (122.7)	7 (515.5)	1 (4.1)	2 (14.7)		2 (27.6)								56	80
	1 (9.5)			10 (16.5)		2 (1.5)								6	23
	5 (89.1)			5 (13.2)										2	13
				5 (63.0)		2 (25.0)			1 (0.1)					1	9
				2 (5.4)										1	3
														1	2
						1 (22.5)						1 (5.0)		0	1
				7 (43.2)										0	8
	1 (19.9)		1 (0.3)	3 (3.6)		12 (12.6)								21	39
				1 (6.6)		2 (1.4)								1	4
									10 (+)				10 (27.3)	9	19
											13 (1.6)			17	30
77 (77.2)				171 (125.3)	48 (35.1)	11 (1.2)			6 (3.9)		1 (0.1)	1 (0.2)		663	968
37 (90.1)			2 (1.4)	203 (84.8)	30 (13.6)	6 (0.7)	3 (1.8)	3 (0.4)	1 (+)	2 (0.1)				219	508
4 (0.8)				5 (0.6)	1 (0.7)					3 (+)				146	189
											3 (0.4)			0	3
						1 (+)			2 (+)					30	33

Numerals without parentheses are the numbers of the fish containing respective organisms in its stomach ; and those in parentheses are the total weight of respective organisms in the stomach of respective predators. Sign, plus in parentheses, means that the organism is present in the fish stomach but too few to weigh or less than 0.1 g.

Table 2. Stomach contents of each member fish caught during the stay of the type of miscellaneous catch in the daytime.

Fish \ Stomach contents	*Ablennes anastomella*	Conger eel	Rizardfish	Filefish	Squids (juv.)	*Bregmaceros japonicus*	Anchovy	*Spratelloides japonicus*	*Caprella*	Euphausiid	Zooplankton	Seaweeds	Empty stomach	Number of individuals examined
Sharks		1 (26.2)		1 (36.0)									2	3
Scombrops boops			1 (5.9)				1 (0.1)						7	9
Parapristipoma trilineatum			1 (12.8)				4 (83.2)	1 (21.8)					3	9
Bastard halibut							4 (36.9)						2	6
Red sea bream					1 (0.1)					1 (13.6)			1	3
Auxis thazard							7 (105.9)						60	67
Euthynnus affinis yaito							1 (1.9)						1	2
Skipjack							1 (11.3)						3	4
Seriola aureovittata (juv.)					1 (0.3)	1 (0.2)						1 (6.7)	3	6
Mackerel							2 (0.5)						3	5
Rachycentron canadum	1 (25.0)												0	1
Girella punctata									2 (+)	3 (+)		5 (13.1)	30	35
Saury										15 (37.1)			5	20
Jack mackerel							2 (0.4)		8 (1.7)		33 (6.4)		11	54
Apogon semilineatus							10 (4.4)		1 (0.1)				81	92
Sardine											1 (12.5)		1	2
Anchovy											65 (12.9)		40	105
Nemipterus virgatus						1 (4.8)							0	1

Besides, the stomach samples of the following species were examined, but we could not find any organism or its fragment contained in them : rabbitfish (6 specimens), scad (5), filefish (2), *Formio niger* (2), *Spratelloides japonicus* (2), dolphin fish (1), *Ablennes anastomella* (1), rainbow runner (1) and sunfish (1).

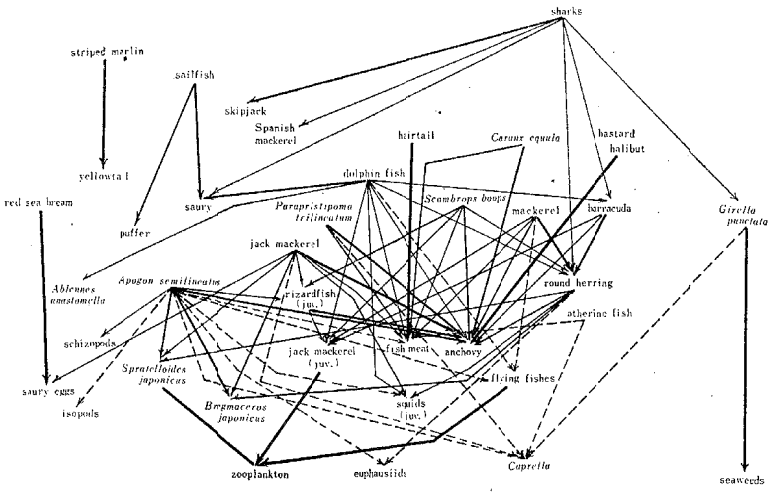

Fig. 3. Food chain observed among the fish caught during the stay of "the dolphin fish type."

Note

: More than three quarters of the stomach contents of the predator

: Neither more than three quarters nor less than two

: Neither more than two quarters nor less than a quarter

: Not more than a quarter

: observed but too few to weigh or less than a percent

important prey of the sharks or the striped marlin respectively, and this suggested the possibility to the dolphin fish being attacked more severely. But the dolphin fish, which was the sole species caught abundantly, was attacked by any of higher predators. And the dolphin fish, thus against the expectation, had not any close relation to higher predators other than the fact that the most important prey of this fish, the saury, occupied a half of the stomach contents of the sailfish and less than a quarter of that of the sharks; (2) the anchovy, on which the arrows showing the predatory relations were concentrated, was the most important prey animal throughout the members of the catch; but this fish could not be the most important prey of the dolphin fish; and (3) the dolphin fish played, thus, no important role in the food-relations against its good catch and there was no fish playing the same role in the food-relations to the dolphin fish.

2) *The saury, the squid and the jack mackerel type* : After the swimming away of the dolphin fish, there occurred another type lacking in any of the large surface swimmers of high trophic levels with strong ability of seasonal migration; and this type was characterized by a good catch of the small surface swimmers of the cold water inhabitants with strong ability of seasonal migration such as the saury and the squids. On account of the fact that the saury and the squids did not approach too closely to the coast, this type was rather characteristic of the opening part and occurred earlier and ended later at the opening part but continued only a short time at the innermost part.

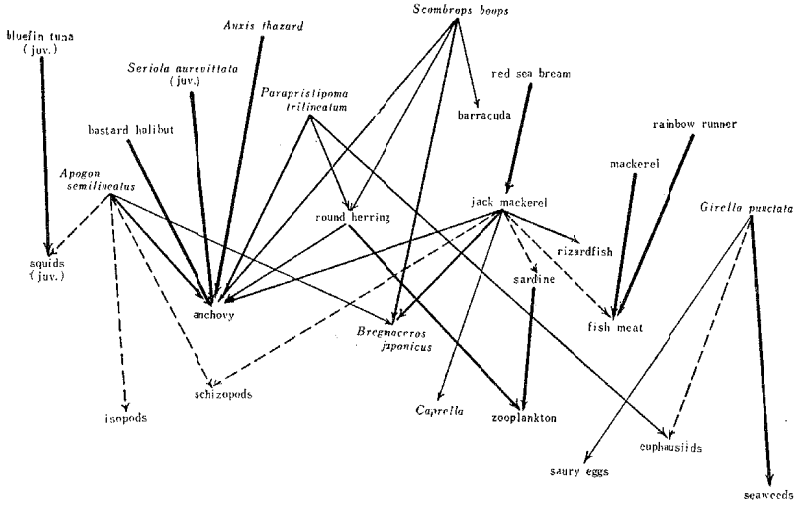

Fig. 4. Food chain observed among the fish caught during the stay of "the saury, the squid and the jack mackerel type."

The saury, which was the species caught most abundantly during this period, was not attacked by any of the predators, moreover we could not find any organism in its stomach despite of the fact that 65 specimens were examined. On the other hand, the jack mackerel, which was the next abundant species in catch, also was not attacked by any of the predators other than the red sea bream which was caught not abundantly at all; and examining 418 specimens, we found that three quarters of the catch had empty stomach and the rest of it took various animals such as the juvenile individuals of the rizardfish (*Saurus undosquamis*), *Bregmaceros japonicus*, the anchovy *etc.* These two abundantly caught members, thus, played no important role in the food-relations against the expectation from good catch together with their body sizes and the habits; and the anchovy still kept its important position in the food-relations as the prey. And it is also one of the remarkable fact that in company with the swimming away of the dolphin fish, which was the piscivore of large size, any of the predators of high trophic levels did not visit this water at all during this type of catch. We are afraid of the fact that the readers may be impressed as if there occurred some differences in the food-habits of some of the member fish from those in the type 1, but we may be aware of the fact that these differences are of insignificance but are merely apparent ones when we consider the fewness of the numbers of the individuals of some of the species examined actually.

3) *The dolphin fish, the bonito, the saury, the squid and the jack mackerel type* : In the midst of the stay of the small surface swimmers (the saury, the squids and the jack mackerel), the large surface swimmers with strong ability of seasonal migration such as the dolphin fish and the bonitos visited the part near the opening of the bay and constructed another type of catch together with the members of type 2; consequently this type was characteristic of the opening part of the bay. And this

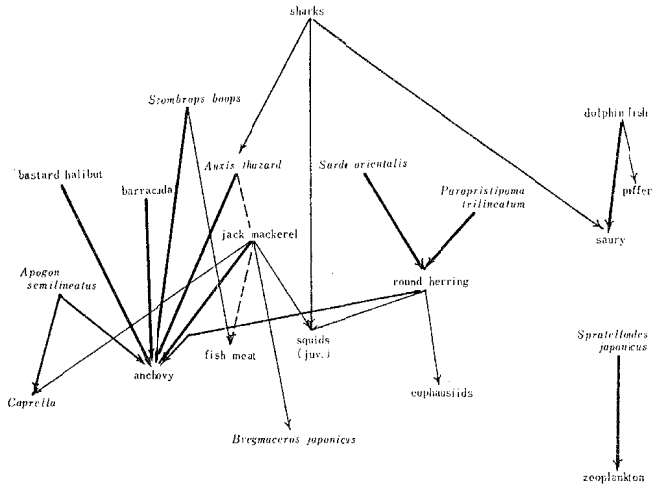

Fig. 5. Food chain observed among the fish caught during the stay of "the dolphin fish, the bonito, the saury, the squid and the jack mackerel type."

was changed again into type 2 with the swimming away of these large surface swimmers.

The fewness of the number of the species relating to one another, especially that of the primary piscivora, simplified the food-relations. It is, of course, of very interesting to tell whether or not the possible prey fish fortunately visited the water abundantly at that period such as the saury and the jack mackerel can play some of the roles of the prey fish in the food-relations such as the anchovy and the sardine when the above-mentioned possible preys were in absence or not in abundance. But the high rate of the occurrence of the individuals with empty stomach prevented us from finding out any suggestion against our aims and efforts.

Notwithstanding this, it may be also worth while to pay attention to the fact whether there were some directly predatory relations between any two of the abundant species or not, in other words, whether or not the predators such as the dolphin fish and the bonitos might visit the water because of being rich in prey fish such as the saury and the jack mackerel. But any fact supporting strongly the presence of such relations mentioned above could not be found out, *i.e.*, we could not find out any evidence suggesting the presence of the directly predatory relations between *Auxis thazard* or *Sarda orientalis* and the saury or the jack mackerel, but we found only an evidence suggesting the possibility of the presence of direct one between the dolphin fish and the saury, but we hesitate to give some significance to this fact because of the high rate of the occurrence of the individuals of the dolphin fish with empty stomach perhaps due to the vomiting during the hauling.

4) The type of miscellaneous catch at night : After the swimming away of the saury, the squids and the jack mackerel in the whole part of the bay and that of the dolphin fish and the bonitos in the opening part, none of the fish were caught

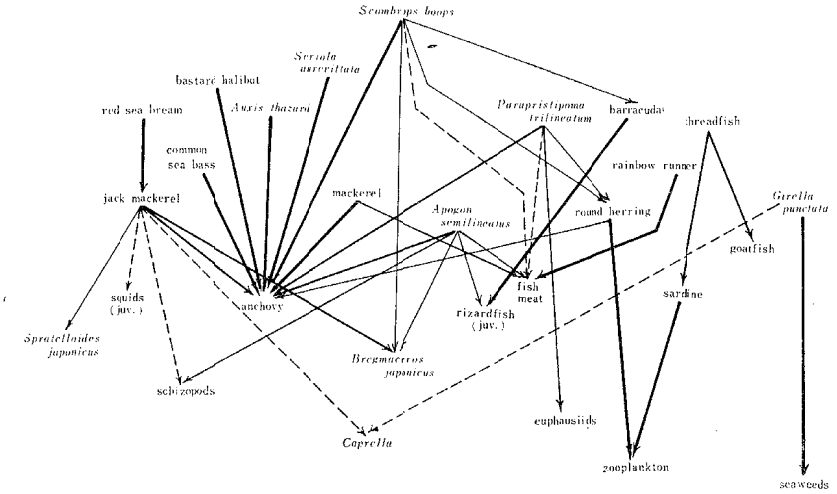

Fig. 6. Food chain observed among the fish caught during the stay of "the type of miscellaneous catch at night."

abundantly till the former three appeared again. This period of poor catch without any characteristic species was for convenience' sake represented as the type of miscellaneous catch at night.

Lack of the abundantly caught species and of high predators but richness in the number of species of the primary piscivora were the characteritics of the catch composition and the food-relations of this type of catch.

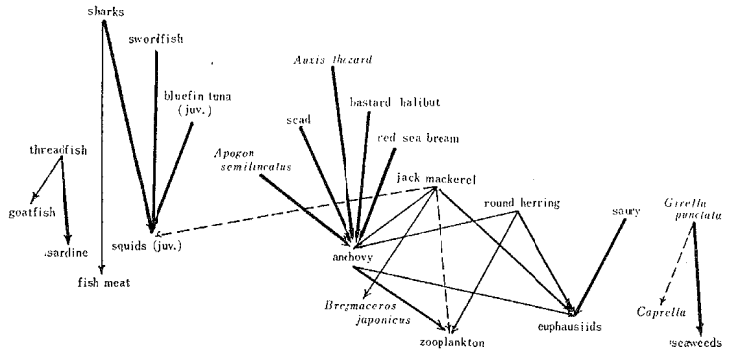

Fig. 7. Food chain observed among the fish caught during the stay of "the saury, the squid and the jack mackerel type with the bonitos."

5) *The saury, the squid and the jack mackerel type with the bonitos* : From Dec. 5 at the inner part or 5 days later at the opening part, there occurred again a good catch chiefly constituted both of the saury and the jack mackerel as the possible prey group and of the bonitos and the large individuals of the squids as the members of the predator group. This type of catch composition was called the saury, the squid

and the jack mackerel type with the bonitos and this type continued till the end of this study.

But against the expectation, any directly predatory relation could be found between the bonitos which were caught abundantly during this period and the saury which came into the bay together with the former and was thought to have a possibility of playing a role of its prey. On Dec. 17 and 18, there occurred an outbreak of euphausiids all over the bay and its adjucent waters, but any change in the food-habits of any of the member fish was induced and none of the member fish took this crustacea abundantly other than the jack mackerel, the round herring and the saury, all of which were usually found with empty stomach in other days, although we expected that the carnivora, especially those of lower orders than the primary piscivora, would have high possibility of changing into euphausiid-feeders during its outbreak.

It is also worth while to be described that high predators of large size such as the sharks, the striped marlin and the juvenile individuals of the bluefin tuna visited this water together with the occurrence in the abundant catch of *Auxis thazard*, and these three fish had directly predatory relations to the squids which also caught again aburdantly during this period.

Diurnal catch (hauled up in the evening)

On account of the rareness of the migratory fish caught abundantly in the daytime (hauled up in the evening), the catch compositions in the daytime became simpler than those at night and the total catch became far poorer. And lack of higher predators than the primary piscivora was one of the most remarkable differences in the food-relations of the diurnal catch from those of the nocturnal one, although any remarkable difference in the food-habits of each member fish could not be found out.

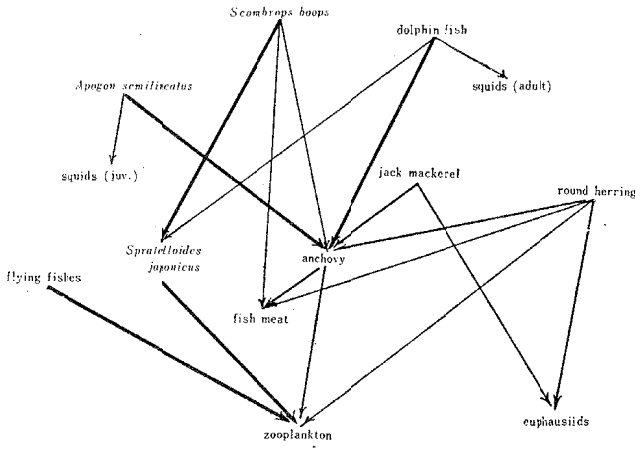

Fig. 8. Food chain observed among the fish caught during the stay of "the flying fish type."

6) *The flying fish type* : The flying fishes were caught chiefly in the daytime till Oct. 25 near the opening of the bay or till Dec. 1 at the innermost part. In consequence, there occurred another type of catch unable to be observed in the nocturnal catch and this type was represented as the flying fish type, although considerable amount of the dolphin fish capable of being regarded as one of the characteristic species was caught together with them.

The dolphin fish fed on the anchovy, but the flying fishes were not attacked by any of the predators moreover most of the individuals had empty stomach. These fishes, thus, played no important role in the food-relations, despite of the fact that they were so abundantly caught that being able to be regarded as the characteristic species and their body sizes suggested that they had high possibility of being taken by many predators.

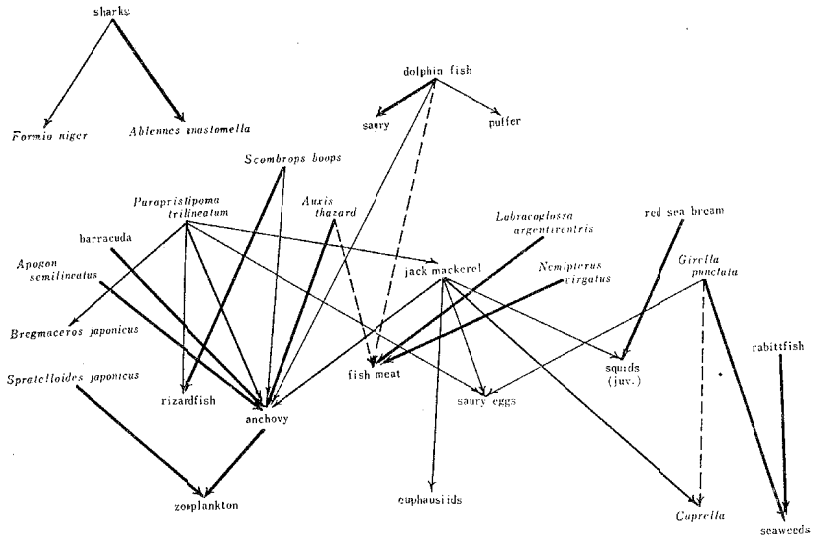

Fig. 9. Food chain observed among the fish caught during the stay of "the dolphin fish type in the diurnal catch."

7) *The dolphin fish type in the diurnal catch* : After the swimming away of the flying fishes, there succeeded to another type of catch common to the nocturnal one characterized by a good catch of the dolphin fish. A little more than 600 stomach samples being constituted of 26 species were examined, but high rate of the occurrence of the individuals with empty stomach made it very difficult to find out some successive food-relations. In consequence, we could not get any relation other than the estranged and discontinuous ones consisted of rather rich species.

8) *The dolphin fish, the bonito and the saury type* : The squids and the jack mackerel and most of the saury were caught at night and the good catch of the dolphin fish in the daytime continued five more days after the end of that at night. These facts made it impossible to be observed the type corresponding to type 2 of

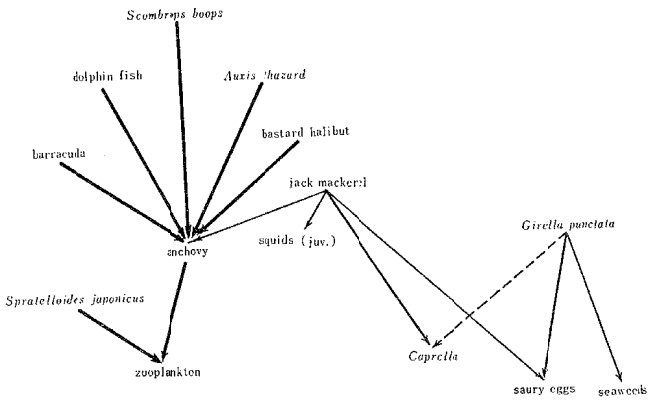

Fig. 10. Food chain observed among the fish caught during the stay of "the dolphin fish, the bonito and the saury type."

the nocturnal catch. And the part in the bay during the period occupied by type 2 in the nocturnal catch was also occupied by one of the modified types of this nocturnal one by the absence of some of the prey fish such as the jack mackerel and including small squids, and this type was represented as the dolphin fish, the squid and the saury type.

We could not clarify the presence of any relation other than simple one being constituted of rather few species. Considerable amount of the saury were caught, and this species has high possibility of playing a role of the anchovy in the food-relations as prey, but any individual or fragment of this fish could not be found out from the stomach of any fish including the dolphin fish and *Auxis thazard*, although its eggs were taken by the jack mackerel and *Girella punctata* both of which were caught not abundantly. On the other hand, we also could not find any individual of the saury with stomach containing any prey at all. The dolphin fish and *Auxis thazard*, both of which were active swimmers caught abundantly, chiefly fed on the anchovy. And any directly predatory relation, thus, could not be found out between the abundantly caught species; and from the food-relational point of view, the saury was well thought to be one of the independent visitors from others against the expectation. The anchovy still kept its importance in the food-relations in respect to the fact that the arrows showing the predatory relations were concentrated on this species. The anchovy was attacked by the dolphin fish and *Auxis thazard*. The barracuda, *Parapristipoma trilineatum* and *Apogon semilineatus* in type 2 and the barracuda, *Scombrops boops* and the bastard halibut of this type took the anchovy. Therefore, it is thought to be very interesting to examine whether or not we could not find any evidence suggesting the possibility of the presence of the repulsive relation of catch among these fish taking the common prey. And we examined carefully the catch records from this point of view, but unfortunately we could not find any suggestion for this problem chiefly because of severe and irregular deviations and some uncertainty in the catch records of such species of the auxiliary catch.

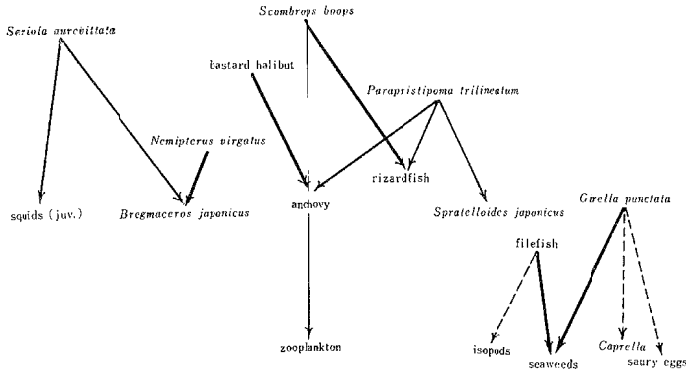

Fig. 11. Food chain observed among the fish caught during the stay of "the *Girella punctata* type."

9) *The Girella punctata type* : Good catch of the algaevora was one of the most remarkable characteristics of the catch compositions during the daytime. And considerable amount of one of the demersal and diurnal algaevora, *Girella punctata*, were caught in the daytime chiefly by the net set at the innermost part of the bay during the period from Nov. 15 to Dec. 10. A good catch of this fish characterized another type of catch specific to the innermost part in the daytime. This type of catch was represented as *Girella punctata* type.

During the continuation of this type of catch, we could not find any relation but very simple ones being constituted of very few species, and this was partly thought to be due to the absence of pelagic fish so abundantly caught as capable of being ranked as characteristic species and due to the poorness of the fish fauna caught in the daytime, which was also one of the general characteristics of the diurnal catch.

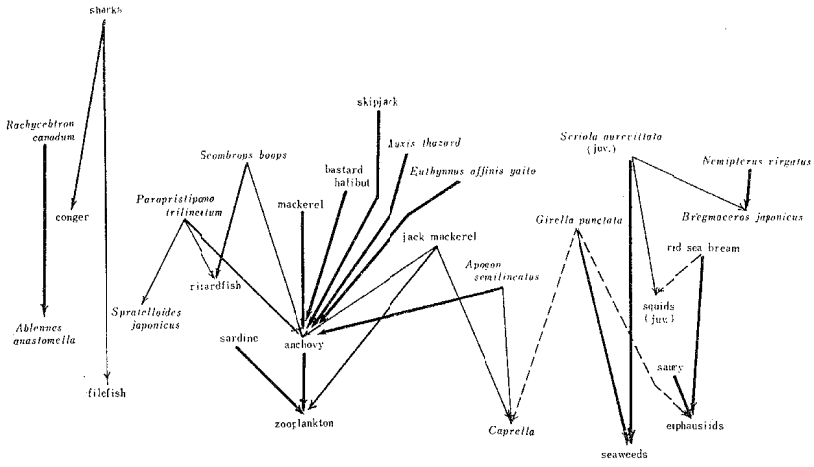

Fig. 12. Food chain observed among the fish caught during the stay of "the type of miscellaneous catch in the daytime."

10) The type of miscellaneous catch in the daytime : During the period from Nov. 20 to the end of this study, we could not find out any of the fish caught abundantly other than the saury, the squids and the jack mackerel. But these fish were all caught at night, and we could catch plentifully none of the fish else than *Girella punctata* in the innermost part and occasionally the bonitos and the juvenile individuals of the bluefin tuna. This period of poor catch without any characterizing species was for convenience' sake represented as the type of miscellaneous catch in the daytime.

For the outline of the food-relations, no fact but those described already in type 7 was able to be found out. And like the nocturnal catch any remarkable change in the food-habits of any of the member fishes was not induced by the outbreak of euphausiids on Dec. 17 and 18.

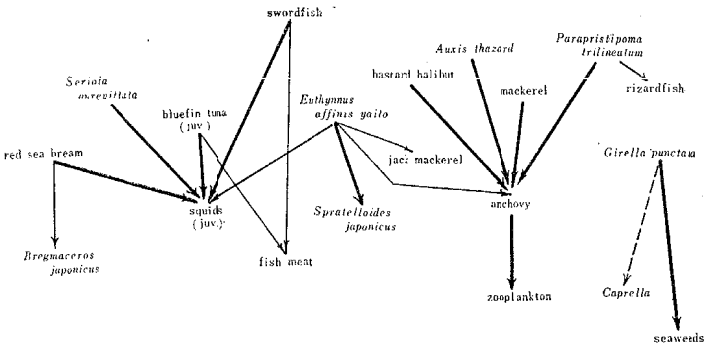

Fig. 13. Food chain observed among the fish caught during the stay of "the juvenile tuna and the bonito type."

11) *The juvenile tuna and the bonito type* : Plentiful individuals of the bonitos with the juvenile bluefin tuna were caught on Nov. 30 and Dec. 12 or thereabout chiefly near the opening part of the bay; this fact and the absence of any other species caught abundantly during this period in this water made us possible to observe one of the types of the catch represented as the juvenile tuna and the bonito type.

Poorness of the fish fauna and high rate of the occurrence of the individuals with empty stomach made it very hard to find out any complicated relation of some significance; and we want to describe here only the fact that there was high possibility of supporting that the anchovy and the small squids were the important animals from the food-relational point of views.

Discussion

It may well be said, from the above-mentioned results, that among the group of fish caught by the set-nets and the animals eaten by them the anchovy was the most important species in the food-relations as prey, on which the arrows showing the

predatory relations were concentrated.

The saury and the jack mackerel, which were caught abundantly showing severe deviation, were expected to have high possibility of playing some parts of the role of the anchovy in the food-relations as prey; but high rate of the occurrence of the individuals of each species with empty stomach perhaps due to the vomiting during the hauling prevented us very much from getting sufficient evidence in support of the affirmative conclusion of the food-habits of the fish especially their quantitative recognition. In consequence, we could neither find out any sufficient evidence suggesting the possibility of these fish taken by predators instead of the anchovy nor find the possibility of taking abundantly the common prey to the anchovy. On the other hand, the large surface swimmers such as the dolphin fish and the bonitos repeated some transit during the studied period, but each of them did not have any close relation to other animals in the water in respect to the food-relational point of views. Moreover, we could not find out any evidence strongly supporting the possibility of the presence of the directly predatory relation between these large surface swimmers and the possible prey fish coming together with them, although we also could not find out any fact clearly denying such a possibility.

We are obliged to conclude nothing but the fact that, despite of our aims and considerable efforts, we unfortunately could not get clear and sufficient evidence in support of or denial of the suggestion that these visitors were not the independent ones but had close relations with each other or with the demersal fish.

And sufficient evidence supporting the clearly daily rhythmic change in the food-habits of any of the member fish could not be found out, but richer fish fauna caught at night than in the daytime caused the food chain of the nocturnal catch constituted of much steps of the links than in the diurnal one. And we could fortunately observed the food-relations of the fish which extended from the fish of so low food ranks as the algaevora such as *Girella punctata* to the secondary piscivora or higher ones perhaps including the end predators of the sea such as the sharks and the marlins.

It is thought to be of very importance to examine whether or not we can find out any evidence suggesting the possibility of the presence of the repulsive relations in the catch between the large surface swimmers with strong ability of seasonal migration and the demersal fish taking the common food to them, but we could not find out any clear suggestion chiefly because of severe and irregular deviations and partly of some uncertainty in the catch records of the auxiliary species.

LARKIN (1956) pointed out that the relatively wide flexibility of food-habits and the breadth at each level of the food chain rather than hight of pyramid of number were the most remarkable characteristics of fresh-water fish communities. But, in our case, in the marine environment, we could not find any evidence supporting the flexibility of food-habits of the fish but could find out many facts suggesting the rigidity of the food-habits of the fish and the importance of the anchovy in the food-relations was not suffered from any influence by the transit of some possible prey

perhaps forming some huge schools. Furthermore, some possibility of the rigidity of the food-habits of the primary piscivora, which usually took chiefly such small fish as the anchovy and *Bregmaceros japonicus* and were expected to have some possi-

Supplemental Table. Name of the fish used in the present study.
1) Science name and Japanese one of the fish described in the common name.

Common name	Science name	Japanese name
Anchovy	*Engraulis japonica*	Katakuchi-iwashi
Atherine fish	*Allanetta bleekeri*	Tougoro-iwashi
Barracuda	*Sphyraena japonica*	Kamasu
Bastard halibut	*Paralichthys olivaceus*	Hirame
Black marlin	*Makaira mazara*	Kurokawa
Bluefin tuna	*Thunnus thynnus*	Maguro
Butterfish	*Pampus argenteus*	Managatsuwo
Common sea bass	*Lateolabrax japonicus*	Suzuki
Dolphin fish	*Coryphaena hippurus*	Shiira
Filefish	*Stephanolepis cirrhifer*	Kawahagi
Flying fishes	Exocoetidae	Tobiuwo
Goatfish	*Upeneus bensasi*	Himeji
Hairtail	*Trichiurus lepturus*	Tachiuwo
Hammer-head shark	*Sphyrna zygaena*	Shumokuzame
Jack mackerel	*Trachurus japonicus*	Ma-aji
Mackerel	*Pneumatophorus japonicus*	Ma-saba
Puffers	Tetraodontidae	Fugu
Rabbitfish	*Siganus fuscens*	Aigo
Rainbow runner	*Elagatis bipinnulata*	Tsumuburi
Red sea bream	*Chrysophrys major*	Ma-dai
Rizardfish	*Saurus undosquamis*	Ma-eso
Round herring	*Etrumeus micropus*	Urume-iwashi
Sailfish	*Histiophorus orientalis*	Basho-kajiki
Sardine	*Sardinops melanosticta*	Ma-iwashi
Saury	*Cololabis saira*	Sanma
Scad	*Decapterus muroadsi*	Muro-aji
Skipjack	*Katsuwonus pelamis*	Katsuwo
Spanish mackerel	*Scomberomorus niphonius*	Sawara
Striped marlin	*Makaira mitsukurii*	Ma-kajiki
Sunfish	*Mola mola*	Manbo
Swordfish	*Xiphias gladius*	Me-kajiki
Threadfish	*Alectis cilialis*	Itohiki-aji
Yellowtail	*Seriola quinqueradiata*	Buri

Note :
bonitos : used for representing *Auxis thazard*, *Euthynnus affinis yaito* and *Sarda orientalis* as a whole, but to indicate each of them the science name is employed.
sharks : chiefly hammer-head shark but usually used including all other ones.

bility of taking small crustacea swimming in the bottom layer, was pointed out. That is to say, we observed an outbreak of the euphausiids all over the bay and its adjucent waters on Dec. 17 and 18 but none of the fish of this group clearly took this crustacea, although we found an evidence suggesting that this outbreak was attacked by the jack mackerel, the round herring and the saury all of which were usually found with empty stomach. For the hight of the number of pyramid in the marine environment, we wish to consider that it is never low but rather high even in such an on-shore water as this, although we should pay heed to the fact that this water is very close to the coast but is under strong influence of an oceanic current.

2) Japanese name of the fish described in the science name.

Science name	Japanese name
Ablennes anastomella	Datsu
Apogon semilineatus	Nenbutsu-dai
Bregmaceros japonicus	Saiuwo
Caranx equula	Kaiwari
Formio niger	Kuroajimodoki
Girella punctata	Mejina
Labracoglossa argentiventris	Takabe
Nemipterus virgatus	Itoyori-dai
Parapristipoma trilineatum	Isaki
Rachycentron canadum	Sugi
Scombrops boops	Mutsu
Seriola aureovittata	Hiramasa
Spratelloides japonicus	Kibinago

Summary

1). Food-relations observed during the period from Oct. 21 to Dec. 17 in 1956 on the groups of the fish caught by 11 set-nets along the coast of the Arikawa Bay were analyzed, for the purpose of finding out an outline of the food-relations observed among the fish caught in an area under strong influence of the Tsushima Current during the period of its seasonal change.

2). Since we expected that the food-relations might differ with the fish fauna consequently with the catch composition which were strongly governed by the transit of some pelagic fish, we treated of the samples classifying into 11 types as represented schematically in Fig. 2 based not exclusively on the catch compcsitions but also on the fact whether hauled up in the morning or in the evening considering together with the location and the seasons.

3). The food-relations observed in each of 11 types of catch compcsitions are shown in Figs. 3~13. And we found that the anchovy was the most important fish

in the food-relations and the arrows showing the predatory relations were concentrated on this fish.

4). Special attention were paid to the problems whether or not the possible prey fish visited the water abundantly at each period can play some of the role of the prey fish which were taken by many fish when the formers were in absence or not in abundance, what kinds of relations were observable between the large fish sometimes visited the water abundantly and other ones caught more or less regardless of the richness or poorness of the catch of the formers, and also to the problems whether or not the large surface swimmers visited the water having directly predatory relations to the possible prey fish coming together with them.

5). But against our aims and efforts, we could, unfortunately, not get any clear and sufficient evidence in support of or denial of the suggestion that these visitors were not the independent ones but had close relations with each other or with the fish caught regardless of their transit.

6). It was pointed out by LARKIN (1956) that the relatively wide flexibility of the food-habits and the breadth at each level of the food chain rather than hight of the pyramid of number were the most remarkable characteristics of fresh-water fish communities. But in the marine environment, we want to consider that the food-habits of the marine fish are not so flexible but rather rigid, and for the hight of the pyramid, we want to consider that it is never low but rather high even in such an on-shore water as this, although we should pay heed to the fact that this water is very close to the coast but is under strong influence of an oceanic current.

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