An Ecological Study on the Fishes Stranded upon the Beach of Northern Kyushu*

By
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Contents

I. Introduction

Mass destruction of the sea life has been noticed from almost all over the world since the days of antiquity.[1, 2] Recently, it was the outstanding phenomena that mass

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destruction of fishes occurred in the Arabian Sea in 1957, in the waters of the Peru Current in 1957 – 1958, and in the seas around Japan in 1963.[3–5] These mortalities triggered the further oceanographical researches of the sea concerned. In each case these phenomena were caused by a sudden change in oceanographical conditions and brought about a disastrous result in the sea life, so that these were called "Mass Mortality in the Sea".[2] BRONGERSMA-SANDERS, who surveyed the accounts up to date, stated that the phenomena were caused by volucanism, earth– and sea– quakes, a sudden change in salinity, a change in temperature, noxiousness of water-bloom, severe storms and vertical currents. Besides these causes, she also stated that spawning runs and stranding of fishes themselves sometimes brought about their mass mortalities.* It is a well known fact that in these mass mortalities two different phenomena are distinguishable from each other, though the discrimination of them is rather difficult in some cases: the one is the abrupt occurrence caused by the sudden changes of environmental conditions mentioned above, and the other is the periodical phenomena accompanied with the periodical changes of oceanographical and meteorological conditions. In northern Kyushu and western Japan many fishes and other marine life have been stranded every winter on the beaches along the Tsushima Current and reaches at times enormous quantities.[6,7] The phenomenon along the Tsushima Current occurs regularily every year[7], being different from the periodical cases observed in North Florida or El niño in the Peru Current region.[2,4,8,9]

In the course of the survey of the stranded squid on the Shingu beach, northern Kyushu, the author found the fact that the fish eggs and larvae, crustaceans, jellyfishes as well as cephalopods belonging to the inshore, offshore and southern constituents, were beached every winter, and revealed that this phenomenon was more prominent on the beach of northern Kyushu than on the beaches along the Tsushima Current between Kagoshima and Niigata Prefectures.[7] Successive observation on this beach led the author to consider that the phenomenon could provide valuable information not only for oceanographical and zoogeographical surveys, but also for fishery interests. The present paper is the outcome of the author's five year study of the fishes stranded on the beach of northern Kyushu and the mechanism of stranding. It is hoped that this study will provide a method to approach the problems of fishery science.

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*The author considers that the recent water pollution brings about more disastrous results in the sea life.

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II. Historical review

Records or descriptions concerning the stranded animals upon the beaches along the Tsushima Current go back many years and, including the fragmentary ones, are many in number. Taking into account this extensive literature, the author considered it is neccessary to divide the history of these studies into three periods. The first period covers the beginning of the records of this phenomenon to about 1900. In this period the phenomenon attracted attention only because of its oddity. It may be sufficient to mention two representative literatures, Chronicles of Japan (Nipponshoki, 720)[1] and Chronicles of Sado (Sado-nendaiki, 1601–1851),[10] in which mass mortality of baloonfish on the Izumo beach, Shimane Prefecture, and beaching of whales, turtles and ocean sunfishes on Sado Island were recorded. Those are no better than the records of the phenomenon, but their continuous accumulation affords important data to elucidate the phenomenon. The next period ranges from about 1900 to the dacade of 1950, corresponding to the period of the establishment of the modern fundamentals of fishery research in our country in 1900[11] to the Tsushima Current Developmental Research by the Fisheries Agency in 1953–1957.[12] In this period the records of stranding or mass mortality of irregular animals on the beaches along the Current comparing the migration process to stranding had been accumulated. TOKUHISA,[13] ARAKI,[14] KINOSHITA and IMAI,[14] UEKI,[15] HONMA,[16,17] NISHIMURA,[6,18] etc. recorded many occurrences of southern fishes, cephalopods, jellyfishes, turtles and sea snakes, and northern seals on the beaches, and suggested that these depended primarily upon the oceanographical structures and meteorological conditions of this area. The third and last stage of the history is from the 1950 decade to the present. During and after the Tsushima Current Developmental Research mentioned above, the oceanographical structure of the Current was extensively explored and made more clear in its appearance.[12,19,20] At the same time several authors made efforts to connect the phenomenon peculiar to this area with the results mentioned above and the meteorological conditions, a beginning of which we could find in the study on the mass mortality of the baloonfish along the coasts of the Tsushima Current by NISHIMURA.[6] According to these studies, the southern elements such as baloonfish,[6] *Boesemanichthys*,[21] *Regalecus*,[22] *Thysanoteuthis*,[23] *Argonauta*,[24] *Dermocelus*,[25] etc. were transported by the Tsushima Current into the Japan Sea during the summer months and perished by the chill and seasonal cold wind in winter on the coasts of the Sea. As was already described, the authors made successive observations at the beach of northern Kyushu, an entrance to the Japan Sea, and concluded that every winter organisms, including not only endemic but also southern constituents, were destroyed by stranding on the beach.[7] These studies suggested that the stranded animals might be considered as living drift-bottles being carried by the warm current. An analysis of these occurrences would help to clarify the processes of transportation and transformation of the tropical and subtropical water masses. Therefore, it is necessary to analyze precisely the relationship between the phenomenon and the oceanographical and meteorological conditions through successive observations on the field.

Besides the studies of fish stranding along the Tsushima Current, fish stranding phenomenon at Suruga Bay, Shizuoka Prefecture,[26,27] and at Shirahama, Wakayama Prefecture,[28] and fish-egg stranding in Hokkaido[29] and in Seto Inland Sea region[30] have been surveyed in our country. We can enumerate the famous foreign studies of fish stranding in the Messina Strait region and on the coast at Nice, Mediterranean Sea,[2,31,32] which was a beginning of the studies on the deep sea organisms in the world, mass destruction in North Florida and El niño in the Peru Current region.[2,4,8,9] Ranging over the literatures concerned, it is recognized that the study history in each region may be divided, at a certain extent, into three periods: period of the record of the phenomenon, period of the record of stranded animals and period of considering the mechanism and trying to utilize its information for fisheries. This is similar to the historical study along the Tsushima Current, and the present study is considered to be in the third period.

III. Materials and methods

The surveys were carried out on the Shingu Beach, Fukuoka Prefecture, northern coast of Kyushu (Fig. 1). This sandy beach forms nearly a straight shoreline (Plate I, B) and faces the western entrance to the Japan Sea, the Tsushima Strait. The station lies in a region of shallow waters, keeping a depth of 10 to 20 meters at a distance of one kilometer from the shore. Originating from the Kuroshio in the northwest near Yaku Island, the Tsushima Current runs toward the Japan Sea and maintains some distance from the shore which causes the inshore waters to flow southwest as a counter current.[12] Seasonal changes of water temperature and chlorinity of the coastal waters during April, 1965 to March, 1966 are shown in the temperature-chlorinity diagram (Fig. 2), based on the observation at Station 1 of the Fukuoka Prefectural Fisheries Experimental Station.[33] The water temperature normally varies between 10 and 30°C, showing the highest temperature in September and the lowest in March. On the other hand, the chlorinity of the water is kept in a range of 17.50‰ to 19.40‰ throughout year, showing the

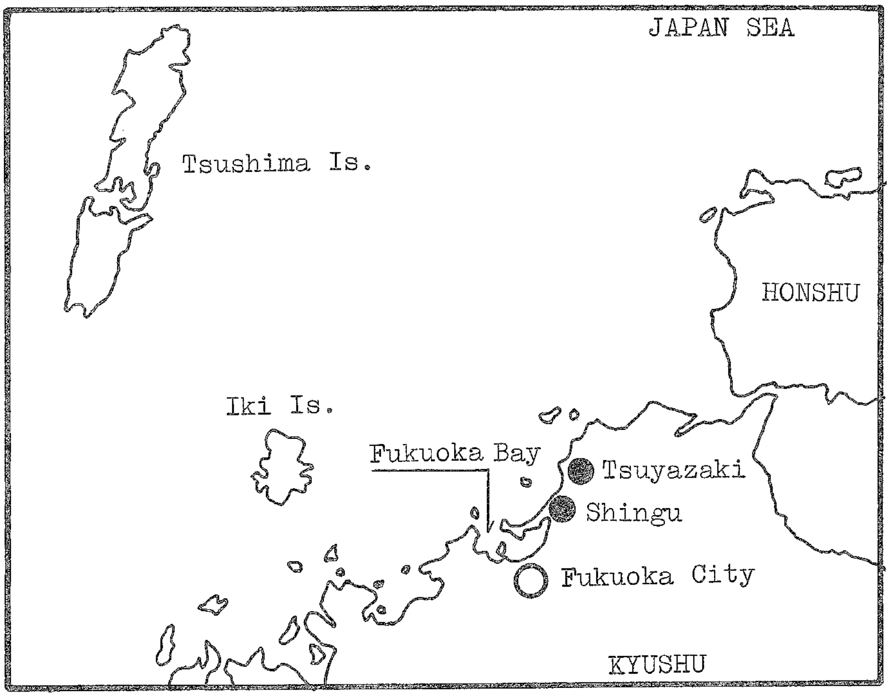

Fig. 1. Map showing the research area.

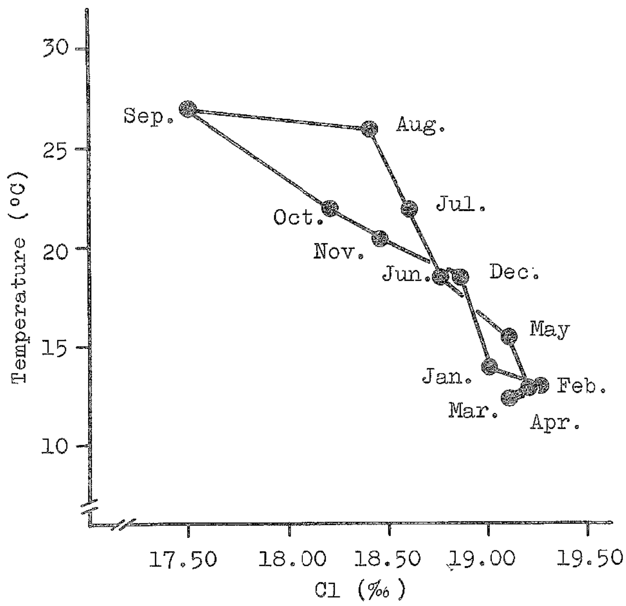

Fig. 2. T-Cl diagram of the coastal waters of northern Kyushu in 1965-1966 (Compiled from the date of Fukuoka Pref. Fish Exp. St. [33]).

highest chlorinity in February to April and the lowest in September. In this region the winter monsoon from the continent normally develops during the winter months, and it is not uncommon for the northwest monsoon of over 10 meter velocity to blow for a period of several days. Through the duration of such a strong northwester, the air temperature suddenly drops to the minimum level, affecting the water temperature.[34,35]

The observation period was from October, 1964 to March, 1968. The observations were held at the beach every morning from January to May, 1965 (the author calls this period the 1965 season), November, 1965 to March, 1966 (the 1966 season), October, 1966 to April, 1967 (the 1967 season) and November, 1967 to March, 1968 (the 1968 season). In the remaining periods observations were made once every ten days. An assigned distance of the Shingu beach, about one kilometer, was employed for the daily observations. The stranded animals left on the sandy wave-marks or entangled in the washed algae on this stretch of the shoreline were collected or counted both going and returning. Almost all of them were brought back to the laboratory for more detailed study. At the same time the weather and tide conditions were recorded. In addition, the author made some observations on the nearby beaches and gathered information regarding the strandings from reliable fishermen and early-morning strollers.

In order to compare the endemic fauna with the studied fauna, several surveys with small shrimp-trawl net and fish larva net in the coastal waters of the beach and observations on fishes landing at the Tsuyazaki Fish Market, near the Shingu beach, were also made in this period. For the sake of analysis of the relationship between the phenomenon and the environmental conditions the following data was used: records of the Nagasaki Marine Observatory, the Fukuoka Prefectural Fisheries Experimental Station, the Fukuoka Meteorological Observatory and the Tsuyazaki Fisheries Cooperative.

IV. Faunistic characters of stranded animals

1. Composition of stranted animals

The collection of stranded animals on the Shingu beach during the four observation seasons from January, 1965 to March, 1968 totaled 300 species or more and covered 7 phylums: Coelenterata 5, Chaetognatha 3, Mollusca 14, Arthropoda 75, Echinodermata 4, Protochordata 2 and Vertebrata over 200 species. As is seen in Fig. 3-A, Vertebrata occupy two-thirds of the total number of stranded animals, and Arthropoda occupy one-fourth. As to each phylum, it is notable that the species of Vertebrata consists exclusively of fishes, except one species of sea turtle (*Dermochelys coriacea*). In Arthropoda 26 species of Macrura and 23 species of Brachyura predominate. In this treatment several kinds of organisms such as leptocephali of Apodes, and Heterosomata larvae (Vertebrata), Euphausiacea (Arthropoda) and so forth are delt with as one group, while they are actually composed of several species to over 20 species. The littoral shellfishes, which appeared on the beach in enormous quantities after severe storms in late autumn and winter, are out of consideration in this paper. Consequently, the species numbers of Vertebrata, Arthropoda, etc. greatly exceed those described above. It was noticed that during this season, fish eggs, floating sargassums, coconut and other tropical life were washed ashore.[7)]

A direct comparison between phylums can not be made, since some members of each phylum appeared at times in numberless quantities on the beach, and their abundances could not be estimated. So the author gives here only the relative abundance of fishes, crustaceans and cephalopods stranded on the Shingu beach in the two seasons of 1966

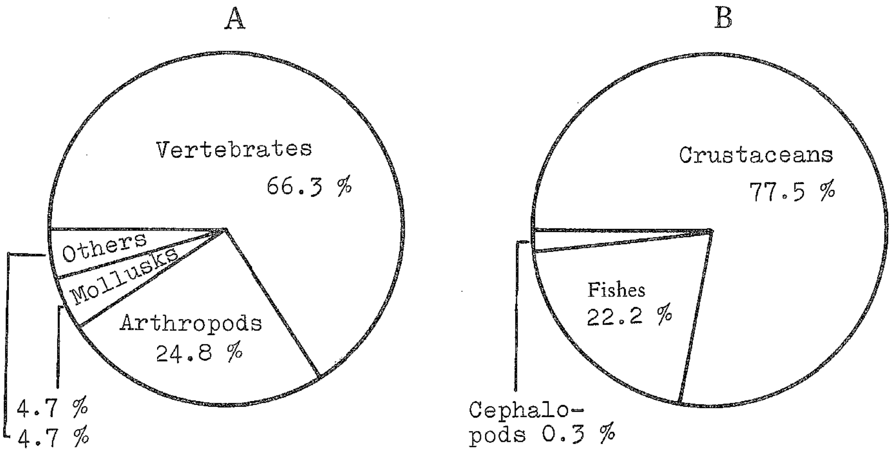

Fig. 3. Percentage compositions of stranded animals.
A, number of species in the 1965 - 1968 seasons;
B, number of specimens of three groups in the 1966 - 1967 seasons.

and 1967 (Fig. 3–B). Of these groups, crustaceans accounted for 77.5%, fishes 22.2% and cephalopods less than 1% of the total number of specimens.

2. Number of species and specimens of fishes

The fishes observed on the one kilometer beach of Shingu in these four seasons are shown in Table 1. According to this Table, 44 suborders, 81 families and about 150 species were observed with more than 50 species of unidentified fishes, resulting in more than 200 species in total. Of these 150 species, 77 species (51%) belong to 7 suborders, of which Percina, Gobiina, Tetraodontina and Cottina highly predominated (Table 2). In this Table, leptocephalus and Bothinae larvae (Plate I, A and C), etc., are also treated as one species, though these consist of several species to over 20 species. In addition to Table 1 the following species were recorded on the beaches neighbouring Shingu: *Regalecus ressellii* (Fukuoka City in December, 1964), *Mola mola* (Fukuoka City in February, 1966), *Trachypterus ijimai* (Tsuyazaki in May, 1967), and sea snail *Hydrophis melanocephalus* (Mitoma, near Shingu in December, 1964).

Of the 150 identified fishes, about 68 species had more than 10 specimens each, and the remaining 85 species, less than 10 specimens each. Above all, 4 species of *Boesemanichthys firmamenturm, Cololabis saira, Macrorhamphosus scolopax* and leptocephalus were estimated at more than 10,000 specimens, and 4 species of *Bregmaceros, Engraulis*

Table 1. Fishes stranded on the Shingu beach, northern Kyushu, during the winter months of 1965-1968.*

No.	Scientific name	Abundance***
1	*Boesemanichthys firmamentum*	+++++
2	*Cololabis saira*	+++++
3	*Macrorhamphosus scolopax*	+++++
4	Leptocephalus larvae**	+++++
5	*Bregmaceros***	++++
6	*Engraulis japonica*	++++
7	*Plotosus anguillaris*	++++
8	*Sebastes* larva	++++
9	Synodontidae**	+++
10	*Ammodytes personatus*	+++
11	*Diodon holacanthus*	+++
12	Bothinae**	+++
13	*Synagrops japonicus*	+++
14	*Maurolicus japonicus*	+++
15	Pomacentridae	+++
16	*Stephanolepis***	+++
17	*Mugil cephalus*	+++
18	*Lubricogobius exiguus*	+++
19	Epinephelinae	+++
20	*Glossanodon semifasciatus*	+++
21	*Coelorhynchus multispinulosus*	+++
22	*Lestidium prolixum*	+++
23	*Fugu niphobles*	+++
24	*Champsodon snyderi*	+++
25	Myctophidae**	+++
26	*Fugu poecilonotus*	+++
27	*Carassius auratus*	+++
28	Hexagrammidae	+++
29	*Hime japonica*	+++
30	Ophichthidae**	++
31	*Labracoglossa argentiventris*	++
32	*Sillago japonica*	++
33	*Uranoscopus japonicus*	++
34	*Pomacentrus coelestis*	++
35	*Malakichthys wakiyai*	++
36	*Oryzias latipes*	++
37	*Evynnis japonica*	++
38	*Trachyrhamphus serratus*	++
39	*Leiognathus nuchalis*	++
40	*Apogon lineatus*	++
41	*Apogon niger*	++
42	*Brama raii*	++
43	*Aluterus monoceros*	++
44	*Lagocephalus lunaris*	++
45	*Vireosa hanae*	++
46	*Canthidermis rotundatus*	++
47	*Caranx*	++

Table 1. — (Cont'd)

No.	Scientific name	Abundance***
48	*Apistus carinatus*	++
49	*Hypodytes rubripinnis*	++
50	*Therapon oxyrhynchus*	++
51	*Upeneus bensasi*	++
52	*Tridentiger obscurus*	++
53	*Triacanthodes anomalus*	++
54	*Sparatelloides japonicus*	++
55	*Gymnopogon japonicus*	++
56	*Girella punctata*	++
57	*Siganus fuscescens*	++
58	*Zonogobius boreus*	++
59	*Daicocus peterseni*	++
60	*Anguilla japonica*	++
61	*Cypselurus***	++
62	*Brachiostegus j. japonicus*	++
63	*Cepola schlegeli*	++
64	*Radrius ercodes*	++
65	*Fugu v. vermicularis*	++
66	*Fugu pardalis*	++
67	*Goniisteus zonatus*	++
68	*Apogon doederleini*	++
69	*Squatina japonica*	+
70	*Raja kenojei*	+
71	*Elops*	+
72	*Gonorhynchus abbreviatus*	+
73	*Plecoglossus altivelis*	+
74	*Idiacanthus panamensis*	+
75	*Zacco temmincki*	+
76	*Hemigrammocypris rasborella*	+
77	*Misgrunus anguillicaudatus*	+
78	*Conger japonicus*	+
79	*Conger myriaster*	+
80	*Muraenesox cinereus*	+
81	*Hemiramphus sajori*	+
82	*Fistularia villosa*	+
83	*Syngnathus schlegeli*	+
84	*Hippocampus coronatus*	+
85	*Allanetta bleekeri*	+
86	*Channa argus*	+
87	*Pneumatophorus*	+
88	*Decapterus*	+
89	*Alectis cilialis*	+
90	*Seriola purpurascens*	+
91	*Leiognatus rivulatus*	+
92	*Psenopsis anomala*	+
93	*Pempheris japonicus*	+
94	*Apogon notatus*	+
95	*Apogon semilineatus*	+
96	*Priacanthus boops*	+

Table 1. – (Cont'd)

No.	Scientific name	Abundance***
97	*Pseudopriacanthus niphonius*	+
98	*Scombrops boops*	+
99	*Gerres oyena*	+
100	*Rhabdosargus sarba*	+
101	*Therapon jarbua*	+
102	*Callionymus lunatus*	+
103	*Callionymus richardsoni*	+
104	*Dasson trossulus*	+
105	*Enedrias nebulosus*	+
106	*Carapus*	+
107	*Tridentiger trigonocephalus*	+
108	*Rhinogobius pflaumi*	+
109	*Rhimogobius similis*	+
110	*Acanthogobius flavimanus*	+
111	*Pterogobius zonoleucus*	+
112	*Chaeturichthys hexanema*	+
113	*Chasmichthys gulosus*	+
114	*Leucopsarion petersi*	+
115	*Luciogobius guttatus*	+
116	*Chromis notatus*	+
117	*Abudefduf vaigiensis*	+
118	*Duymaeris flagellifera*	+
119	Labridae	+
120	*Platax pinnatus*	+
121	*Chaetodontoplus septentrionalis*	+
122	*Chaetodon collaris*	+
123	*Paramonacanthys oblongus*	+
124	*Ostracion tuberculatus*	+
125	*Lactoria diaphanus*	+
126	*Fugu rubripes*	+
127	*Fugu stictonotus*	+
128	*Fugu v.porphyreus*	+
129	*Fugu chrysops*	+
130	*Chilomycterus affinis*	+
131	*Sebastes p.pachcephalus*	+
132	*Erisphex potti*	+
133	*Platycephalus indicus*	+
134	*Paralichthys olivaceus*	+
135	*Heteromycteris japonicus*	+
136	*Physiculus*	+
137	*Lotella*	+

*In addition to these fishes, more than 50 species of unidentified fishes were observed in the periods.

**These consist of more than 2 species.

***Marks of abundance are:

+,	1-10
++,	10-100
+++,	100-1,000
++++,	1,000-10,000
+++++,	10,000-.

japonica, Plotosus anguillaris and *Sebastes* were counted at 1,000–10,000 specimens, respectively. Moreover, fishes of 100–1,000 specimens stranded in these periods were recorded to have 21 species, and the ones of 10–100 specimens, 39 species (Table 1). Finally, only one specimen of sea turtle (*Dermochelys coriacea*) was observed on the beach in the periods.

Table 2. Taxonomical characteristics of stranded fishes.

Name of suborder	No. of species	Percent to total No.
Percina	22	14.7
Gobiina	14	9.3
Tetraodontina	12	8.0
Cottina	10	6.7
Balistina	7	4.7
Myctophina	6+	4.0
Carangina	6	4.0

3. Numbers of species and specimens of invertebrates

As indicated in Table 3, except for the fishes, about 100 species of invertabrates covering 6 phylums were recored. The members of Arthropoda (Plate II, A) accounted for 70% (77 species) of the total species, those of Mollusca 13% (14 species) and the remaining 4 phylums 12% (13 species). Arthropoda, the most dominant group, consisted mainly of 26 species of Macrura (34% in Arthropoda), 23 species of Brachyura (30%), 8 species of Anomura (10%), and 7 species of Stomatopoda (9%). The numerous gastropods and bivalves were not considered in the analysis of the Mollusca population. Only cephalopods were counted (Plate III).

Certain species reached at times unestimated numbers even in the beach of one kilometer distance (Fig. 4 and Plate II, B). These species are shown in Table 4 with the number of days observed during about a 400 day observation period in the 1966 and 1967 seasons. The most outstanding example of this occurrence was shown by *Spirocodon saltatlix* & *Aurelia aurita* (Coelenterata), *Iasis zonaris* & *Pegea confoeda* (Protochordata), and *Porpita porpita* (Coelenterata), which frequently spread all over the beach (Fig. 4). *Spirocodon* & *Aurelia*, and two species of salpa were counted together, because they were partially destroyed and unidentifiable. But in Coelenterata, *Spirocodon* seemed more abundant than *Aurelia*.

The relative abundance of each species of crustaceans and cepahlopods counted on the beach in the 1966 and 1967 seasons are tabulated in Table 5. In the crustaceans, 2 species of *Lophogaster pacificus* and *Oxycephalus porcellus* (Plate II, A–b and-c) numbered more than 10,000 specimens, and the following stomatopod larvae reached about 8,000 specimens. On the contrary, the remaining 8 species of crustacean were limited to 1,000 specimens. Stomatopoda larvae consisted of 6 species belonging to 3 genera, of which *Squilla* and *Lysioerichthys* greatly outnumbered *Pseudosquilla* in number of specimens. *Phyllosoma* larva and *Lepas fascicularis* did not occur in the 1966 and 1967 seasons, but the former numbered over 200 specimens and the latter was observed in mass quantities clinging to the disk of *Porpita* in 1965. Although 23 species of Brachyura were recorded, the number of specimens and days observed were not recorded. The

Table 3. Invertebrates stranded on the Shingu beach during the winter months of 1965-1968.

No.	Scientific name
	COELENTERATA
1	*Spirocodon saltatlix* (TILESIUS)
2	*Physalia physalis* (LA MARTINIERE)
3	*Porpita umbella* O. F. MÜLLER
4	*Dactylometra pacifica* GOETTE
5	*Aurelia aurita* LAMARCK
	CHAETOGNATHA
1	*Sagitta hexaptera* D'ORBIGNY
2	*Sagitta enflata* GRASSI
3	*Sagitta nagae* ALVARINO
	MOLLUSCA
1	*Violetta globosa* (SWAINSON)
2	*Aplysia kurodai* (BABA)
3	*Creseis acicula* RANG
4	*Sepia esculenta* HYLE
5	*Sepia anderanoides* HYLE
6	*Euprymna morsei* VERRILL
7	Loligonidae
8	*Thysanoteuthis rhombus* TROSCHEL
9	*Cranchia scabre* LEACH
10	*Octopus vulgaris* CUVIER
11	*Octopus minor* (SAKAI)
12	*Tremoctopus violaceus* DELLE CHAIAJE
13	*Argonauta argo* LINNÉ
14	*Argonauta hians* (SOLANDER)
	ARTHROPODA
1	*Tachypleus tridentatus* LEACH
2	*Calanus helgolandicus* CLAUS
3	*Lepas fascicularis* ELLIS ET SOLANDER
4	*Lophogaster pacificus* FAGE
5	Mysidacea
6	Cumacea
7	*Hyperia galba* MONTAGU
8	*Phronima sedentaria* (FORSKAL)
9	*Oxycephalus porcellus* CLAUS
10	Euphausiacea
11	*Lucifer reynaudi* H. MILNE-EDWARDS
12	*Solenocera brevipes* KUBO
13	*Metapenaeopsis barbata* (DE HAAN)
14	*Metapenasopsis acelivis* (RATHBUN)
15	*Metapenaeopsis dalei* (RATHBUN)
16	*Sicyonia cristata* DE HAAN
17	*Leptochela gracilis* STIMPSON
18	*Leptochela aculeocaudata* PAULSON
19	*Plesionika unidens* BATE
20	*Plesionika binoculus* (BATE)
21	*Chlorotocus crassicornis* (COSTA)
22	*Chlorotocella gracilis* BALSS
23	*Alpheus brevicristatus* DE HAAN
24	*Alpheus haani* ORTMANN
25	*Betaeus yokoyai* KUBO
26	*Heptacarpus rectirostoris* (STIMPSON)
27	*Latruetes laminirostris* ORTOMANN
28	*Palaemon macrodactylus* RATHBUN
29	*Rhynchocinetes uritai* KUBO
30	*Processa japonica* (DE HAAN)
31	*Ibacus ciliatus* (V. SIEBOLD)
32	*Scyllarus cultrifer* (ORTMANN)
33	*Pracambarus clarki* (GIRARD)
34	*Nephrops thomsoni* BATE
35	*Icotopus*
36	*Phyllosoma* larva of *Ibacus*
37	*Upogebia major* (DE HAAN)
38	*Laomedia astacina* DE HAAN
39	*Callianassa japonica* ORTMANN
40	*Callianassa harmandi* BOUVIER
41	*Galathea orientalis* STIMPSON
42	*Dardanus arrosor* (HERBST)
43	*Hippa pacifica* (DANA)
44	*Hippa trancatifrons* (MIERS)
45	*Dorippe japonica* VON SIEBOLD
46	*Myra fugax* (FABRICIUS)
47	*Leucosia longifrons* DE HAAN
48	*Leucosia nittata* DE HAAN
49	*Matuta planipes* (FABRICIUS)
50	*Matuta*
51	*Hyastenus diacanthus* (DE HAAN)
52	*Lambrus validus* DE HAAN
53	*Ovalipes punctatus* (DE HAAN)
54	*Macropipus corrugatus* (PENNANT)
55	*Scylla serrata* (FORSKAL)
56	*Portunus pelagicus* (LINNÉ)
57	*Portunus gladiator* FABRICIUS
58	*Portunus hastatoides* FABRICIUS
59	*Charybdis japonica* A. MILNE-EDWARDS
60	*Charybdis*
61	*Thalamita sima* H. MILNE-EDWARDS
62	*Halimede ochtodes* (HERBST)
63	*Macrophthalmus telescopicus* (OWEN)
64	*Hemigrapsus penicillatus* (DE HAAN)
65	*Sesarma picta* (DE HAAN)
66	*Eriocheir japonicus* DE HAAN
67	*Megalopa* larva
68	*Squilla oratoria* DE HAAN
69	*Lysiosquilla maculata* (FABRICIUS)
70	*Squilla* larvae
71	*Lysioerichthus* larvae
72	*Pseudosquilla* larva
	ECHINODERMATA
1	*Asteria pectinifera* (MÜLLER ET TROSCHEL)
2	*Clypeaster japonicus* (DÖDERLEIN)
3	*Anthocidaris crassispina* (A. AGASSIZ)
4	*Stichopus japonicus* SELENKA
	PROTOCHORDATA
1	*Iasis zonaria* (PALLAS)
2	*Pegea confoederata* (FORSKAL)

species which occurred frequently were as follows: *Eriocheir japonicus, Portunus pelagicus, P. gladiator, Ovalipes punctatus, Matuta* and *Leucosia.*

In cephalopods Loligonidae larvae are shown to be the most dominant species. *Thysanoteuthis* (Plate III, A) supports the local stranded squid fishery. Therefore, Table 5 is biased due to the collection of this squid by the fishermen and can not be used for

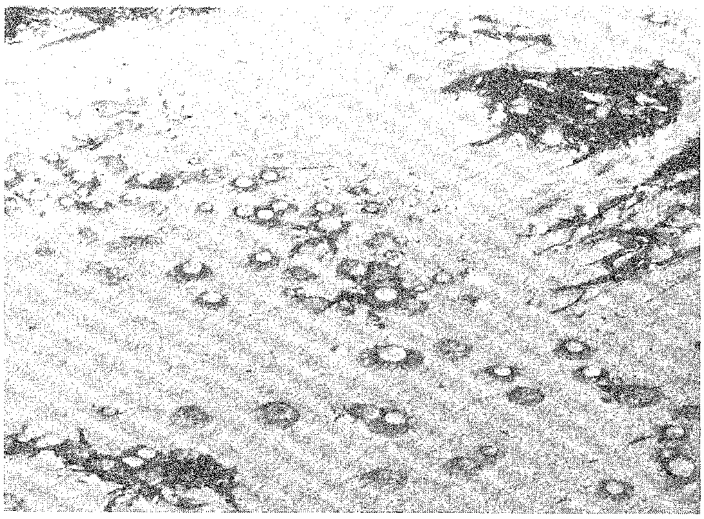

Fig. 4. The stranded jellyfish, *Porpita porpita*, on the Shingu beach on December 2, 1965.

Table 4. Number of observed days in each species belonging to Coelenterata, Chaetognatha, Mollusca, Echinodermata and Protochordata during about a 400 days observation period in the 1966 and 1967 seasons.

Species name	Days observed*
Physalia physalis	16 (1)
Porpita porpita	25 (22)
Spirocodon & Aurelia	58 (45)
Sagitta	15 (6)
Violetta globosa	17 (11)
Clypeaster japonicus	8 (5)
Iasis & Pegea	45 (27)

*Figures in parentheses indicate the number of days when enormous amounts of the species were observed.

this study. In these seasons several specimens of *Cranchia scabre, Sepia, Euprymna* and *Octopus* were observed.

Besides the mass occurrence species which are listed in Tables 4 and 5, great numbers of *Creseis acicula* (Mollusca) and two minute crustaceans (*Calanus helgolandicus* and

Table 5. Crustaceans and cephalopods stranded on the Shingu beach in the 1966-1968 seasons.

Species name	Abundance**
CRUSTACEANS	
Lophogaster pacificus	+++++
Oxycephalus porcelus	+++++
Stomatopoda larvae*	++++
Chlorotocus crassicornis	+++
*Leptochela**	+++
Euphausiacea*	+++
*Metapenaeopis**	+++
Icotopus	+++
Mysidacea*	+++
Plesionica binoculus	+++
Solenocera brevipes	+++
Phronima sedentaria	++
CEPHALOPODS	
Loligonidae*	+++
Argonauta argo	++
Thysanoteuthis rhombus	++
Tremoctopus violaceus	++
Argonauta hians	++

*These consist of more than 2 species.
** Marks of abundance are : ++, 10-100
+++, 100-1,000
++++, 1,000-10,000
+++++, 10,000-.

Megalopa larvae of Brachyura) sometimes attracted the author's attention on the beach, but the number of days observed was not recorded precisely.

Consideration

The records* show that in the past several large animals such as a fur seal, porpoises, etc., have washed ashore on the Shingu beach. These animals together with whales, seals, sea snakes and sea turtles are known to be stranded at times on the Japan Sea coast.[6,10,14,15,18] It must be pointed out that minute organisms such as *Calanus* and *Megalopa* larva have doubtlessly escaped the fishermen's attention. Thus, the members appearing on the beach which belong to all phylums inhabited in or migrated into this area and ranging from less than one millimeter to several meters in body length are considered to have perished by stranding on the beach during the winter, and the comparatively larger specimens alone seem to have drawn the fishermen's and early-morning strollers' attention up to date. In our coastal region along the Tsushima Current, it has been noticed that great quantities of some members of Pisces (*Diodon, Boesemanichthys*, etc.)[6,18] Mollusca (*Creseis*),[7] Protochordata (*Pegea*),[7] and Coelenterata (*Physalia* and *Stomolophus*)[36,37] died from stranding on the beaches in the cold season. The same is true on the beach in question. Besides those animals mentioned above,

*Several votive pictures of porpoises, fur seals, etc. stranded on the Shingu beach are enshrined in the shrines of this town.

mass mortality of fish eggs, fish larvae and crustaceans has been reported for the first time.[7]

There are several fishes stranded upon the beaches in the winter along the Japan Sea coast from northern Kyushu through Honshu to western Hokkaido or western Sahalin. Of the larger fishes recorded in the past, *Diodon,*[6] *Boesemanichthys,*[21] *Canthidermis,*[14] *Mola,*[14] *Mastulus,*[14] *Regalecus,*[22] *Trachinopterus*[18] and *Ostracion*[14] are the most common. *Maurolicus,*[7,37] *Gymnopogon,*[7,38] *Hypodytes,*[38] etc., are small and have been recorded in only a few cases. *Diodon* and *Regalecus* are the only species in the above list which have received any attention in the past and were reported by NISHIMURA.[6,22] In regard to the other fishes the records of stranding are rather sporadic. In these observations, as noted easily from Table 1, the fishes stranded on the beach are divided into the following 4 groups by the number of specimens: massive species, more than 1,000 specimens appearing, 8 species; numerous species, 100–1,000 specimens, 21 species; frequent species, 10–100 specimens, 39 species; rare species, less than 10 specimens, about 85 species. Had this investigation been prolonged and / or the observation area enlarged, some species may have been placed in other categories. For example, *Diodon* and *Canthidermis* have been placed in the numerous and frequent species groups, respectively. But, according to the other study, these two species would fall in the massive species group.[6,14] It should be pointed out that the following 25 fishes belonging to the rare species group have each appeared once during the 4 observation periods and are considered "stray fish" in the stranding community: *Squatinina japonica, Raja kenojei, Idiacanthus panamensis, Hemigrammocypris rasborella, Zacco temminski, Decapterus* sp., *Alectis cilialis, Seriola purpurasceus, Bempherus japonicus, Priacanthus boops, Pseudopriacanthus niphonius, Gerres oyena, Rhabdosargus sarbe, Callionyms richardsoni, Enerdrias nebulosus Pterogobius zonoleucus, Chaeturichthys hexanema, Platax pinnatus, Chaetodon collaris, Chaetodontoplus septentrionalis, Lactoria diapanus, Fugu stictonotus, Physiculus* sp. and *Lotella* sp. In future studies, some of these species may fall into other categories.

It is of interest to compare the endemic fauna with the stranding fish community. The data used here is essentially taken from the list provided by UCHIDA.[39] However, the author has extended the observations at the Tsuyazaki Fish Market and neighbouring tide pools of the Shingu beach to the products of the small shrimp trawlers operating in nearby waters. The list of endemic fauna consists of 280 fishes belonging to 108 families and 47 suborders. On the other hand, the stranding fishes numbered about 150 species included in 81 families and 44 suborders as described already, occupying 54% of the species, 80% of the family and 95% of the suborder in the inhabitant community. The results of a qualitative comparison between the two communities made in Table 6 are given as follows: (1) 8 suborders appeared in the stranded fish community alone. Some of them are scarce in numbers of species and specimens. A few individuals were found to be inhabitants of rivers pouring into the waters (Cyprina and Channina). 8 suborders also are seen only in the inhabitant community. (2) As for the each member belonging to both communities, of the suborder Myctophina, only the family Synodontidae belongs to the endemic fish community. Families Myctophidae and Aulopodidae of the same suborder belong to the stranded fish community, besides Synodontidae. (3) Leptocephali of Apodes and Bothinae larvae are most numerous in species number in the stranded community. (4) The fishes of the stranded community referred to Chondorichthyes, Pleuronectina and Soleina are extremely scarce in species compared with the

Table 6. Comparison of stranded fishes with inhabitants.

(A) Suborders peculiar to inhabitant and stranded communities.

Suborders peculiar to inhabitant community	Suborders peculiar to stranded fish community
Heterodontina	Elopina
Lamnina	Gonorhnchina
Torpedinina	Opisthoproctina
Berycina	Stomiatina
Zeina	Alepisaurina
Echeneina	Cyprinina
Lophiina	Channina
Antennariina	Gadina

(B) Suborders common to both communities.

Name of suborder	Number of inhabitants	Number of stranded	Remarks
Myctophina	6 species	6 spp.*	Inhabitants belong to Synontidae alone; the stranded to Synodontidae, Myctophidae and Aulopodidae.
Auguillina	10	5	In the stranded, leptocephali of 20 species upward appeared, besides these 5 species.
Scombrina; Carangina	10; 9	3; 6	
Percina	49	22	
Trachinina	7	1	
Gobiina	17	14	
Balistina; Tetraodontina	8;14	7;12	
Cottina	30	10	
Pleuronectina; Soleina	12;10	8; 1	In the stranded, 6 species of Bothinae included; 2 other species of Bothinae in inhabitant community.

*These figures are tentatively indicated. Species number of these suborders will increase on further identification.

inhabitant one. Finally, (5) such suborders as Carangina, Percina, Gobiina, Cottina, Balistina, and Tetraodontina which are rich in species in the endemic fauna are reflected in the stranded community by species number. Summing up these points, a considerable number of allogenetic species (Elopina, Gonorhynchina, Opisthoproctina, Stomiatina, and Alepisaurina; Myctophidae and Aulopodidae; leptocephalus of Apodes, Bothinae larva, etc.) are recognized in the stranded fish community, in addition to the autogenetic, endemic fishes known in this area. The demersal fishes belonging to Chondorichthyes, Heterosomata, and Trachinia are exceedingly scarce in the community. Climatologically, one of the most prominent features of the stranded community is that almost all of the stranded fishes belong not to the arctic or subarctic group, but to the temperate, subtropical, and tropical group.[40)]

With respect to stranding of the invertebrates along the Japan Sea coast, we find sporadic records on *Physalia*,[36)] *Porpita*,[7)] *Aurelia*,[7)] *Stomolophus* (Coelenterata),[37)] *Creseis*,[7)] *Thysanoteuthis*,[23,41)] *Tremoctopus*,[41)] *Argonauta*,[24,41)] *Architeuthis* (Mollusca),[7)] *Phyllosoma* larvae (Arthropoda),[42)] and *Pegea* (Protochordata).[7)] Those, excluding *Stomolophus* and *Architeuthis*, are also members of the stranded community at the Shingu beach. The species listed in Table 4, together with *Lophogaster*, *Oxycephalus* and *Stomatopoda* larvae (Table 5), may be assigned to the massive species group of the stranded fish community even though their numbers are much higher than 1,000. As mentioned previously, *Creseis*, *Calanus* and *Megalopa* larvae might also be included in this group. *Thysanoteuthis* which is an object of stranding fisheries on those beaches and considered to beach far beyond the number shown in Table 5 may not be grouped into the massive species, because they do not occur as often as other fishes or other invertebrates found on the stretch of this beach. Therefore, it can be said that all members of cephalopods and each species of crustaceans (except *Lophogaster*, *Oxycephalus* and stomatopod larvae) are treated here as the numerous species group or the frequent species group. Other invertebrates listed in Table 2 have not been assigned to any grouping in regard to stranded specimen number. It has been left for future study.

We now turn to a comaprison of the endemic and stranded invertebrate fauna. A list of endemic fauna was not available from past studies as was the case with the fish endemic fauna. Therefore, a list was made from some encyclopedias of the Japanese

Table 7. Peculiar species to stranded community excluding fishes, compared with inhabitant community.

Phylum & species name	Phylum & species name
COELENTERATA	APTHROPODA
Physalia physalis	*Lophogaster pacificus*
MOLLUSCA	*Solenocera brevipes*
Violetta globosa	*Plesionika binoculus*
Thysanoteuthis rhombus	*Plesionika unidens*
Cranchia scabre	*Chlorotocus crassicronis*
Tremocotpus violaceus	*Nephrops thomsoni*
Argonauta argo	
Argonauta hians	

fauna[43)] and from the survey results of related Prefectural Fisheries Experimental Stations,[12)] MIYAKE et al.,[44)] NISHIMURA[41)] and TOKIOKA.[45)] As a result of the comparison between the stranded and endemic communities thus provided, there are a considerable number of species to be considered as peculiar animals to the stranded community (Table 7). Of these, the members of Coelenterata, Mollusca and most of the crustaceans are allogenetic in our waters. Additional consideration of the species of Arthropoda in Table are left for a later discussion. All of these exotic species were from temperate, subtropical, and tropical areas, and were entirely devoid of arctic and subarctic speices.[40]

In closing this chapter, it must be emphasized as a faunistic characteristic of the stranded community that it is composed of the endemic animals as well as the allogenetic southern or warm water elements, and the northern elements are, if any, very scarce in both species and specimens.

V. Seasonal and annual changes of stranded animals

Although the stranding phenomenon on these beaches along the Tsushima Current is stated to occur generally during the winter months,[6] the seasonal change and the annual change of the phenomena have not been scrutinized on the basis of successive field observation, except in the case of some limited species.[22-24] Such patterns of phenomena were not always observable in the same degree throughout these survey periods. To make clear the seasonal and annual changes of the phenomena, this chapter presents the duration and peak of the appearance of the stranded animals on the Shingu beach and their annual change along with some consideration.

1. Monthly change

In every cold season the first noticeable species as a stranded animal on the Shingu beach are always the jellyfishes (*Porpita* and *Physalia*), floating shells of *Violetta*, and cephalopods (*Thysanoteuthis, Argonauta,* etc.).[7] It should be possible to fix the stranding season of each animal by noting the months during which the animals were observed on the beach. In Fig. 5, the appearance period of fishes which accounted for more than 10 specimens in total in the two seasons of 1966 and 1967 is shown under the leading species of each duration group. The stranding periods of the fishes range from one to eight months by species, and in turn these fishes may be classified into 3 groups on their durations, tentatively under the following names: long term group, appearing for a period of 6 to 8 months; intermediate term group, 4 to 5 months; short term group, less than 3 months. Besides the species indicated in Fig. 5, the following fishes appertained to each appearance term group (the following numbers corresponds to the fish sign in Fig. 5):

Long term group: (1) *Fugu niphobles,* (2) *Fugu poecilonotus,* (3) *Ammodytes personatus, Cololabis saira, Coelorhynchus multispinulosus.*

Intermediate term group: (6) *Bregmaceros, Synagropsis japonicus,* (7) *Mugil cephalus, Maurolicus japonicus, Stephanolepis,* (8) *Leiognathus nuchalis,* (10) Myctophidae, *Trachyrhamphus serratus, Lubricogobius exiguus, Boesemanichthys firma-*

mentum.

Short term group: (12) *Hypodytes rubripinnis, Aluterus monoceros,* Bothinae larvae, *Labracoglossa argentiventris, Goniisteus zonatus,* (13) *Malakichthys wakiyai,* (14) *Canthidermis rotundatus, Lagocephalus lunaris, Gymnopogon japonicus, Upeneus benisashi,* Pomacentridae, Ephinephelinae, (15) *Cypselurus,* (16) *Sebastes, Apogon dederleini.*

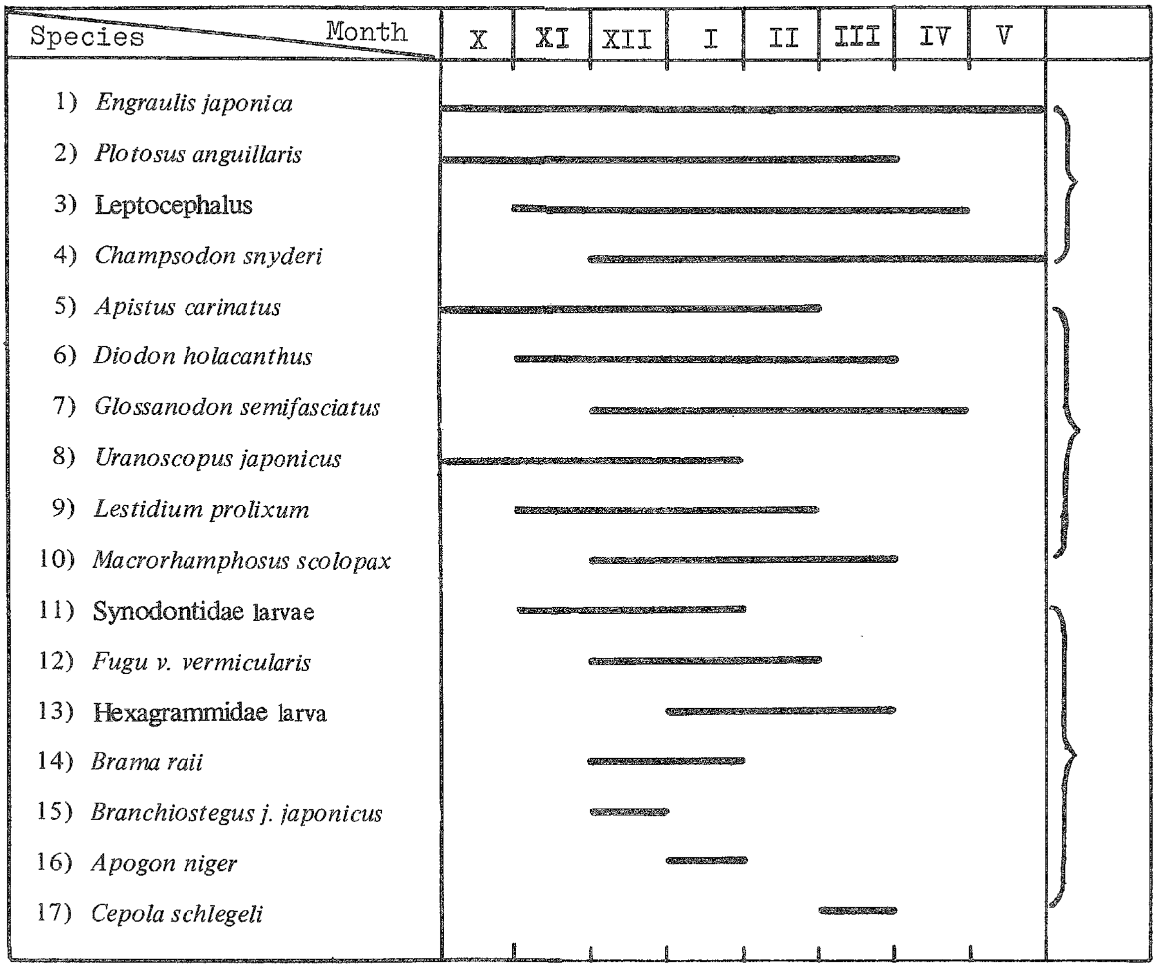

Fig. 5. Appearance period of stranded fishes. The species treated here are those of more than 10 specimens in total in the 1966 and 1967 seasons. The fishes which belong to each type of appearance are described in the text.

Consequently, if the species were listed in order of abundance, it would be seen that the short term group would hold the largest number by species. Conversely, by specimen the short term group would hold the least number and the long term group would hold the most. Thus, the species and specimen numbers are inversely related when listed in order of their abundance. These tendencies in both the species and specimens may be enforced, if the species with less than 10 specimens during the two seasons are taken into consideration, because of the resultant increment in species of the short term group, but not so in specimens. Therefore, most species are stranded in the relatively short period from one to three months, but almost all of the massive appearance species mentioned in the previous chapter belong to the long and intermediate term groups.

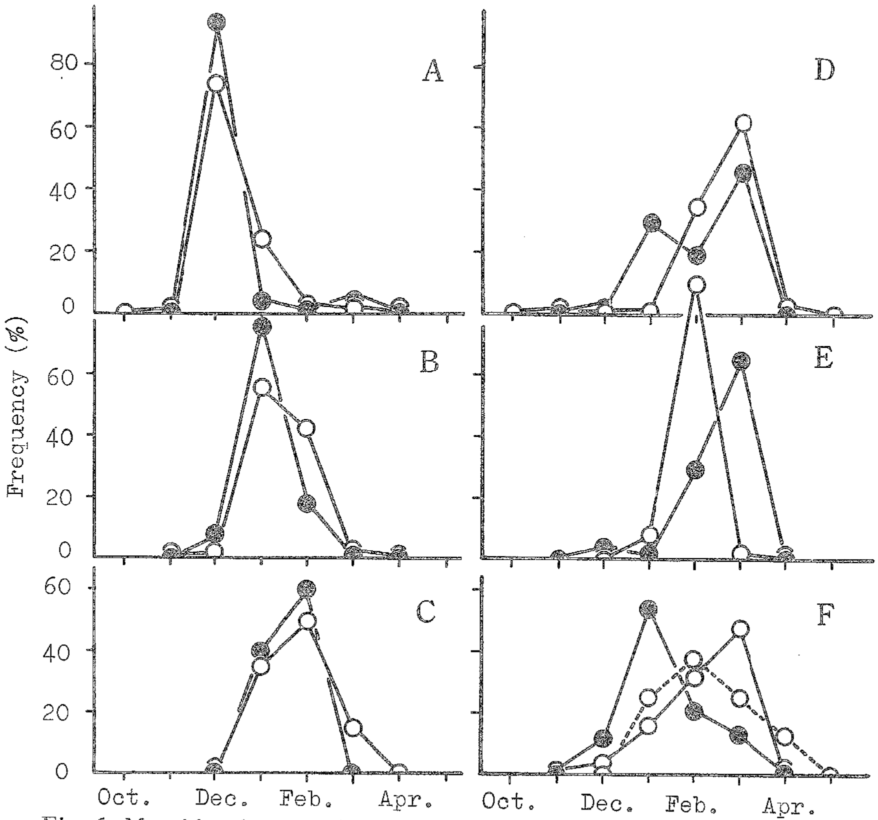

Fig. 6. Monthly changes of specimen number of stranded fishes. White circle, 1966 season; black circle, 1967 season; white circle and dotted line in F, 1965 season.
A) *Cololabis saira* (1966, 1965 specimens; 1967, 558 specimens).
B) *Macrorhamphosus scolopax* (1966, 293; 1967, 511).
C) *Lubricogobius exiguus* (1966, 20; 1967, 127).
D) *Ammodytes personatus* (1966, 250; 1967, 275).
E) *Maurolicus japonicus* (1966, 23; 1967, 278).
F) *Coelorhynchus multipinulosus* (1965, 24; 1966, 25; 1967, 24).

The maximum appearance month may be regarded as the peak of stranding in each fish. These months are noticed to be December, January, February, March, January to March and February to March by species, without extensive variation in years in most species, as depicted in Fig. 6. Such patterns of appearance are seemingly divided into three types: the first is the group having their stranding peaks in or before December, the second in January and the third in February to March. The typical species in each group are as follows: *Cololabis, Engraulis, Lestidium, Uranoscopus, Brama, Fugu, Goniisteus, Labracoglossa,* Pomacentridae, Ephinephelinae, etc. which belong the first group; leptocephli, *Macrorhamphosus, Bregmaceros, Plotosus, Synagrops,* Synodontidae, *Stephanolepis*, Hexagrammidae, *Diodon*, *Boesemanichthys*, Bothinae larvae, Myctophidae, *Sebastes* larva, etc., to the second group; *Maurolicus*, *Ammodytes*, *Lubricogobius*, *Glossanodon*, *Mugil*, *Coelorhynchus*, *Champsodon*, *Cepola*, *Triacanthods*, etc., to the third group. The massive appearance species belong to the second group (leptocephali, *Macrorhamphosus*, *Bregmaceros*, *Plotosus*, *Sebastes*, *Boesemanichthys*) and the first group (*Cololabis* and *Engraulis*), whereas the third group is only composed of the numerous and frequent appearance species. Thus, the species and specimen numbers of each group show the highest in the second group and the lowest in the third group. These tendencies of appearance are reflected in the total occurrence of species and specimens of fishes, as seen in Fig. 7. Therefore, the fishes are stranded in a period from October to May and the peak of stranding is witnessed to be in December or January in both species and specimens, varing of course to a certain extent by years.

In regard to body length composition, most fishes have the same length compositions in every month (Fig. 8–A), while the monthly change is clearly seen in *Ammodytes* (Fig. 8–B). Several species such as *Macrorhamphosus*, *Plotosus*, *Synagrops*, *Champsodon*, etc. belong to the latter group in length composition, though their monthly changes were within a very limited range.

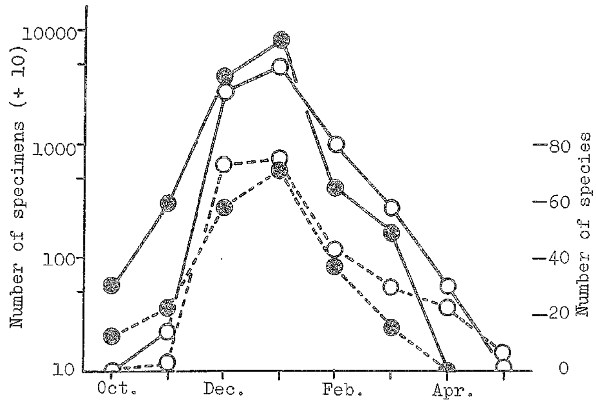

Fig. 7. Monthly changes of species and specimen numbers of stranded fishes in the 1966 and 1967 seasons. White circle, 1966; black circle, 1967; solid line, specimens; dotted line, species.

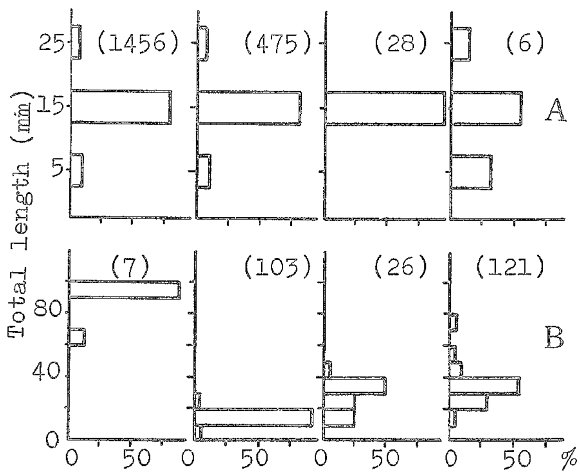

Fig. 8. Monthly changes of total length composition. Figures in parentheses indicate the number of specimens measured.
A) *Cololabis saira* in 1965 - 1966.
B) *Ammodytes personatus* in 1966-1967.

As for the period and peak of appearance of crustaceans the author examined only 13 species belonging to Mysidacea, Amphipoda, Euphausiacea, Macrura and Stomatopoda, and did not pay any attention to the minor species such as those of Brachyura, Cumacea and Anomura in this paper. The appearance period of these species is a comparatively long period, usually over 4 months, as shown in Fig. 9. From the viewpoint of the maximum appearance month which is easily seen from Fig. 9 these species are divided into the following three types just like in the case of fishes: the first group, having the peak in December (Stomatopoda larvae, *Icotopus, Phronima,* etc.); the second group, peaking in January (*Lophogaster, Oxycephalus, Chlorotocus,* Mysidacea, *Plesionika,* etc.); the third group, peaking in February to March (*Metapenaeopsis, Leptochela, Solenocera, Processa,* etc.). In this connection, it is very interesting to note that the massive species

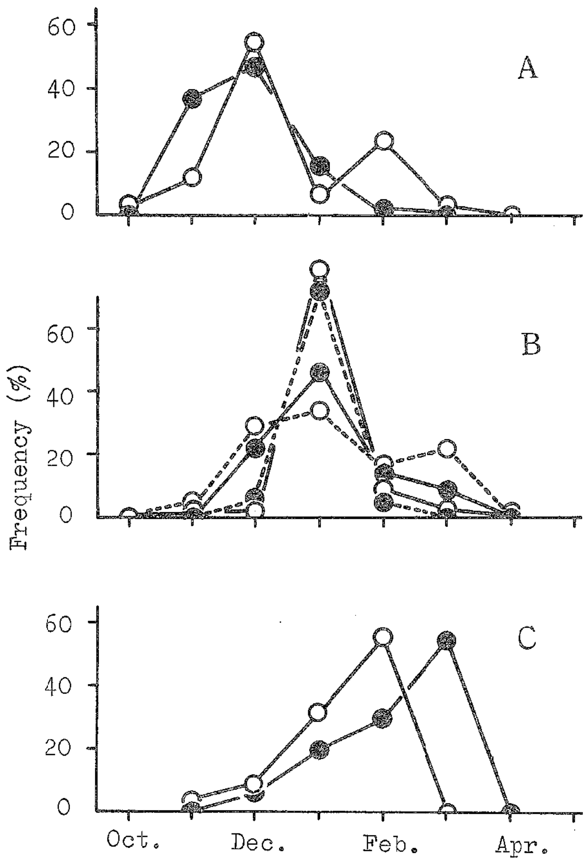

Fig. 9. Monthly changes of specimen number of stranded crustaceans in the 1967 season. A) White circle, *Icotopus* (90 specimens); black circle, Stomatopoda larvae (about 7,000 specimens). B) White circle and solid line, *Oxycephalus* (12,000); white circle and dotted line, *Lophogaster* (30,000); black circle and dolid line, Euphausiacea (900); black circle and dotted line, *Chlorotocus* (90). C) White circle, *Leptochela* (1,100); black circle, *Metapenaeopsis* (150).

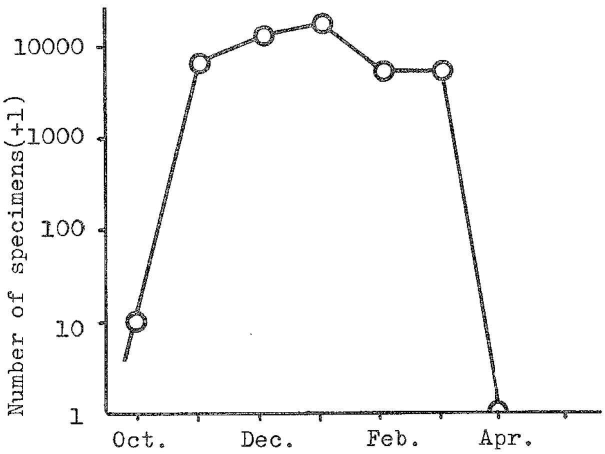

Fig. 10. Monthly change of specimen number of crustaceans in the 1967 season.

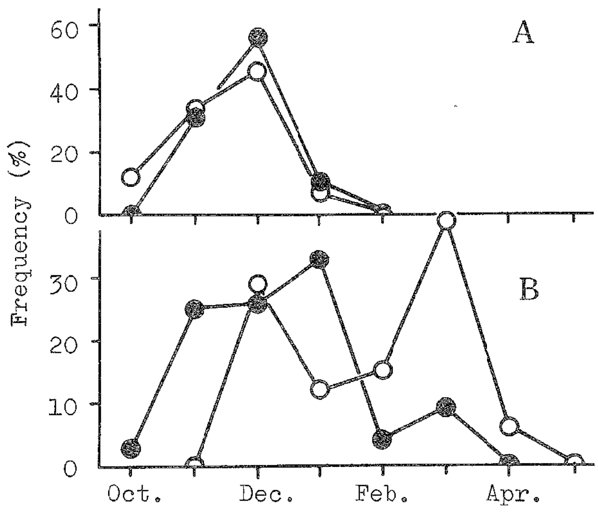

Fig. 11. Monthly changes of specimen number of stranded cephalopods. A) White circle, *Thysanoteuthis rhombus* collected by Mr. Takahashi at Tsuyazaki, near the Shingu beach, in 1965 (41 specimens); black circle, *Argonauta argo* (51 specimens in 1967 season). B) Loligonidae larvae: white circle, 1966 season (156 specimens); black circle, 1967 (72).

defined in the preceding chapter belong to the second group (*Lophogaster* and *Oxycephalus*) and the first group (Stomatopoda larvae). In conclusion these crustaceans make their appearance from October to March, and stranding peaks in or around January

(Fig. 10). The body length composition of these crustaceans did not indicate monthly changes as in the case of most fishes.

Species of cephalopods are classified into two groups in regard to period and peak

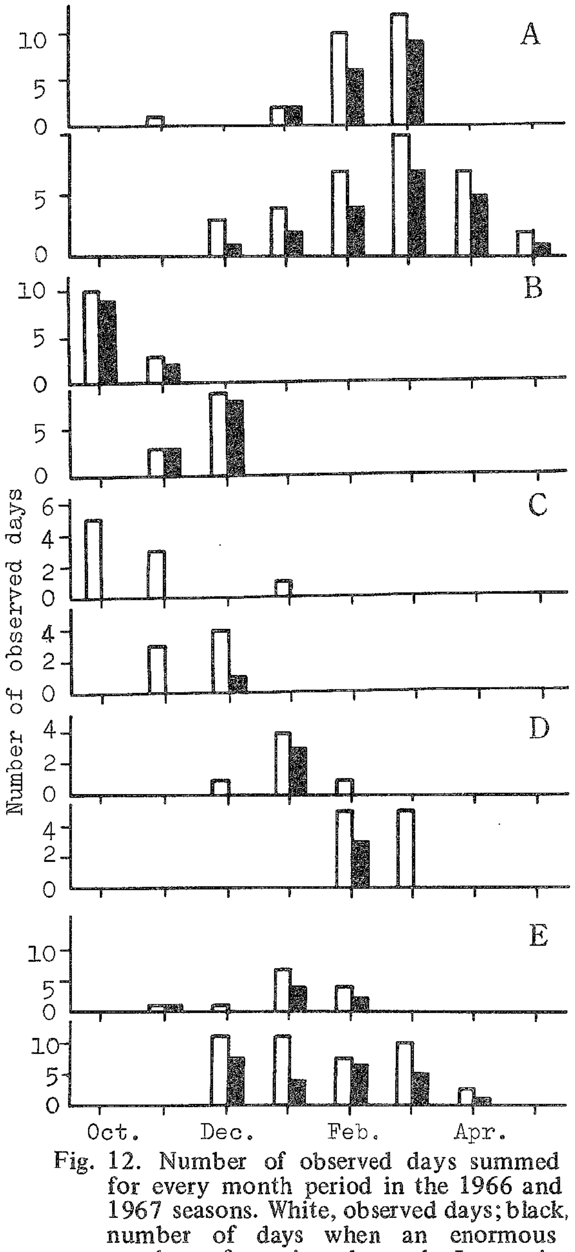

Fig. 12. Number of observed days summed for every month period in the 1966 and 1967 seasons. White, observed days; black, number of days when an enormous number of species observed. Lower in each set, 1966 season; upper, 1967.
A) *Spirocodon* & *Aurelia*.
B) *Porpita porpita*.
C) *Physalia physalis*.
D) *Sagitta*.
E) *Iasis* & *Pegea*.

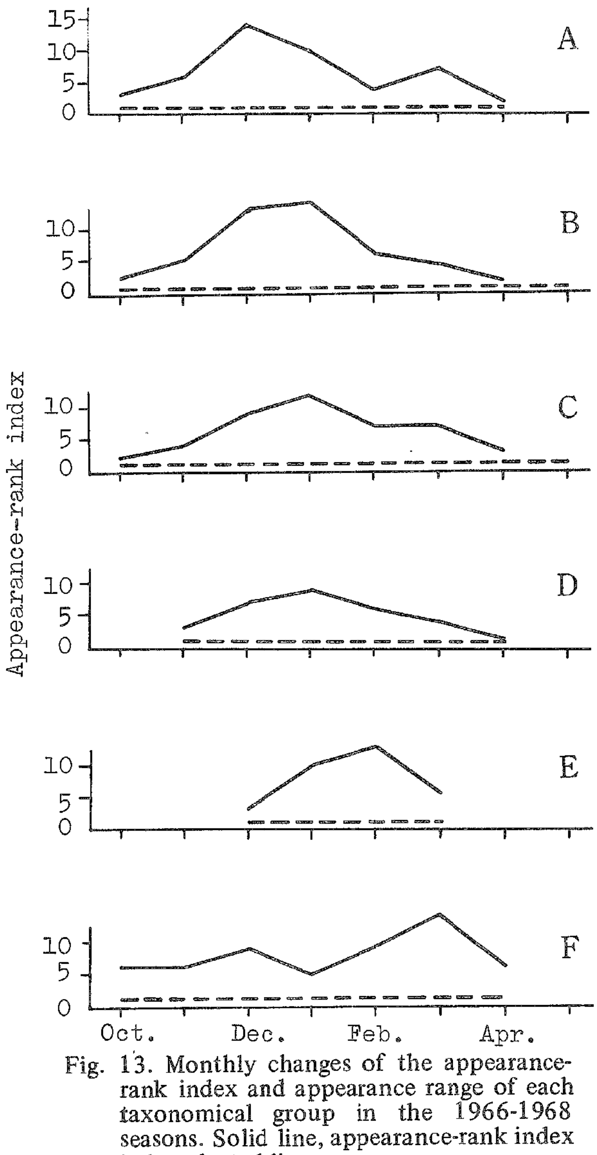

Fig. 13. Monthly changes of the appearance-rank index and appearance range of each taxonomical group in the 1966-1968 seasons. Solid line, appearance-rank index index; dotted line, appearance range.
A) Cephalopoda. B) Pisces. C) Crustacea. D) Protochordata. E) Chaetognatha. F) Coelenterata.

of appearance. One group contains the species occuring in a shorter period from October to January with the peak in December, and the other group has a longer occurrence period and more or less two distinct peaks, December–January and March (Fig. 11). *Thysanoteuthis, Argonauta, Tremoctopus,* etc. belong to the former which correspond to the first group in fishes and crustaceans. The larvae of Loligonidae belong to the latter which correspond to the first and third groups of the 1966 season or the second and third groups of the 1967 season. *Violetta* (Mollusca) falls into the latter group in both the 1966 and 1967 seasons.

Fig. 12 shows the total number of days when the species were observed during the winters of 1966 and 1967 with the number of days when an enormous numbers of the species was observed. *Spirocodon* & *Aurelia* are distinguished from other members of Coelenterata in having a long appearance period with the peak in March. The other two members of Coelenterata, *Porpita* and *Physalia,* appeared in a short period from October to January with the maximum appearance month being December (Fig. 12, A–C). *Sagitta* (Chaetognatha) appeared from December to March, and *Iasis* & *Pegea* (Protochordata), from November to April, but their appearances varied profoundly by years, and it is impossible to establish their peaks only from the observation of the 1966 and 1967 seasons. Furthermore, *Clypeaster,* a massive species of Echinodermata, was observed from November to January with its peak in December in both seasons.

Finally, the peaks of appearances of the major taxonomical groups mentioned above are obtained by using the monthly change of the appearance-rank index in the 1966–1968 seasons in the following procedure: in each group, the author gives the appearance-rank index 5 to the first rank, 4 to the second rank, ... and 1 to the fifth rank in order of the monthly abundance in the 1966–1968 seasons, respectively, and regarded the month of maximum appearance-rank index which was gained at the result of monthly summing of these indexes from 1966 to 1968 as the appearance peak of each group. In conclusion, as indicated in Fig. 13, the appearance periods of these groups are distinguished into 3 groups: fishes, crustaceans, cephalopods and Coelenterata belong to the long term group appearing from October to April or May; Chaetognatha and Echinodermata to the short term group appearing mainly from November to March; Protochordata to the intermediate term group appearing from November to April. The appearance peaks are in December–January (cephalopods, fishes, crustaceans and Protochordata), February (Chaetognatha) and March (Coelenterata), with most in January.

2. Annual change

TABETA and TSUKAHARA already indicated that the stranded fish groups had varied little between the 1965 and 1966 seasons, and speculated that the fishes belonging to the same community appeared during every cold season on this beach.[7] These tendencies have been enforced on further observation.

In order to compare the stranded fish community in the 1966 season with one in the 1967 season from the viewpoint of species-specimen composition, the specimen rank curve for the average number of these two seasons is drawn in Fig. 14. The curves obtained from each community may be superimposed together as the average curve in Fig. 14, if the species composition of these two communities are similar.[7] Except for leptocephali of Apodes (Rank No. 1), *Sebastes* (4), *Maurolicus* (10), *Boesemanichthys* (17) and *Glossanodon* (21), the variation in points around the curve is rather small, and the difference of numbers of specimens in each year may be in a certain limited range for ranked species. Thus, a violent variation between two stranded fish communities

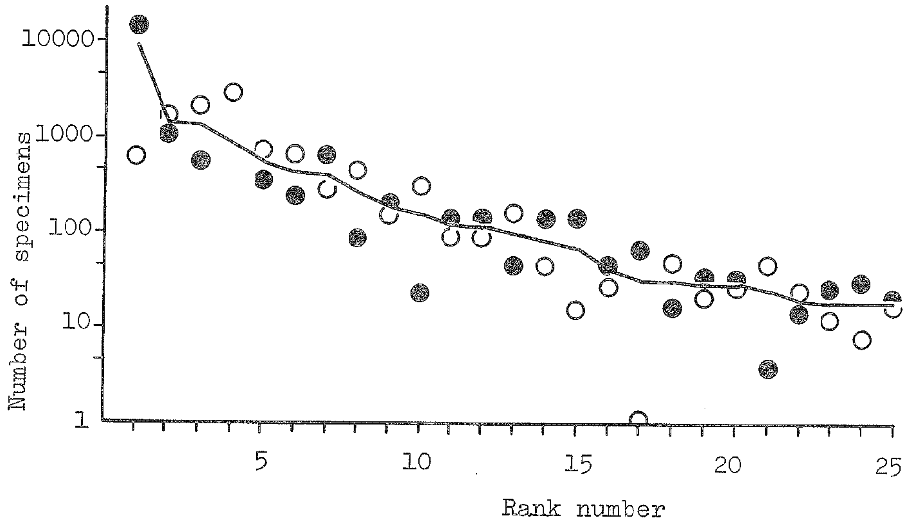

Fig. 14. Specimen rank curve for average number of stranded fishes in the two seasons. White circle, 1966 season; black circle, 1967.

1) Leptocephali
2) *Bregmaceros*
3) *Cololabis saira*
4) *Sebastes*
5) *Engraulis japonica*
6) *Plotosus anguillaris*
7) *Macrorhamphosus scolopax*
8) *Diodon Holacanthus*
9) *Ammodvtes personatus*
10) *Maurolicus japonicus*
11) *Syngropsis japonicus*
12) Synodontidae
13) *Stephanolepis*
14) Pomacentridae
15) *Lubricogobius exiguus*
16) Epinephelinae
17) *Boesemanichthys firmamentum*
18) *Mugil cephalus*
19) *Fugu niphobles*
20) *Coelorhynchus multispinulosus*
21) *Glossanodon semifasciatus*
22) Hexagrammidae
23) *Champsodon snyderi*
24) *Lestidium prolixum*
25) Bothinae larvae

is not recognized except for some species mentioned above; this may be supported by the fact that the common species occupies about 50% in all 87 species excluded from the Figure. Despite such agreement of stranded fish communities between the 1965 and 1966, and the 1966 and 1967 seasons, annual stranded amounts indicated by the catch-index, which is defined as the catch per effort (an observation in the early morning) in the maximum appearance month varied considerably, showing high values in the 1965 and 1968 seasons, and lower ones in the 1966 and 1967 seasons (Fig. 15). However, the catch-indexes are rather constant in the range of 37 to 71, unless the massive species are taken into consideration. The representative types of annual changes of each fish observed in three seasons from 1966 to 1968 are shown in Fig. 16. As readily seen in this Figure, leptocephali and *Bregmaceros* were observed more or less constantly, but *Boesemanichthys* appeared intermitently in the seasons. Thus, the former might be regarded as a regular constituents and the latter, as an irregular constituent of the stranded fish community. The irregular constituent in these seasons were as follows: *Boesemanichthys, Sebastes* larva, *Coelorhynchus, Glossanodon, Brama, Caranx, Labracoglossa,* Labridae larvae, *Malakichthys, Hime,* etc., and these numbered 18 species out of 50 species of more than 10 specimens in total in these 3 seasons. Both numbers of species and specimens of regular constituents greatly exceeded those

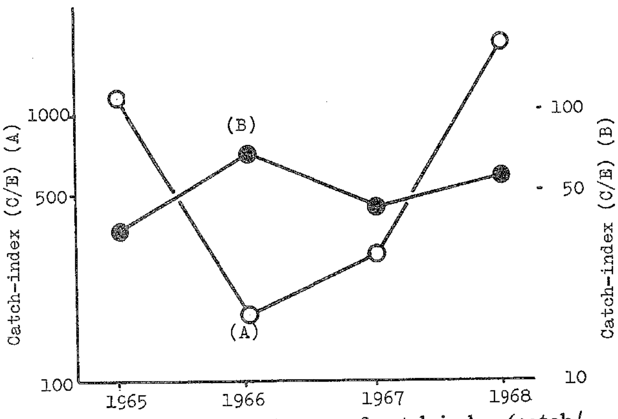

Fig. 15. Annual change of catch-index (catch/effort in January) of stranded fishes. White circle (A), included all species; black circle (B), excluded massive appearance species.

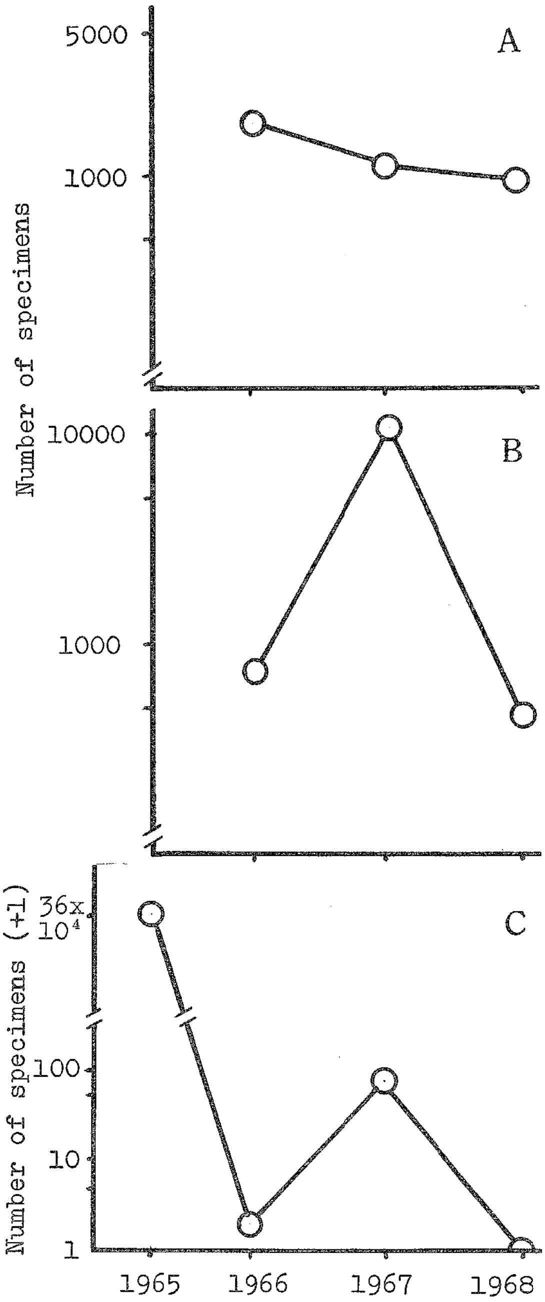

Fig. 16. Annual changes of specimen number of stranded fishes in the 1966-1968 seasons.
A) *Bregmaceros.*
B) Leptocephali.
C) *Boesemanichthys firmamentum.*

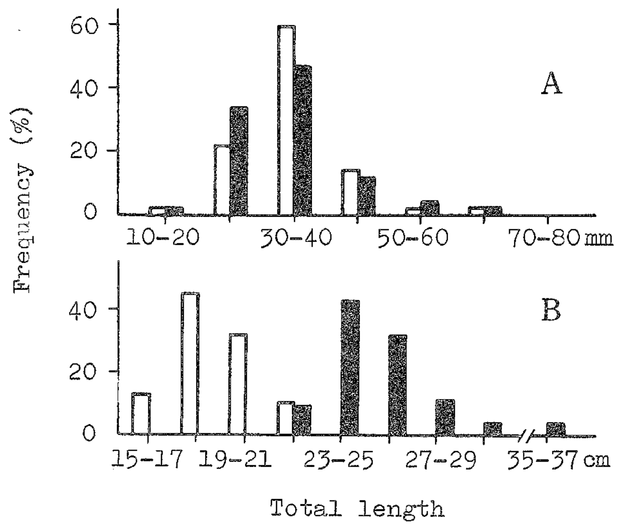

Fig. 17. Annual changes of total length composition of stranded fishes. A) *Bregmaceros*: white, 1966 season (1,612 specimens); black, 1967 (1,012). B) *Boesemanichthys firmamentum*: white, 1965 (117) specimens; black, 1967 (35).

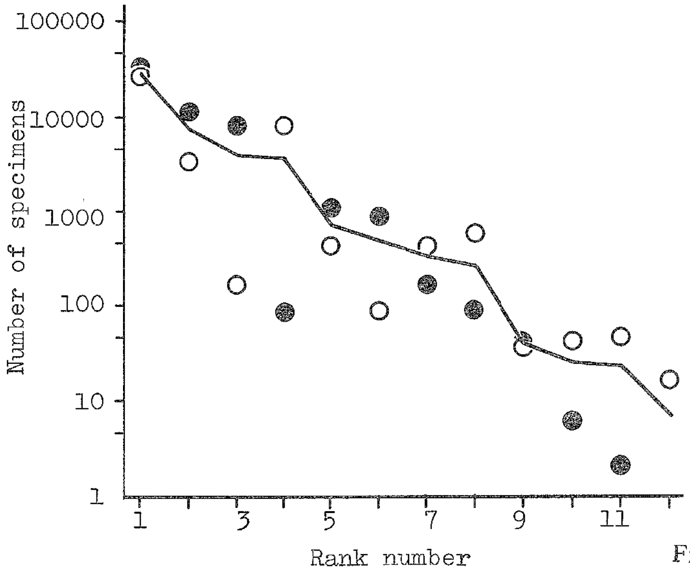

Fig. 18. Specimen rank curve for average number of stranded crustaceans. White circle, 1966 season; black circle, 1967.
1) *Lophogaster pacificus*
2) *Oxycephalus porcellus*
3) Stomatopoda larvae
4) *Chlorotocus crassicornis*
5) *Leptochela*
6) Euphausiacea
7) *Metapenaeopsis*
8) *Icotopus*
9) Mysidacea
10) *Plesionika*
11) *Solenocera brevipes*
12) *Phronima sedentaria*

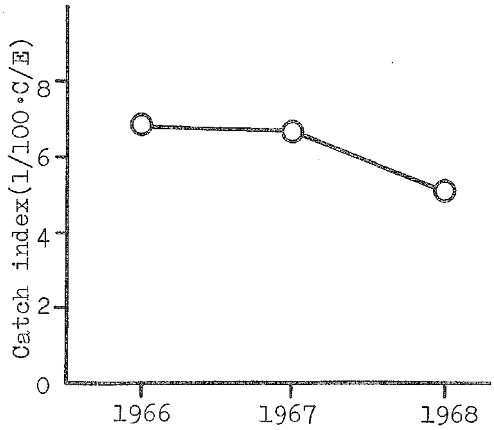

Fig. 19. Annual change of catch-index (catch/effort in January) of stranded crustaceans.

Table 8. Number of specimens of each species belonging to cephalopods in the 1966 and 1967 seasons.

Species name	1966	1967
Loligonidae	156	72
Argonauta argo	11	51
Thysanoteuthis rhombus	4	16
Tremoctopus violaceus	9	10

Table 9. Number of observed days (A) and days when enormous numbers of the species were observed (B) and occurrence index (C) for each species belonging to Coelenterata, Chaetognatha, Mollusca, Echinodermata and Protochordata in the 1966 and 1967 seasons. The occurrence index (C) is defined as $\sqrt{AB^2}$.

Species name	1966		1967	
	A (B)	C	A (B)	C
Physalia physalis	7 (1)	3.6	9 (0)*	3.0
Porpita porpita	12 (11)	38.1	13 (11)	39.7
Spirocodon & Aurelia	33 (20)	115.0	25 (17)	85.0
Sagitta	10 (3)	9.5	5 (3)	6.7
Violetta globosa	9 (8)	24.0	8 (3)	8.5
Clypeaster japonicus	5 (2)	4.5	3 (3)	5.2
Iasis & Pegea	32 (20)	113.1	13 (7)	25.2

*Number of days when an enormous number of *Physalia* observed in the 1967 season is treated as 1 in this calculation.

of irregular constituents, as was expected also from Fig. 15.

Annually, it is a prominent feature that *Boesemanichthys* indicated a year to year change in body length composition, and the massive appearance population in 1965 (Plate I–B) was biased to the smaller length composition, and the intermitent appearance population in 1966 and 1967 to the larger one (Fig. 17–B). But most species do not show any year to year change in length composition (Fig. 17–A).

The specimen rank curve for the average number of crustaceans observed in the 1966 and 1967 seasons is shown in Fig. 18 for the purpose of comparing these two communities. In the crustacean community, though the specimen number of several species such as *Phronima*, Stomatopoda larvae, *Chlorotocus*, and *Solenocera* varied considerably in the two seasons, broadly speaking the species-specimen relations in two seasons, were rather similar. The species indicated in Fig. 18 are regarded as the regular constituents of the stranded community excepting for *Phronima*. The annual catch-index of these crustaceans maintains itself at a constant level (Fig. 19). Thus, the crustaceans may be regarded to be cosistent in their appearance in every season. The same tendency is true in the stranded cephalopod community observed in the 1966 and 1967 seasons (Table 8). *Argonauta hians*, which is considered as an irregular species in the community, is not listed in the Table. The species of Coelenterata, Chaetognatha, Mollusca, Echinodermata and Protochordata observed in the 1966 and 1967 seasons are considered in Table 9 noting the number of days observed and massive appearance days with the occurrence-index of the respective years. The occurrence-index is defined as $\sqrt{AB^2}$, where A is the number of observed days, and B, the number of massive appearance days. The Table shows that the species appeared in the same range during these two seasons but much more in the 1966 season than in the 1967 season, and this similarity in appearance continued throughout the 4 seasons.

Consideration

In our coastal region along the Tsushima Current, besides these winter strandings mentioned above, some cases of summer strandings have been reported so far from western Hokkaido or Yamaguchi Prefecture.[45] On the beaches of northern Kyushu *Tremoctopus* and *Thysanoteuthis* drifted ashore more or less abundantly from August to September, 1967, as was already reported.[47] These summer strandings may be considered to be another aspect of the phenomenon treated in this paper, and provide important information to elucidate the phenomenon. It will be discussed in Chapter VII.

The two peaks of cephalopods and Coelenterata (Fig. 13) reflect the different types of appearance groups involved in these communities (Figs. 11 and 12). In cephalopods the major peak in December is caused by *Thysanoteuthis, Argonauta, Tremoctopus* and Loligonidae A, and, on the other hand, the minor one in March by Loligonidae B. The major peak of Coelenterata in March is caused by *Spirocodon* & *Aurelia* and the minor one in December by *Porpita* and *Physalia*. In regard to the appearance peaks, the representative species of fishes, crustaceans, cephalopods and jellyfishes are tabulated in Table 10. Both autogenetic and allogenetic species are included in each appearance group, but peculiar animals to the stranding community of crustaceans, cephalopods and jellyfishes (Table 7) appear in the first and second groups, except *Solenocera* which appears in the third group. Quantitatively, the massive species did not occur at the peak of February–March (the third group), as mentioned previously.

Table 10. Species of fishes, crustaceans, cephalopods and jellyfishes by each maximum appearance-period.

	1st group*	2nd group**	3rd group***
FISHES	*Cololabis saira* *Engraulis japonica* *Lestidium prolixum* Pomacentridae *Labracoglossa argentiventris* *Fugu niphobles* *Fugu poecilonotus* *Brama raii* *Canthidermis rotundatus*	Leptocephali *Macrorhamphosus scolopax* *Bregmaceros* *Plotosus anguillaris* *Synagrops japonicus* Synodontidae *Diodon holacanthus* Bothinae *Aluterus monoceros* *Stephanolepis*	*Lubricogobius exiguus* *Glossanodon semifasciatus* *Trachyrhamphus serratus* *Maurolicus japonicus* *Ammodytes personatus* *Mugil cephalus* *Champsodon snyderi* *Triacanthodes anomalus* *Anguilla japonica*
CRUSTACEANS	Stomatopoda larvae *Phronima sedentaria*	*Lophogaster pacificus* *Oxycephalus porcellus* *Chlorotocus crassicornis* *Plesionika binoculus* Mysidacea	*Metapenaeopsis* *Leptochela* *Solenocera brevipes* *Processa*
CEPHALOPODS	*Tremoctopus violaceus* *Thysanoteuthis rhombus* *Argonauta argo* Loligonidae A		Loligonidae B
JELLYFISHES	*Physalia physalis* *Porpita porpita*		*Spirocodon saltatlix* *Aurelia aurita*

*animals appearing at the peak of December.
**animals appearing at the peak of January.
***animals appearing at the peak of February-March.

The annual changes in fish strandings are principally influenced by the appearance of the massive species (Fig. 15). In 1965 such species as *Boesemanichthys* (36,000 specimens or more) and in 1968 *Macrorhamphosus* (16,000) and *Cololabis* (15,000) shifted the annual amount from an average to a high level. On the other hand, *Sebastes* (2,500) in 1966 and leptocephali (12,000) in 1967 did not greatly effect the yearly amounts. In crustaceans, the leading massive species, *Lophogaster* and *Oxycephalus*, were observed to be rather consistent throughout the 3 seasons, so that the catch-index would still maintain a comparable level in spite of the inclusion or exclusion of these two species, as shown in Fig. 19. Cephalopods and other species tabulated in Tables 8 and 9 appeared much more regularly throughout the 4 seasons and this indicated the high consistency as members of the stranding community. But the annual changes in the amount stranded are another problem and are left to a later discussion in relation to the environmental conditions.

On further analysis of the annual change the regular constituents may be divided into two subgroups. The first is the stable appearance group such as *Engraulis, Bregmaceros,* Synodontidae, *Lestidium,* Myctophidae, *Stephanolepis, Uranoscopus, Fugu poecilonotus,* Pomacentridae, Epinephelinae, etc. which in the maximum year totals less than 10 times the amount in the minimum year (Fig. 16–A). The second is the unstable appearance group such as leptocephali, *Macrorhamphosus, Cololabis, Diodon, Maurolicus, Plotosus, Mugil, Champsodon, Canthidermis,* Bothinae, etc., which in the maximum year totals more than 10 times the amount in the minimum year during the 3 seasons from 1966 to 1968 (Fig. 16–B). The subgroupings are applicable to the regular constituents of crustacean and cephalopod communities. *Lophogaster, Oxycephalus, Leptochela,* Euphausiacea, *Metapenaeposis, Icotopus* and Mysidacea among crustaceans, and each species of cephalopod in Table 8, may be classed in the stable appearance group. Stomatopoda larvae, *Chlorotocus, Plesionika* and *Solenocera* of the crustaceans may be classed in the unstable appearance group. Hence, most of the allogenetic fishes are irregular constituents (*Boesemanichthys, Coelorhynchus, Glossanodon, Brama,* etc.) or unstable species among the regular constituents (leptocephali, *Diodon, Maurolicus,* Bothinae, *Canthidermis,* etc.) but some allogenetic species such as *Lestidium, Synagrops,* Myctophidae, etc. belong to the stable species group of the regular constituents. On the other hand, the allogenetic species of crustaceans and cephalopods can be stated for the time being to be seen in both the regular and irregular constituents.

As for the annual change of body length composition of *Boesemanichthys,* taking also into consideration the fact that the fish, caught sporadically with a set net in Sado Island, Niigata Prefecture, almost every year and caught in Tsuyazaki in January, 1957, belong to a larger length-composition, the massive appearance population alone is supposed to bias to smaller body length, compared with the intermitent appearance population; this supposition is supported by the statements of fishermen who observed the massive strandings of this smaller fish at Karatsu City, Saga Prefecture, in 1955.

In conclusion it may be said that the stranding animals appeared on the Shingu beach mainly in the period from October to May with the peak in January, but in some taxonomical groups these periods and peaks of their appearance varied prominently by species or by years. Although the species-specimen relation in each taxonomical group did not show a drastic year to year change, the annual amount of stranded fishes varied rather noticeably, being affected by the appearance of massive species. Most animals, both fishes and crustaceans, have the same body length composition in every month or year studied except for some species. These phenomena will be considered in a later chapter in relation to the environmental conditions.

VI. Biological characteristics of stranded animals

In this chapter the author considers the developmental stage, the body form, distributional aspect, and ecological aspect of the individual species in regard to their strandings. The data used here for the vertebrates is those obtained in the 1965–1968 seasons, and for the invertebrates, in the 1966 and 1967 seasons.

1. Developmental stage

In each taxonomical group a range in development from larva to adult was found to be present in the collection of stranded marine life.[7] Because of the subjective nature of separating developmental stages into distinct steps, it was necessary for the author to use the following 3 general stages in each species: larva stage (larva and juvenile), young stage (young and immature), and adult stage (adult and old fish).

Using the classification mentioned above, the vertebrate population has been assigned to various categories according to the range in development shown by the species. The author has divided stranded species into 5 categories in the following manner:

A) Larva type (Fig. 20–A): The fishes which appeared in larva and / or juvenile stages belong to this category. These are *Cololabis*, leptocephali, *Labracoglossa*, *Uranosco-*

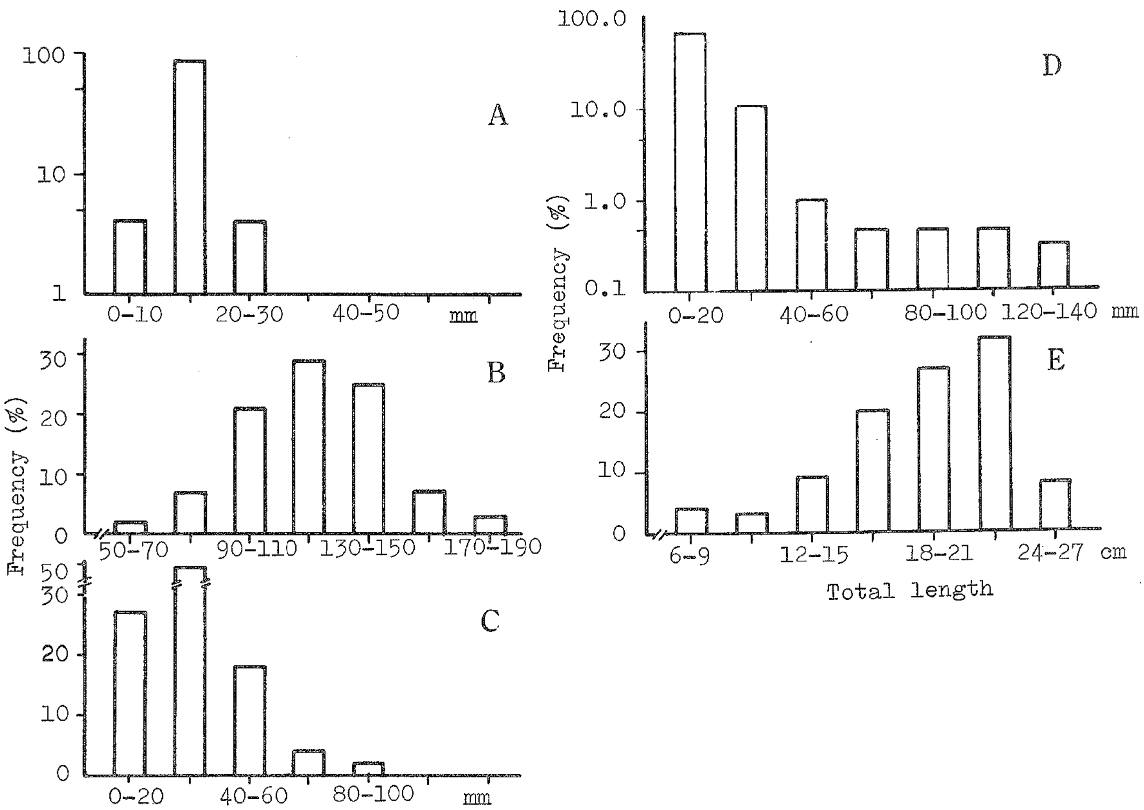

Fig. 20. Body length composition of stranded fishes especially showing the developmental stages, which were collected in the 1966 and 1967 seasons.
A) *Cololabis saira*, 793 specimens measured (larva stage).
B) *Diodon holacanthus*, 296 (young stage).
C) *Ammodytes personatus*, 424 (larva - adult stage).
D) *Macrorhamphosus scolopax*, 804 (larva - young stage).
E) *Fugu poecilonotus*, 120 (young-adult stage).

pus, Cypselurus, Caranx, Pomacentridae, Epinephelinae, etc., and amounted to 27 species (accounting for 21% of the total species) and about 42,000 specimens (40% of the total speicmens).

B) Larva-young type (Fig. 20–D): *Macrorhamphosus, Synagropsis, Maurolicus, Champsodon,* Myctophidae, *Upeneus,* Hexagrammidae, etc. were stranded in larva-young stages alone. These fishes amounted to 11 species (9%) and 18,000 specimens (17% in total).

C) Larva-adult type (Fig. 20–C): The fishes of this type appeared in each stage from larva to adult. 7,500 specimens (7%) of 5 species (4%) such as *Engraulis, Bregmaceros, Ammodytes, Mugil* and *Lagocephalus* were recognized.

D) Young type (Fig. 20–B): The fishes appearing in young and / or immature stages are assorted to this type, such as *Boesemanichthys, Diodon, Plotosus, Stephanolepis, Glossanodon, Leiognathus, Canthidermis, Brama,* etc., totaling 32 species (25%) and 38,000 specimens (36%). The category ranks the second abundance in species and specimen numbers.

E) Young-adult type (Fig. 20–E): 53 species of *Fugu* spp., *Aluterus, Lubricogobius, Coelorhynchus, Liognathus, Trachyrhamphus,* etc. belong to this type which is the most dominant in species number, and accounted for 41% of the total species, while the specimens are enumerated at most 600 (less than 1%). This is the lowest number among the types. Most species belonging to this type are the aforementioned "stray fish", so the increment of specimens may not be expected on further examination.

The species-specimen relation of each developmental stage which is based on the author's classification is shown in Fig. 21. Thus, the specimen number of larva and young indicates a high level and, on the other hand, the number of adults is very scarce in spite of many more species.

The categories of developmental stage in fishes are fairly applied to other animals. Twelve species of crustaceans indicated in Table 5 are:

A) Larva type: Stomatopoda larvae and *Icotopus* (8,400 specimens) account for 10% of the total specimen. This type is the second largest in specimen number. Besides these species, *Megalopa* larvae of Brachyura are included in this type.

B) Larva-adult type: *Lophogaster* and *Oxycephalus* total 70,000 specimens or more. The larva-adult type is the most numerous in specimen number and accounts for 85% of the total specimens. *Calanus* may also be assigned to this type as well.

C) Young type: *Chlorotocus* totals about 800 specimens.

D) Young-adult type: *Metapenaeopsis, Leptochela,* Euphausiacea, Mysidacea, *Plesionika, Solenocera* and *Phronima* total 3,200 specimens. The individuals belonging to this type are the most numerous.

Furthermore, 30 or more species of Brachyura, Anomura, Cumacea, Stomatopoda, etc., were stranded in the young and / or adult stages; hence, these species may be assigned to the above young-adult type. If the species mentioned above are taken into consideration, the young-adult type of crustaceans increases many more in species.

The stranded cephalopod community is composed of species belonging to the larva type and the young-adult type. Loligonidae larvae belong to the former type, and *Argonauta argo, Tremoctopus, Thysanoteuthis,* etc. to the latter type; other cephalopods such as *Argonauta hians, Sepia, Octopus,* and so forth as well as pelagic gastropods (*Violetta* and *Creseis*) may also be assigned to the latter. Each species referable to Coelenterata, Chaetognatha, Echinodermata and Protochordata (Tables 4 & 9) were seen to be stranded on the beach in the young and / or adult types (Fig. 4).

2. Body form

Body form is important in relation to the ease of stranding and is directly related to swimming ability and / or mobility. From these standpoints the main body form of the fishes are described below, tentatively separating the larva from the young and adult fishes.

A) **Larval fishes**

a) Leptocephalus type (Plate I, A): Except for 2 specimens of clupeid leptocephali all of these larvae belong to Apodes; 14,000 specimens were represented by this type of body form and included 20 or more species, ranking the second to the *Cololabis-Macrorhamphosus-Labracoglossa* type in specimen number.

b) Shirasu type: The post larvae which belong to or resemble closely the clupeid or sardine larvae are grouped into this type in which 12 species and 3,700 specimens are included.

c) Heterosomata larva type (Plate I, C): Heterosomata larva, before completion of metamorphosis, were represented by 8 or more species and totaled upwards of 500 specimens.

d) Myctophidae larva type: Myctophidae and *Maurolicus* larvae numbered about 400 specimens including 6 or more species.

e) *Cololabis-Macrorhamphosus-Labracoglossa* type: The larvae having body forms between the elongate *Cololabis* through *Macrorhamphosus* form and the laterally compressed *Labracoglossa* form are included in this type. These numbered 10 species and 43,000 specimens, this being the highest number of specimens.

B) **Young and adult fishes**

In general, the body shapes of fishes are divided into several types as follows[48,49]: torpedo form (scombroid, dogfish, etc.), arrow form (belone, pike, etc.), compressed form (filefishes, pleuronectiids, etc.), anguilliform (eel, needlefish, etc.) ribbon form (ribbonfish, oarfish, etc.), sphere form (puffers, etc.), depressed form (various skates, etc.) and the intermediates between them. According to this division, most of the stranded young and adult fishes belong to the sphere form (*Boesemanichthys, Diodon, Fugu,* etc., about 15 species and 37,000 specimens), compressed form (*Stephanolepis, Rudarius, Canthidermis, Aluterus, Apogon,* etc.; 32 species and 750 specimens), anguilliform (*Anguilla,* etc.; less than 100 specimens of 5 species), intermediate form between torpedo-arrow forms (*Engraulis, Bregmaceros, Mugil,* etc.; 5 species and 4,500 specimens) and one between arrow-anguilliform (*Plotosus, Glossanodon, Coelorhynchus,* etc.; 5 species and 1,800 specimens). The torpedo, ribbon and depressed forms were almost entirely lacking in the stranded community.

Body forms of the crustaceans are divided into following 5 types.

a) Shrimp type (Plate II, A–a and –d): About 30 species of macrurans, anomurans, and stomatopods belong to this type. The shrimp form is the most numerous in species. Except for a few species (*Icotopus*, *Chlorotocus*, etc.), most of them appeared in the young-adult stages. The massive species were never found in this type.

b) Crab type: 26 species of brachyurans belong to this type occupying the second largest in species number. The massive species are not observed to be in this group either. They may be in adult stages.

c) Stomatopod-*Phyllosoma* larva type: Stomatopod larvae (6 species) and *Phyllosoma* larva are assigned to this type of which the stomatopod larvae are the massive species.

d) Euphausia-mysid type (Plate II, A–b, –c, –e and –f): Several body forms of smaller crustaceans are included in this type (3 species of amphipods, 2 species of mysids and one cuma). The massive species such as *Lophogaster* and *Oxycephalus* are in the larva-adult stage.

e) Copepod type: The minute crustaceans (*Calanus* and *Megalopa* larva) which belong to the massive group are classified in this group.

Other invertebrates are classified as follows:

a) Squid-octopus type (Plate III): 11 species of cephalopods are included in this type indicating the highest number among these invertebrates. They belong to the young-adult stages except Loligonidae larvae.

b) Jellyfish type (Fig. 4 and Plate II, B–b): 5 species of Coelenterata assigned to this type of which 4 may be the massive species. The constituents of this type seems to be one of the most numerous aimals in the stranded community.

c) Arrow worm-*Creseis*-salpa type: In this type there is a range in several body forms from the elongated to the cylindrical forms (Chaetognatha 3, Protochordata 2 and Mollusca one species). Most of them are the massive species.

d) Sea cucumber-urchin-star type: The inshore benthic species are referable to the type, one of which is the sporadic massive species (*Clypeaster*).

e) *Lepas*-*Violetta* type (Plate II, B–a): The southern strollers are assorted into one group. Both of them are members of the massive appearance group.

3. Distributional and ecological aspects

TABETA and TSUKAHARA have already reported that the stranded community on the Shingu beach consists of the inshore and offshore animals and southern migrants.[7] This chapter represents an extension of these observation which enabled the author to analyse more closely the ecological and distributional aspects of the stranded community. The stranded animals which are divided geographically into the inshore, offshore and southern types as mentioned above are further divided to 3 ecological groups as follows: Group I, represented by the planktonic and pelagic groups such as fish larvae, jellyfishes, epi- and meso-pelagic animals; Group II, nektonic, especially good swimmers such as *Mugil*; Group III, benthic which includes demersal fishes and associated animals of the *Sargassum* belt. In this connection, the stranded fish community is characterized as being composed of the following distributional and ecological groups.

A) Inshore type: The main stranded fishes inhabiting in the inshore waters are *Engraulis, Plotosus, Ammodytes,* puffers, gobies, filefishes, rockfishes, etc.; these numbered 86 species (62% in the total fishes) and 7,500 specimens (7% in the total specimens). This type is the most numerous in species number compared with the later offshore and southern types, and lowest, in specimen number. Ecologically speaking, Group III holds a high percentage (84% of this type) in species; Group I is high in specimen number (68% of this type); Group II is low in both species and specimens (Table 11). The

Table 11. Number of species and specimens of stranded fishes by distributional and ecological groups. Each group is defined in the text.

Distributional type	Ecological group	No. of species	No. of specimens
Inshore	Group I	11	5,000
	Group II	7	600
	Group III	68	2,000
Offshore	Group I	33	62,000
	Group III	8	500
Southern	Group I	12	37,000

Table 12. Numbers of species and specimens of stranded fishes by developmental stage in each distributional type.

Distributional type	Developmental stage	No. of species	No. of specimens	Representative species
Inshore	Larva	6	2,500	*Sebastes* *Uranoscopus japonicus*
	Young	17	1,500	*Plotosus anguillaris* *Stephanolepis*
	Larva-adult	8	3,000	*Engraulis japonica* *Ammodytes personatus*
	Young-adult	55	500	*Fugu niphobles* *Fugu poecilonotus*
Offshore	Larva	23	39,000	*Cololabis saira* Leptocephali
	Young	4	300	*Glossanodon semifasciatus* *Champsodon snyseri*
	Larva-adult	1	5,000	*Bregmaceros*
	Larva-young	7	18,000	*Macrorhamphosus scolopax* *Maurolicus japonicus*
	Young-adult	6	300	*Coelorhynchus multispinulosus*
Southern	Young	12	37,000	*Boesemanichthys firmamentum* *Diodon holacanthus*

species and specimen numbers of this type in relation to the developmental stage types are shown in Table 12 with the representative species of each type. The number of species is the highest in the young-adult type which is the least in specimens; in turn, the specimen is numerous in the larva and larva-adult types. On the ecological aspect the former belongs to Group III and the latter to Group I (or Group II in an extremely lesser degree). Thus, of the inshore type the species number is high in young-adult and young appearance types of Group III, and the specimen number is high in larvae of Group I.

B) Offshore type: This type consists of fishes of Group I such as *Cololabis, Macrorhamphosus*, leptocephali, *Bregmaceros, Synagrops, Maurolicus, Lestidium*, Bothinae larvae, etc., and fishes of Group III such as *Glossanodon, Coelorhynchus, Champsodon, Macrorhamphosus* (young), etc. Group II is entirely missing (Table 11). The specimen number of this type is the most numerous (58%) and the species number retains the second largest (30%) among three distributional types. Group I occupies almost all of this type in both species and specimens. Needless to say, these fishes belong to the larva or larva-young appearance type on the developmental stage's viewpoint (Table 12). Thus, most of the offshore type is composed of larva belonging to Group I in both species and specimens.

C) Southern type: The allogenetic fishes which occurred in more southern waters and appeared temporarily in our waters are assigned to this type. Fishes of this type are *Boesemanichthys, Diodon, Brama, Canthidermis*, etc., and total 12 species and 37,000

Table 13. Number of species of stranded animals excluding fishes by distributional and ecological groups.

Distributional type	Phylum	Ecological group		Total
		Group I	Group II	
Inshore	Coelenterata	3 (2)*		3 (2)
	Mollasca		7	7
	Arthropoda	9 (2)	48	57 (2)
	Echinodermata		4 (1)	4 (1)
	Subtotal	12 (4)	59 (1)	71 (5)
Offshore	Chaetognatha	3 (2)		3 (2)
	Mollusca	1 (1)		1 (1)
	Arthropoda	7 (2)	9 (1)	16 (3)
	Protochordata	2 (2)		2 (2)
	Subtotal	13 (7)	9 (1)	22 (8)
Southern	Coelenterata	2 (2)		2 (2)
	Mollusca	6 (1)		6 (1)
	Arthropoda	1		1
	Subtotal	9 (3)		9 (3)
Total		34 (14)	68 (2)	102 (16)

*Numerals in parentheses indecate the number of massive stranding species.

specimens, ranking the second largest in specimen number. It is an outstanding feature that most of these fishes are ecologically referable to Group I, and the adult of this type have so far never appeared on the Shingu beach.

Moreover, the freshwater fishes (*Carassius, Oryzias, Misgrunus,* etc.) which were inhabitants of the rivers effluent of the study area, were stranded on the beach after heavy rainfall and totaled 7 species and 150 specimens (5% and 0.1% of the total species and specimens).

The same distributional and ecological categories are employed in the case of the invertebrates (Table 13).

A) Inshore type: The species number of this type counts about 71 species (70%) and is the most numerous among these types. On the ecological aspect the animals of Group III accounted for 80% or more and of Group I, only 17%. On the other hand, specimen number of the latter was far beyond that of the former (Table 13). Group III consisted mostly of Brachyura and Macrura (80% of the total Group III), littoral cephalopods and each of Echinodermata. Group I consisted of *Megalopa,* stomatopod larvae, Euphausiacea, etc. (Crustacea), and *Spirocodon & Aurelia* (Coelenterata). Except for Loligonidae larvae (Cephalopoda), most of Group III species of crustaceans, Mollusca and Echinodermata appeared in the young-adult stages. However, in Group I crustaceans (*Megalopa,* stomatopoda larvae, etc.) appeared as larva, and *Spirocodon & Aurelia* were seen in the young-adult stages. Consequently, the species number was numerous in the young-adult Group III, but the specimen numbers were numerous in the larval crustaceans or jellyfishes of Group I.

B) Offshore type: 22 species of Group I (13 species) and Group III (9 species) were recognized. Sixteen species belonged to the crustaceans (73%) of which 9 species seemed to be in Group III. The respective species of Chaetognatha, Mollusca, and Protochordata occurred exclusively in the young-adult type. On the contrary, the crustaceans appeared in each developmental stage; namely larva stage (stomatopod larvae, *Icotopus* and *Phyllosoma* larva), young stage (*Chlorotocus*), young-adult stage (*Solenocera, Plesionika,* etc.), and larva-adult stage (*Lophogaster, Oxycephalus, Phronima,* etc.). Hence, in the offshore invertebrates the crustaceans of Group I and III were high in species number, while the specimens were high in each Group I.

C) Southern type: The allogenetic southern type accounted for 9 species of which 3 species were assigned to the massive species. Ecologically, all of them are classified into Group I. The massive species such as *Porpita* and *Physalia* (Coelenterata) and *Violetta* (Mollusca) occurred in larva-adult and young-adult stages.

Finally, it seems particularly important to point out as a characteristic of the stranded communities that in both fishes and other animals the specimens are numerous in Group I (planktonic and pelagic group), while the species are numerous in Group III (benthic group including demersal fishes and associated animals to *Sargassum* belt). Group II (nektonic, especially good swimmer animals) is extremely scarce in species and specimens.

Consideration

As was stated previously, the species number of stranded fish was high in the young-adult appearance type which in turn was very low in specimen number, while the specimen numbers were exceedingly numerous in the larva or young appearance type. Although the sporadic mass occurrence of *Boesemanichthys* in 1965[7,21] supported a high level of specimen number in the young appearance type, a possibility of the type maintaining this status might be retained on further observation because the latent massive species, *Diodon* and *Canthidermis* which appear always in young stage in our waters, are included in this type as well. In fishes, the specimen numbers of larva and young indicated the high level, while the numbers of adult are much lower (Fig. 21). In crustaceans, however, the species are high in the young-adult appearance type and the specimen, in the larva-adult type. In order to elucidate the difference of the developmental stages of the prominent appearance of specimens between the fish and crustacean communities, it may be sufficient for the time being to indicate that the body length of the massive appearance species of crustaceans, *Lophogaster* and *Oxycephalus* which belong to the larva-adult appearance type, are within the length of the fish larvae (Figs. 20–A and 22). On the other hand, both species and specimens of other animals are dominant in the young-adult type of appearance as mentioned before; this seems to suggest another aspect of the biological characteristics of the stranded communities, namely, almost all of them belong to the pelagic groups except for one species (*Clypeaster*).

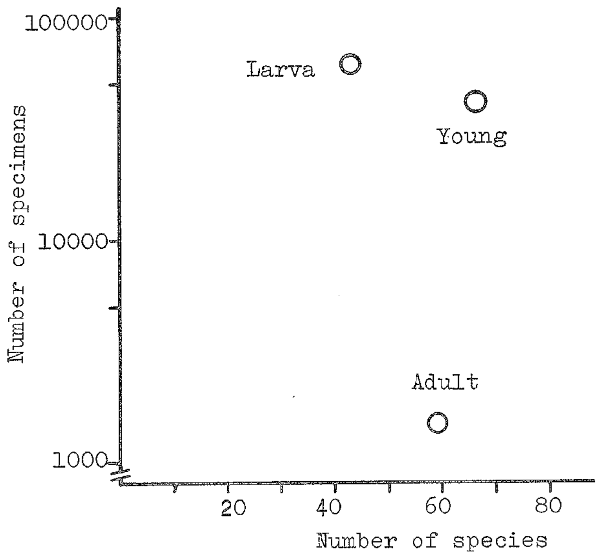

Fig. 21. Relationship between species and specimen numbers in each developmental stage. Total number of species of this Figure is over 150 species. Because a fish contained 3 developmental stages is counted as 3 species.

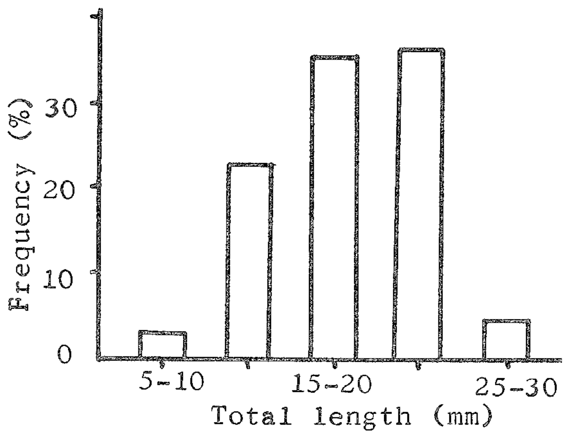

Fig. 22. Body length composition of *Lophogaster pacificus*, 110 specimens in 1967.

Of the stranded young and adult fishes, the members of the sphere, compressed, and intermediate between torpedo-arrow or torpedo-depressed body forms, which are poor swimmers because of feebly developed caudal fins, are the dominant constituents of the stranded fish community. Fishes of torpedo and ribbon forms are quite scarce. In this connection, it is particularly interesting to note that the fishes belonging to the genuine torpedo body form, which are the best swimmers and the inhabitants of the water column,[48] are entirely missing from the stranded community except for one specimen of *Seriola*. These trends, that the poor swimmers are outstandingly prominent in the young and adult fish group, may reflect on the large proportion of pelagic larval fishes occupied in the total fish community (Fig. 21). In the larval fish group, most of body forms recorded[50] are in the stranded fish community, of which the pelagic *Cololabis-Macrorhamphosus-Labracoglossa,* leptocephalus and shirasu types are extremely

Table 14. Representative species beponging to each distributional and ecological group of stranded animals.

Distributional type	Ecological group	Representative species of fishes	Representative species of invertebrates
Inshore	Group I	*Engraulis** *Ammodytes** *Sebastes** Hexagrammidae*	*Spirocodon* *Aurelia* *Megalopa* larva Stomatopoda larva
	Group II	*Engraulis* *Mugil* *Stolepholus* *Atherina*	
	Group III	*Plotosus* *Stephanolepis* *Fugu* *Sillago*	shrimps; crabs; octopus; squids; sea urchin
Offshore	Group I	*Cololabis* *Macrorhamphosus* *Labracoglossa* *Goniisteus* Leptocephali *Bregmaceros* *Maurolicus*	*Phyllosoma* larva *Sagitta* *Creseis* *Calanus* *Oxycephalus* *Phronima* *Chlorotocella*
	Group III	*Glossanodon* *Coelorhynchus* *Champsodon* *Macrorhamphosus***	*Lophogaster* *Solenocera* *Chlorotocus* *Plesionika* *Nephrops*
Southern	Group I	*Boesemanichthys* *Diodon* *Brama* *Canthidermis* *Chilomycterus*	*Physalia; Porpita* *Violetta* *Tremoctopus* *Argonauta* *Thysanoteuthis*

*indicates the larva in the same species.
** indicates the young in the same species.

abundant. The members belonging to the shrimp, crab and squid-octopus types are very numerous in species but are less abundant in specimens. On the contrary, the massive appearance species are seen in the jellyfish, arrow worm-*Creseis*-salpa, *Lepas-Violetta* types as well as the smaller crustaceans (Stomatopoda larvae, *Lophogaster, Oxycephalus, Calanus* and *Megalopa* larva). In spite of such a discrepancy among body forms in these animals we can easily recognize that they are quite well adapted to the pelagic or floating mode of life. From the standpoint of the mode of life *Clypeaster* (Echinodermata), which is a littoral benthos, is the only one exception among the massive species. These animals which live in the nearshore bottom are another popular stranding group in our waters.

The representative species of fishes belonging to each distributional and ecological group thus defined together with the invertebrates are shown in Table 14. As is readily seen from the Table, Group II is devoid of each distributional type of both fish and invertebrates without the inshore type in which this group was recognized to be extremely scarce, and in the southern type Group I alone was admittable as an ecological group. These animals tabulated in each column of Table 14 are referable to the same distributional and ecological groups. Comparing the species-specimen relations between

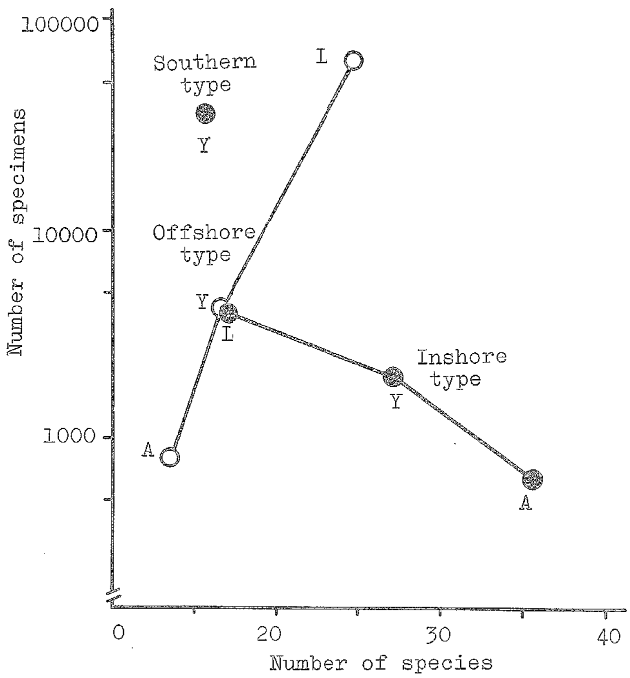

Fig. 23. Relationship between species and specimen numbers by distributional type and developmental stage of stranded fishes. Abbreviations are: L, larva; Y, young; A, adult.

each distributional type, these types can be arranged as the inshore–offshore–southern type in order of the species abundance, and offshore–southern–inshore type in order of specimen abundance. Thus, the offshore and southern types are exceedingly abundant in specimens (Tables 11 and 12), and these distributional types consist of a peculiar species-specimen relation in regard to each developmental stage (Fig. 23).

In conclusion it may be said that the species number of the stranded community is extraordinarily numerous in the inshore type almost regardless of taxonomical groups, while the specimen number is extremely high in the planktonic and pelagic groups or smaller crustaceans irrespective of the distributional type. Moreover, the skillful swimmers such as the torpedo-form animals and the benthic animals of both inshore and offshore waters (except *Clypeaster* or littoral shellfishes) are suprisingly scarce in specimen number in comparison with the inhabitant community. These characteristics of the stranded community may suggest the biological aspects of the easiness of stranding of animals under the conditions in question.

VII. Environmental conditions on the stranding phenomenon and an analysis of the process of stranding

In the previous chapter, it was stated that not only the inshore animals but also offshore and southern species are stranded on the beach, and the majority of the stranded community consists of members belonging to these latter groups (Table 11). In analysing the relation between the phenomenon and the environmental conditions from the meteorological and oceanographical viewpoints, the direct stranding process should be treated independently from the transporting process of these exotic animals into our coastal waters.

1. Relationship between environmental conditions and stranding

Although the destructive strandings of animals on the beaches along the Tsushima Current are said to be caused by either the winter monsoon or the low water-temperature,[6] the relationship between these phenomena and the environmental conditions has not been examined through successive observation on the field. In order to make clear these relationships, the author here analyses the relationship of the daily amount of stranded fishes to the environmental conditions based on the observations on the Shingu beach during December, 1965 to January, 1966 (the 1966 season). Prior to these analyses observations on the phenomena in the 1966 season are summarized as follows:[7]

On December 1, 1965, an unexpected appearance of numberless *Porpita* driven ashore on the Shingu beach was found; this had not been seen anywhere else for four days prior to this. Among *Porpita*, a considerable number of *Creseis, Physalia, Violetta* and *Lepas* were observed. The one kilometer of shoreline retained 90 specimens of 11 fishes, and several mysid, alima larva and larval squid. These strandings of *Porpita* and so forth were seen on the beaches between Karatsu of Saga Prefecture to Kanezaki in northern Kyushu. The phenomenon lasted for six days at the Shingu beach. After that time, the stranded fishes continued to be observed on the beach almost every morning during the five-month-observation period. The fishes observed on the beach in this season reached more than 10,000 specimens of 135 species (Fig. 7). The same tendency of appearance was true in the case of crustaceans. In these field observations the prominent strandings were exclusively seen on cold days with a strong northwest wind.

Then, the author considered the seasonal wind, temperature and tidal levels as worthy factors to be examined as a direct effect on the stranding process. These factors used here are: the wind- and air-temperature observed at Fukuoka City by the Fukuoka Meteorological Obserbatory; water-temperature derived from the Fukuoka Prefectural Fisheries Experimental Station's observation at Tsuyazaki; and tidal levels at Fukuoka Bay. Each observation station is located near the Shingu beach (Fig. 1).

Preceding the analysis of the relationship between the daily stranding and the environmental conditions, we must pay special attention to the diurnal change of stranding. Whenever we went to the beach for the purpose of research in this season, we could find any stranded fishes, but in the afternoon we saw the half-integrated or half-consumed specimens by gammariid crustaceans at times. Sometimes the stranded fishes were seen being eaten by birds. According to successive observations throughout the daytime, the early-morning collections (at 6:30–10:00 AM) indicate a high value in species and specimen numbers and are usually preserved in good condition compared with the other specimens found later in the day. Therefore, considering the relationship of daily stranding to environmental conditions, the author regarded the early-morning collections as the daily amount of stranding.

(1) Wind, temperature and tide level

As previously indicated, in this region seasonal cold winds from the continent prevail during the winter and winds of over 10 meter velocity blow from north to west frequently for a period of several days.[34,35] Considering that the Shingu beach faces the Tsushima Strait in a northwest direction (Fig. 1), this monsoon appears to be directly connected with the stranding phenomenon. The winds may be divided into the following two components as factors affecting the phenomenon: wind-direction, and wind-velocity.

In matters of the wind-direction, those of maximum wind-velocity in a whole day are regarded as daily direction; these are assorted into 8 directions (Fig. 24). Fig. 24 shows the frequency distribution of wind-directions, specimen and species numbers in each day in December, 1965 to January, 1966. The daily wind-direction varied from north, northwest to west accounting for 76% (47 days) in the 62 days of observation; the species and specimens in the 47 days accounted for 88 and 97% of the total species and specimens. Thus, the north to west wind-directions and the stranding of fishes are closely related to each other.

The maximum wind-velocity during the whole day is treated as a daily wind-velocity. The relationship between the stranded fishes and the wind-velocity in each day of the season is presented in Fig. 25. The correlation between wind-velocity and specimen number is rather obscure, although a positive upper limiting curve can be seen. Then,

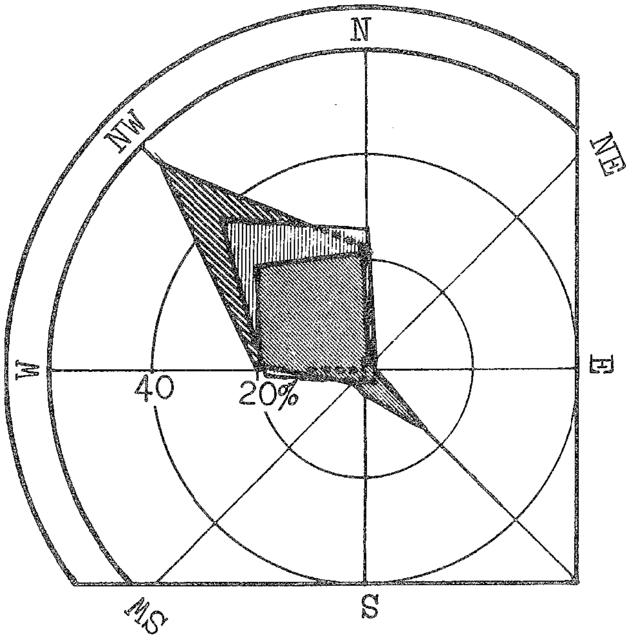

Fig. 24. Frequency distribution of wind-direction, species and specimen numbers of stranded fishes in each day in December, 1965 to January, 1966. Thin oblique line area, wind-direction; bold oblique line area, specimen number; vertical line area, species number.

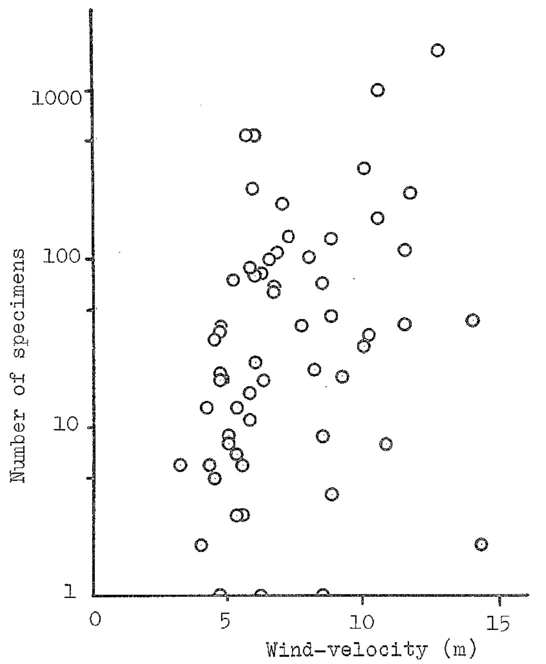

Fig. 25.* Relationship between maximum wind-velocity and number of specimens of stranded fishes in each day in December, 1965 to January, 1966.

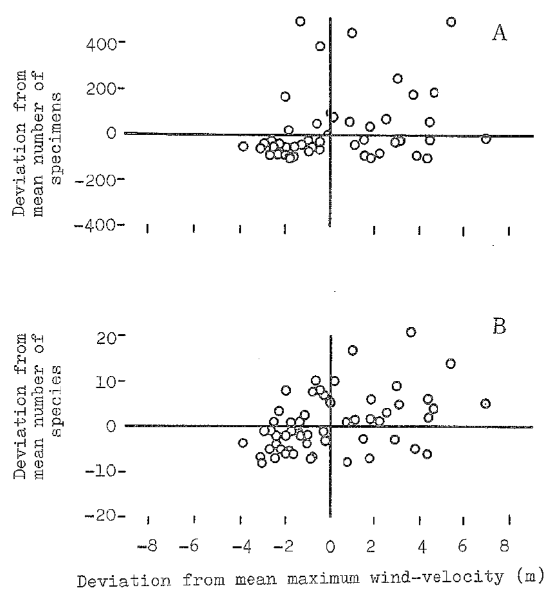

Fig. 26. Relationship of deviation from mean maximum wind-velocity to that from mean numbers of specimens (A) and species (B) of stranded fishes in each day in December, 1965 to January, 1966.

*Number of specimens in ordinate in Figs. 25, 27, 29, 31, 32 and 35 is added one to real number of observed specimens.

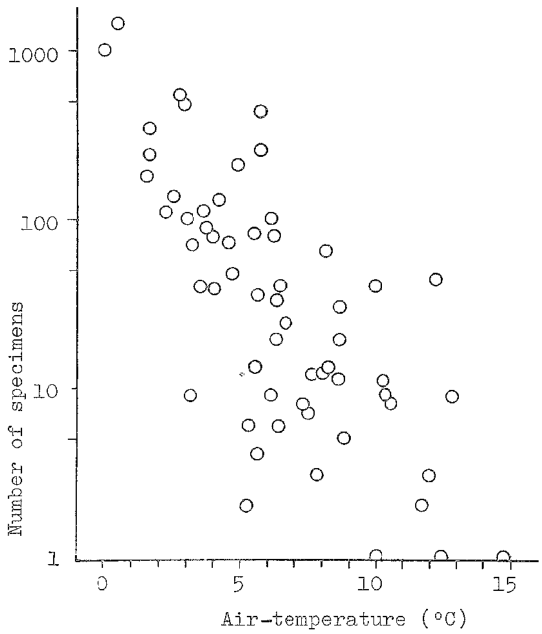

Fig. 27. Relationship between air-temperature and number of specimens of stranded fishes in each day in December, 1965 to January, 1966.

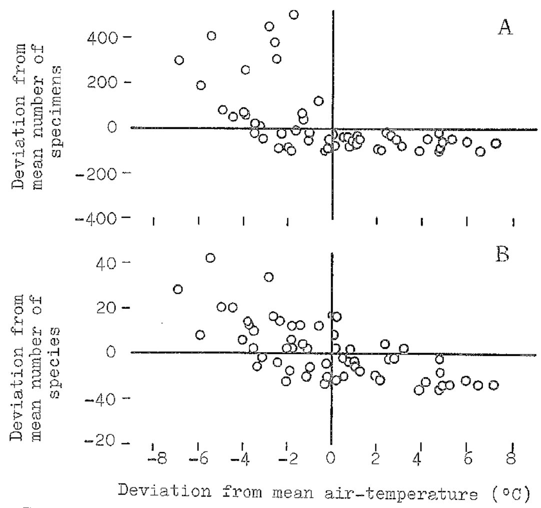

Fig. 28. Relationship of deviation from mean air-temperature to that from mean numbers of specimens (A) and species (B) of stranded fishes in each day in December, 1965 to January, 1966.

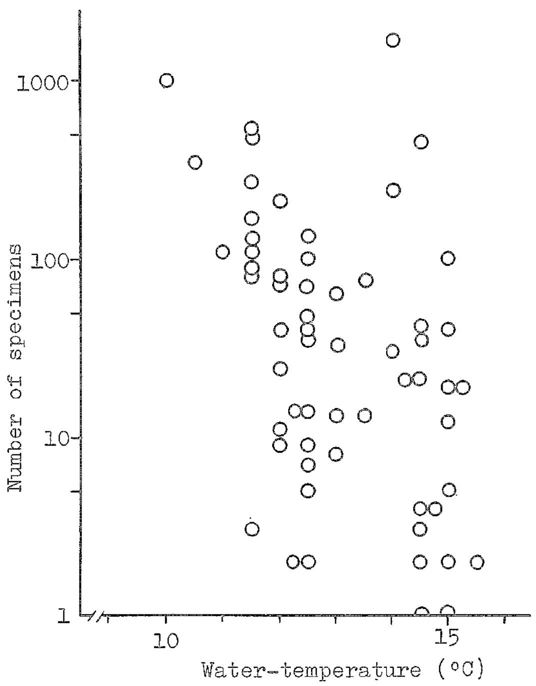

Fig. 29. Relationship between water-temperature and number of specimens of stranded fishes in each day in December, 1965 to January, 1966.

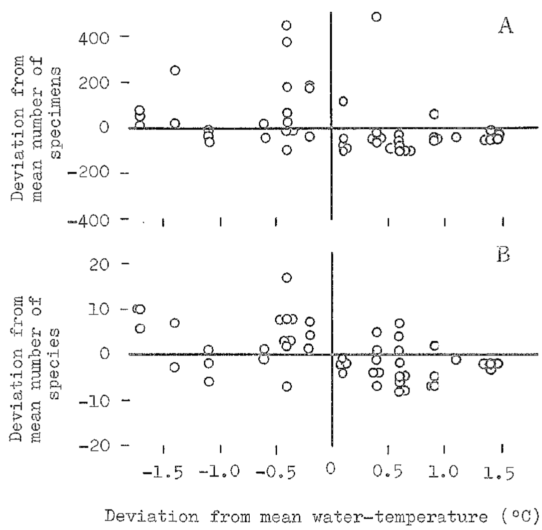

Fig. 30. Relationship of deviation from mean water-temperature to that from mean number of specimens (A) and species (B) of stranded fishes in each day in December, 1965 to January, 1966.

the relations between the deviations from mean maximum-velocity and that from mean numbers of specimens and species in each day are taken into account (Fig. 26). As is evident from the Figure, the high deviations from the mean numbers of specimens and species correspond generally to the high deviations from the mean maximum velocity and *vice versa.* Generally speaking, therefore, the prominent fish strandings may be stated to have been observed in the days of high wind-velocity, as was expected. In this connection, however, the daily winds should be treated as having a directional velocity relationship, since, according the field observation, the south-east winds, even during high velocity, never produced such prominent strandings; this will be discussed later.

That the temperatures may have a considerable effect on the stranding of fishes is to be expected from the facts of the daily observations mentioned before or from previous reports.[7] This expectation has certainly proved to be valid by the daily inverse-proportional relationship between the air-temperature and the number of specimens of stranded fishes in each day in the season (Fig. 27). More precisely, we can see this relationship in Fig. 28. High deviations from the mean specimen and species numbers correspond to the low deviation from the mean temperature; this indicates that the prominent fish strandings might occur on low air-temperature days.

Similar trends recognized in the relationship of the air-temperature to fish stranding is seen in the relationship between the water-temperature and the numbers of specimens and species of fishes in each day of the same season (Figs. 29 and 30). In this case, how-

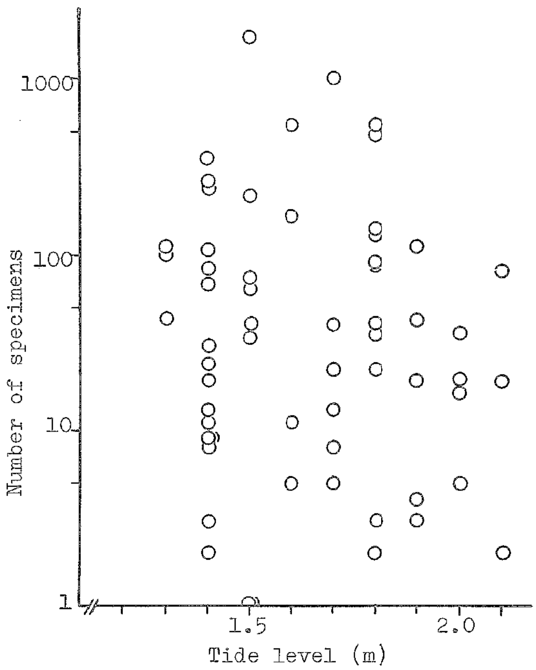

Fig. 31. Relationship between maximum tide level and number of specimens of stranded fishes in each day in December, 1965 to January, 1966.

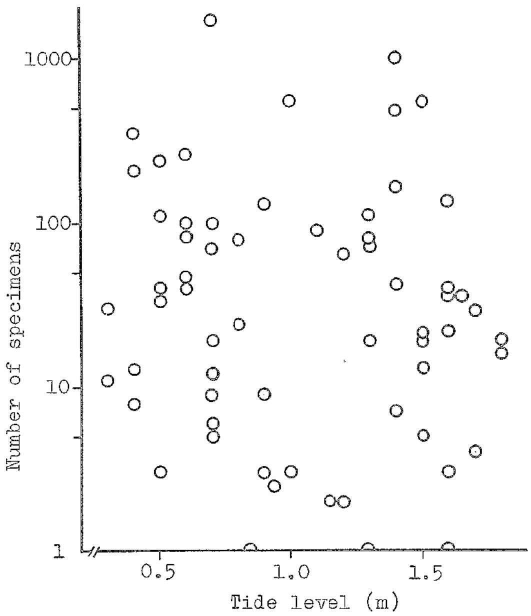

Fig. 32. Relationship between tide level at the time of collection and number of stranded fishes in each day in December, 1965 to January, 1966.

ever, the inverse-proportional relationship between them is not so clear as in the former relationship (Figs. 27–28). The relationship of both ambient and air-temperatures to the fish strandings suggests that the air-temperature should be considered as a more salient indicator than the water- temperature.

The daily maximum tide levels indicate an aspect of the vertical and horizontal movement of water in the sea as well as horizontal spreading of the water on the beach where the stranded fishes are found. At the same time, the tide levels at the collection time indicate the extent of collection area on the beach. The relationship of the maximum tide level and tide level at the collection time to the numbers of specimens in each day are depicted in Figs. 31 and 32. No correlation can be drawn from the Figures. Thus, no relationship is found between the tide levels and the number of stranded fishes.

(2) Wind direction-velocity-temperature

Of the above-mentioned factors, wind-direction and -velocity, and air- and water-temperatures are revealed to be in a definite relationship to the fish strandings. The relationship of these factors to the specimen and species numbers in December, 1965 and January, 1966 are shown in Fig. 33. In this connection, it should be noted that those

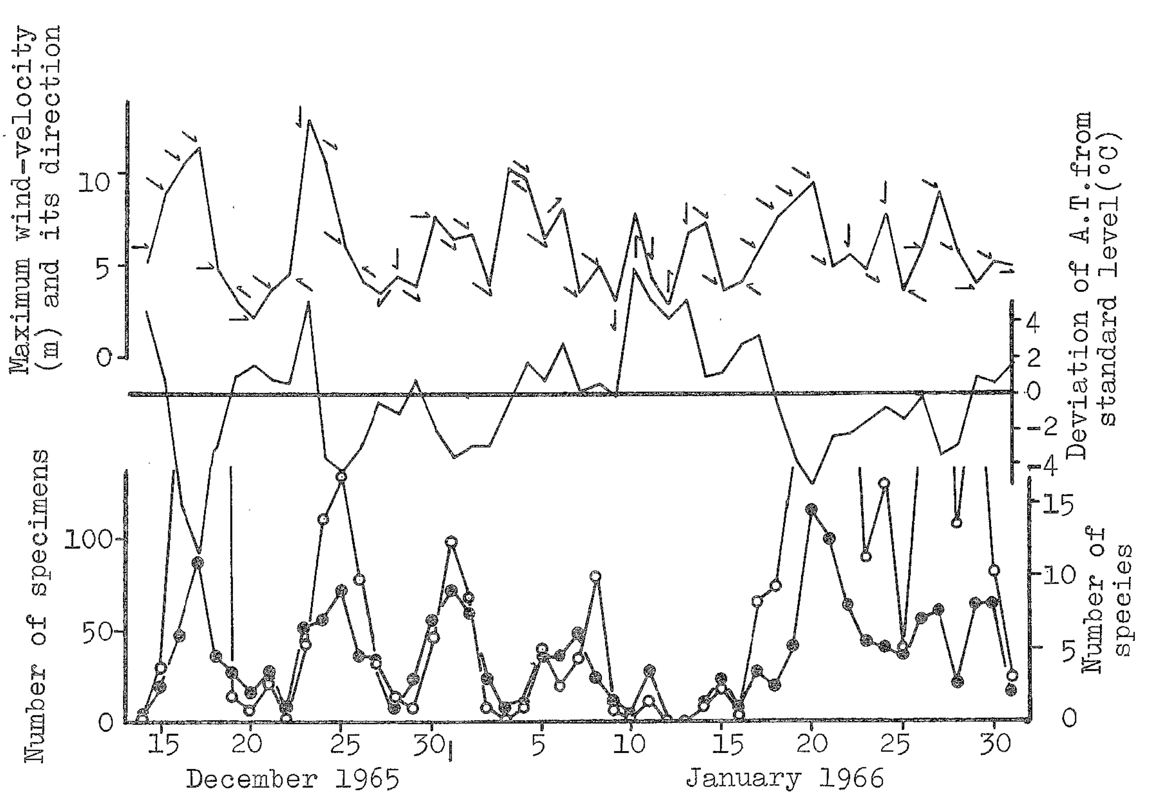

Fig. 33. Relationship of numbers of specimens and species of stranded fishes to air-temperature (A. T.), maximum wind-velocity and its wind-direction. White circle, number of specimens; black circle, number of species. Standard temperature used is obtained from the data of the daily average temperature in 1956 - 1965.

days having a south-east wind, even if in much higher velocity (for example, on January 3 and 10, 1966 in Fig. 33), the prominent strandings are not observed as was pointed out before; moreover, the successive blasts of north-west winds (for example, on December 14–17, 1965 and January 17–20, 1966 in Fig. 33) and corresponding lower temperatures are clearly much more effective on stranding than the intermitent north-west winds. It is generally stated in this region that during the winter months the air-temperatures suddenly drop just after a prevailing north-west winds, and in turn the water-temperatures vary in accordance with these air-temperatures[12,34,35]; consequently, they may not be split into separate components as factors on the stranding. Thus, the condition index (the north-west wind and temperature index) is defined as $\sqrt{Vi\,(20-Ti)}$, where Vi is the daily maximum velocity of north-west wind and $(20-Ti)$ is the difference of daily mean air-temperature (Ti) from the mean temperature (20°C) in the initial and the last strandings (in October and May). As for the days having winds other than the north-west direction, the condition indexes are given as 40% of the index of the last north-west wind day to the first day, 10% to the second day, and 0% to the third day

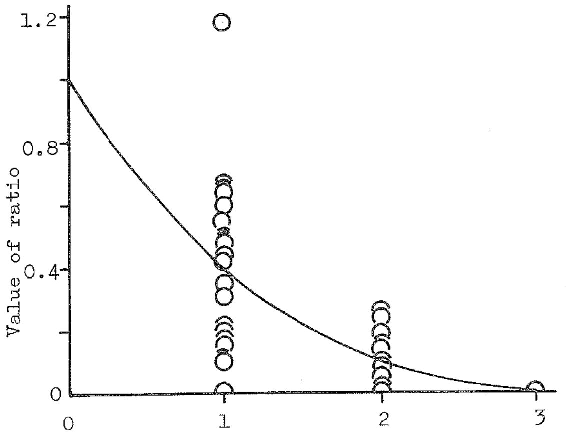

Fig. 34. Daily change of collection ratio on days having winds other than the north-west dierction to the collection on the last north-west wind day in the 1966 and 1967 seasons.

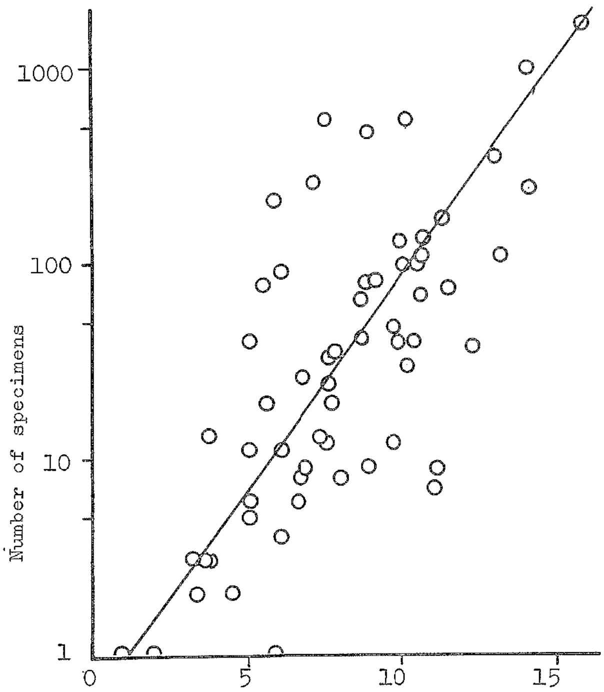

Fig. 35. Relationship between condition index (north-west wind and temperature index) and number of specimens of stranded fishes in each day in December, 1965 to January, 1966.

from the last north-west wind day. The reduction in the trend of condition indexes is estimated from the daily change of ratio of the collections in the respective days other than the north-west wind to that in last day of the north-west wind in the 1966 and 1967 seasons (Fig. 34). The relationship of the condition indexes to the number of stranded fish specimens in the season is shown in Fig. 35, indicating a fairly high correlation between them.

Any differences in the relationship between environmental conditions and strandings of southern, offshore, and inshore constituents of fishes are not recognized together with those in Group I, II and III from the distributional and ecological viewpoints. In regard to stranding of invertebrates, an identical relationship between the environmental conditions mentioned above were observed: the crustaceans appeared on the beach in parallel with the fishes (Fig. 36); the prominent appearances of cephalopods, jellyfishes, *Sagitta,* and *Iasis* & *Pegea* were always observed just after or during the north-west monsoon.

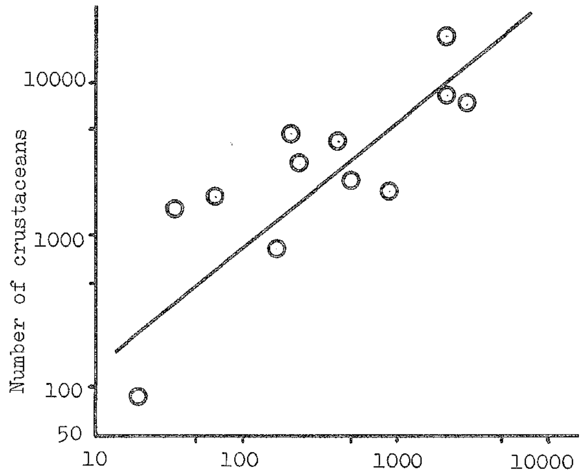

Fig. 36. Relationship between number of crustaceans and number of stranded fishes summed for every 10 day period in the 1967 season.

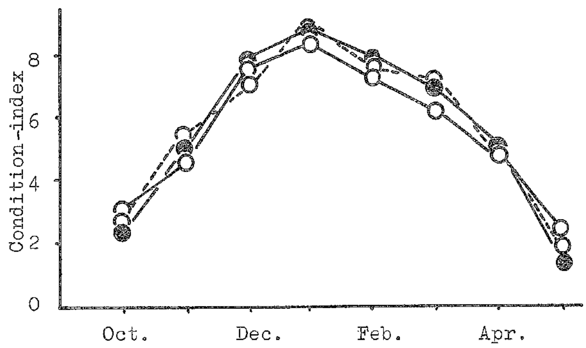

Fig. 37. Monthly change of daily average condition-index in the 1966-1968 seasons. White circle and solid line, 1966; black circle and solid line, 1967; white circle and dotted line, 1968.

According to the monthly changes in the condition indexes, which were expressed as the mean daily index in the 1966–1968 seasons, these indexes indicated the similar trends for each year (Fig. 37). Higher indexes were seen in December–March, lower in October and May, and intermediate in November and April. For meteorological reasons, therefore, the strandings of the fishes as well as the invertebrates should be observed mainly in December–March in each season. As was described before, however, more than 90% of the fishes are observed during December and January in the 1966 and 1967 seasons (Fig. 7), thus the fish strandings are biased to the first half in the period of the higher condition index (December–March). Moreover, *Spirocodon* & *Aurelia* appeared mostly in March, and *Porpita* and *Physalia* mostly in October or December; cephalopods appeared in two peaks, that is the major one in December and the mior one in March (Figs. 11–13). Such contradictions in the meteorological conditions and resultant strandings must be considered from the oceanographical and biological aspects of the phenomenon.

2. Analysis of the process of stranding

In considering the relationship between stranding and environmental conditions, another important factor must be elucidated: migration of the offshore and southern animals. In this section, the general distribution of the salient animals among the stranding community are enumerated and interpreted in relation to the hydrographical, geographical and meteorological features or their biological characters.

(1) General distribution of the southern and offshore constituents

The general distribution of stranded exotic animals is given below:

Southern type: *Diodon* and its related form (*Boesemanichthys,* etc.) are tropical species of Tetraodontida and represent one of the most remarkable examples of exotic species found in our waters.[45] *Diodon* is usually found in the southern waters, especially around islands; in its young stage it is sometimes found forming great shoals at mid-sea. In the early half of the year this fish spawns in the coastal waters in the vicinity of Luzon, Taiwan, and Yaeyama Islands.[51] The juvenile or young are driven into the Japan Sea by the Tsushima Current. For many years people have noticed shoals of young *Diodon* stranded on the Japan Sea coast from Honshu to northern Kyushu during rough winter days. The amount of stranding reaches at times an astonishing number, and in December, 1957, the author observed about 30,000 specimens per kilometer of the Tsuyazaki beach, near Shingu. *Boesemanichthys,* which is a tropical and subtropical puffer, affords another outstanding example; the young of this fish likewise appear sometimes in enormous quantities in our waters,[7,21] although not as frequent as *Diodon.* *Canthidermis, Chilomycterus, Ostracion,* etc. among Tetraodontida and *Brama, Aciancea,* etc., southern bathypelagic fishes, show the same distributional pattern as the puffers.

Of the cephalopod community, *Thysanoteuthis,* primarily an epipelagic member in the southern seas, is often reported stranded on the beaches along the Tsushima Current.[23] In fact, this giant squid is well known by the fishermen of Izu and Miura of the Pacific coast of Japan and Izu-oshima, Hachijo and Bonin Islands. *Argonauta* and *Tremoctopus* are members of this southern epipelagic group, and *Cranchia* is likewise a tropical-subtropical species but lives in the deeper levels.[41] They are apparently regular migrants in our waters from the more southern waters and are unable to reproduce in our sea under normal conditions. *Physalia,* an epipelagic jellyfish, is a famous inhabitant of the warm waters of the Central Pacific and is sometimes transported into this marginal sea by the warm current.[52] In our waters this jellyfish is found at times in the offshore waters during the summer months[43] and, more frequently, seen stranded during the winter months. *Violetta,* which is a floating gastropod from the southern waters, invades our waters to perish by stranding in winter.[43] Moreover, *Porpita,* another epipelagic jellyfish, indicates the same distributional pattern, but this jellyfish is much more common in our waters.[43]

Offshore type: The distributional pattern of offshore animals will be treated here in some detail, since strandings of these animals have previously been missed in the studies related to environmental conditions.

Of the fish larvae, *Macrorhamphosus* is one of the most prominent epipelagic larvae of our offshore waters.[12] According to the fish larva survey made during the period of the Tsushima Current Developmental Research, the larva appeared in the waters from Ryukyu to Oki Islands of Shimane Prefecture; during November to March south and west of Kyushu, and December to January west of San-in district. Thus, the appearance period of the larva was delayed and shortened by going to the north; moreover, the amount of collection was more abundant in the southern waters than in the northern waters.[12] Therefore, this fish is thought to spawn in the southern waters of the Tsushima Strait, most likely in the ramifing area of the Tsushima Current from the Kuroshio and its environ. The fish is then transported into our waters by the Tsushima Current. *Synagrops, Bregmaceros,* Myctophidae larvae, etc. show a rather similar distributional pattern to our waters, although they are not epipelagic larvae but rather inhabitants of deeper levels. *Synagrops* is known as an important food fish eaten by lizard fishes in the East China Sea, but the fish has not been recorded in our waters.[39,53] *Bregmaceros* is seldom noticed in our waters, although this larva is frequently seen in the plankton samples obtained from East China Sea. Myctophidae larvae such as *Benthosema pterota, Myctophum affine, Diaphus tanakai,* etc. are frequent members of the stranded community, but cannot be found in the fish list of endemic fish fauna nor in the plankton samples from nearby waters. But, these fishes are usually seen in the waters south of Kyushu.[54] Leptocephali of Apodes total about 28 species belonging to Congridae, Ophichthidae, Muraenidae, etc. Bothinae larvae total more than 6 species in the stranded community. However, we can only find 11 species of Apodes (Congridae, Ophichthidae, Muraenidae and Muraenisocidae) and 2 species of Bothinae (*Engyprosopon grandisquama* and *E. multisquama*) in the fish fauna of our waters.[19] Although these two groups are assigned to the offshore distributional type due to their common appearance in the plankton samples year around in our offshore waters,[12] most of them have certainly originated from waters further south near Ryukyu Islands, and have migrated into our waters and perished (Plate I, A and C).

The seasonal change of a congrid leptocephalus (Fig. 38) in the waters off Shingu–

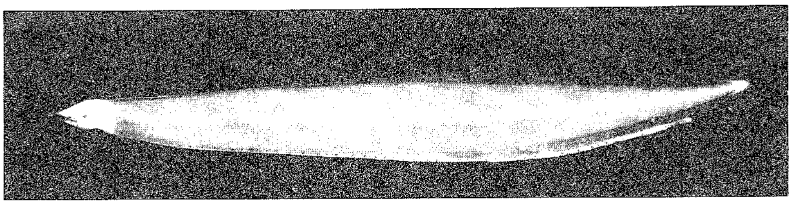

Fig. 38. A congrid leptocephalus stranded on the Shingu beach on December 10, 1965 (natural size).

Tsuyazaki which was obtained from the fish larva net survey made in the surface, middle and bottom layers during February, 1966 to February, 1967 is shown in Fig. 39 together with the seasonal change of the stranded specimens on the Shingu beach. This discrepancy in seasonal appearances of the two populations gives an invaluable clue to elucidate the relationship between stranding of fish larvae and environmental conditions. *Cololabis* larva provides another outstanding example of pelagic fish larva in our offshore waters. This larva appears in two period: from March to June and November to February (Fig. 40).[55] Taking into account the adult fish migration, it can be said that the larva observed from the former period represents offspring of the northern migrating population, and the one in the latter period represents offspring of the southern migrating population.[7] Therefore, most of the stranded larva, which are observed in the period from November to April, appear to belong to the offspring of the southern migrating population (Fig. 6–A). Why the offspring of northern migrating population are not stranded on the Shingu beach brings about another aspect of the fish larva stranding.

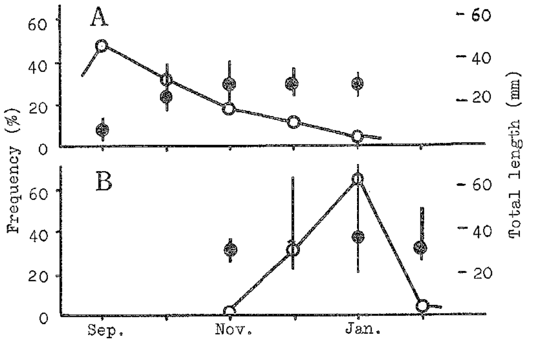

Fig. 39. Monthly changes of a congrid leptocephalus collected with fish larva net in the waters off Tsuyazaki, near Shingu (A: 42 specimens) and stranded on the Shingu beach (B: ca 3,000 specimens), and their total length ranges in 1966-1967. Black circle indicates the mode of the total length.

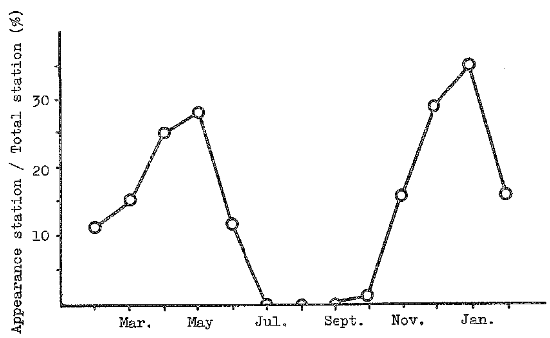

Fig. 40. Monthly change of *Cololabis* larva in the waters off western and northern Kyushu in 1952-1957 (After FUKATAKI[55]).

Maurolicus and *Glossanodon* are likewise striking constituents of the stranded community. These fishes adapt to life more or less restricted to the edge and slope of the continental shelf of the Japan Sea.[45] Particularly, *Maurolicus*, which is one of the most plentiful fishes in the Sea, plays an important part in the bio-economy of the Japan Sea. This is ascertained from the evidence of the stomach contents surveys of commercially important fishes or squids. The major portion of the population thrives in waters deeper than 150–160 meters, usually 250–300 meters. In the Tsushima Strait region, this fish has not been listed as a part of the endemic fish fauna nor has it been found in the plankton samples.[39] *Glossanodon* is better adapted to demersal life than *Maurolicus*, and is closely restricted to the edge of the continental shelf fringing Honshu and South Korea. According to the annual landing of this fish in recent years,[56] the main fishing ground seems to be off Hyogo Prefecture, middle Honshu. The eggs of *Glossanodon* are scarce in the plankton samples towed in the western waters of Kyushu, and are not found at all in the inshore waters off northern Kyushu.[12] The seasonal change of the offshore distribution in the waters centered around the Tsushima Strait is shown in Fig. 41. As clearly seen from the Figure, the main population, which lives

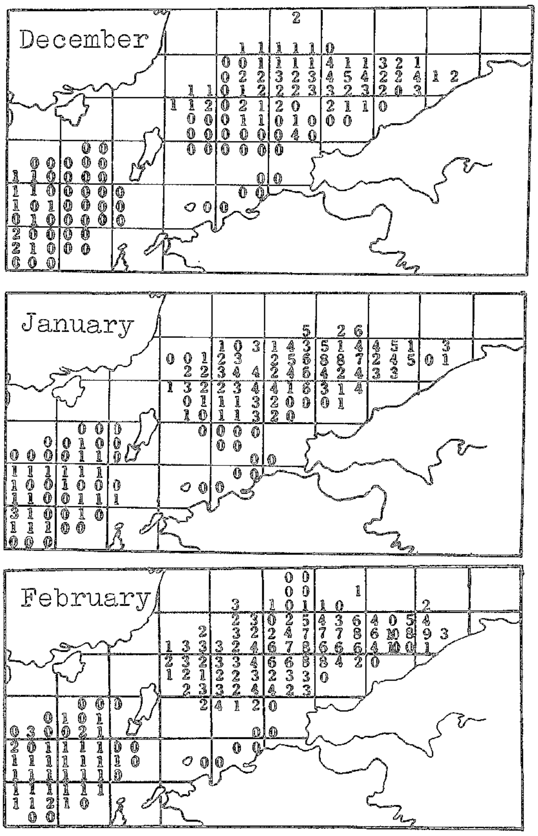

Fig. 41. Seasonal change of offshore distribution of *Glossanodon semifasciatus* in the waters off northern Kyushu and adjacent in 1966-1968. The numerals are indicated as mean values of $\sqrt[3]{A}$ in these three years, counting fractions of 0.5 and over as whole number and disregarding the rest, where A is the catch in number of boxes (12kg box) per hour by the trawler in each 1 / 36 degree square(Complied from the unpublished data of Fisheries Agency and Fukuoka Pref. Fish. Exp. St.).

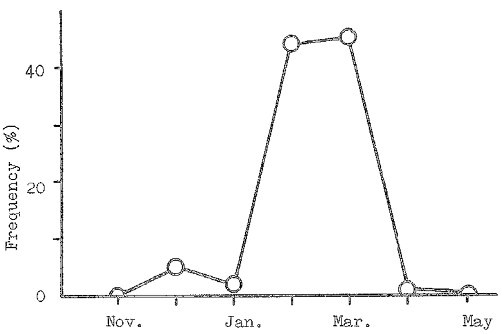

Fig. 42. Seasonal change of *Glossanodon semifasciatus* stranded on the Shingu beach in the 1965-1968 seasons.

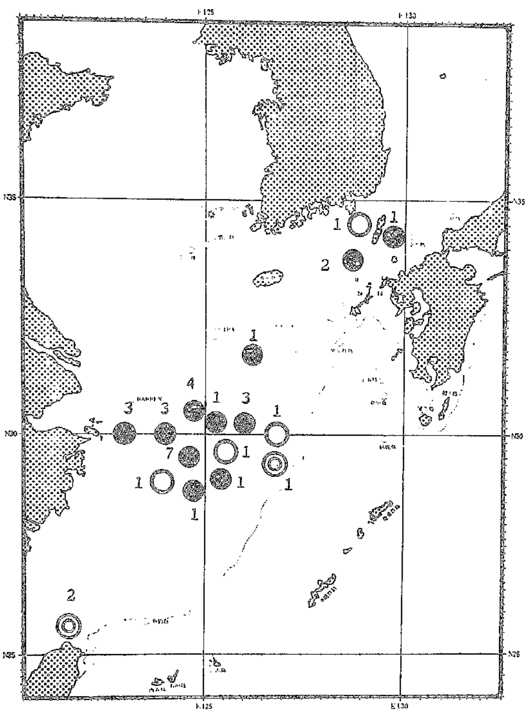

Fig. 43. Distribution of crustaceans in the East China Sea and its adjacents. Double circle, *Lophogaster pacificus* (FAGE[57] and MURANO[59]); black circle, *Plesionika binoculus* (FUJINO and MIYAKE[60]); white circle, *Chlorotocus crassicornis* (FUJINO and MIYAKE[60]). Numerals in each station indicate the numbers of specimens collected.

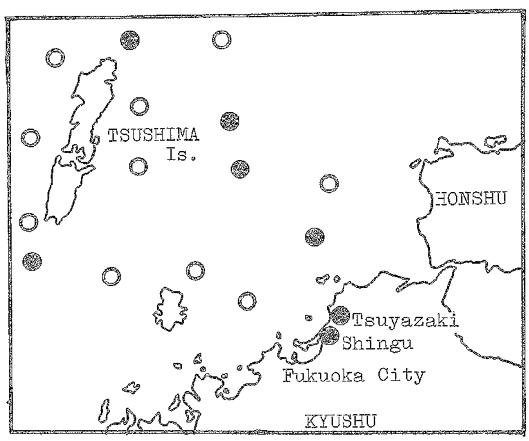

Fig. 44. Distribution of *Solenocera brevipes* in the waters of the Tsushima Strait in July, 1969 (Compiled from the unpublished data of MIYAKE, MINEI and HAYASHI). White circle, negative station; black circle, positive station.

in waters far off the San-in district in December, gradually approaches the inshore waters of San-in district and northern Kyushu during January and February. This landward approach may be relevant to stranding of fish on these beaches (Fig. 42). Several specimens of *Coelorhynchus multispinulosus,* which thrives on the bottom of the East China Sea and is the only species among Macrouridae fishes to succeed in settling in the westernmost part of the Japan Sea are sometimes fished with small shrimp trawlers in our coastal waters in January–March. This trend to approaching toward land in late winter agrees well with that of *Glossanodon* mentioned before.

Lophogaster pacificus, L. japonicus and *L.* sp. which belong to deep sea mysid have been indentified from several specimens taken from the waters around the East China Sea.[57] Recently, these latent, rare mysids have been collected rather frequently with plankton nets towed vertically from the bottom to the surface in waters south of the Tsushima Strait (especially in the waters of 75–200 meters in depth). This data comes from the survey on the spawning of the common squid (*Todarodes pacificus*) by the Seikai Regional Fisheries Research Laboratory, the Fisheries Agency. In November, 1969 and Febraury, 1970, considerable number of *Lophogaster* were obtained in the same waters with a bottom net which was specially designed by that laboratory for the purpose of collecting the spawned eggs of the common squid on the sea bed. These mysids, however, belong not to *pacificus* which is the most numerous species in the stranded crustacean community, but to *japonicus* and sp. The hitherto known localities of *pacificus* on the Sea are confined to the waters south of 30° N (Fig. 43).[57,59] Thus, of the 3 species belonging to *Lophogaster,* which are considered to be constituents of the benthic fauna in the East China Sea, *pacificus* is the most southern species. *Plesionika binoculus* somewhat resembles in its distribution. This small caridean shrimp has only been recorded once by YOKOYA from Shimane Prefecture, although investigations on the crustacean fauna in these waters have been made by several authors.[12,43–45,60] Recently, FUJINO and MIYAKE reproted frequent occurrences of this shirmp in the dredge samples carried out on the continental shelf of the East China Sea by the Seikai Laboratory.[60] These specimens were found exclusively on the sea bed of the central part of the Sea, 52-102 meters in depth, being affected by the warm current (Fig. 43). *Chlorotocus crassicornis* may be considered as another example. The four specimens of the caridean shrimp were first recorded by the authors (Fig. 43).[60] As was stated before, these crustaceans are frequently stranded upon the Shingu beach.

Solenocera brevipes, a penaeid shrimp which has come to science from specimens obtained at a 300 meters depth off Mie Prefecture (Kumanonada),[61] has not been found previously in the waters of the Tsushima Current, even from samples of trawls or dredges of the Seikai Regional Fisheries Research Laboratory. However, recent investigation reveals that this penaeid shrimp lives in the waters of the Tsushima Strait, especially in the waters deeper than 60 meters (Fig. 44).

(2) Oceanographical structures of the Tsushima Strait and adjacent waters

As was stated before, in the waters of northern Kyushu the Tsushima Current flows toward the Japan Sea and is in some distance from the coast, while the southern counter current flows near the shore during summer and autumn.[12] In this section the oceanographical structures of the Tsushima Strait and adjacent waters are presented in relation to the migration of the southern and offshore constituents.

The three following water systems in the East China Sea have been recognized.[2,3,19,62,63]

a) Kuroshio: This warm, haline current originates in the eastern waters off Philippines and Taiwan and enters into the East China Sea between Taiwan and Ishigaki Island. Then, the current runs northeast along the continental slope at 1–3 knots to the western waters 100 miles off Yaku Island. Here the current changes direction to east or east-southeast, and flows through the Tokara Strait to the Pacific. In the course of running along the continental slope, the current ramifies into two branch currents: the continental-side branch of the Kuroshio, which is divided from the main current northeast of Taiwan and flows north, and the Tsushima Current.

b) The Coastal Waters of China Mainland and the Yellow Sea Cold Waters: The lower haline waters generated by the inflow of river waters from China Mainland are called the Coastal Waters of China Mainland. During the autumn and winter months these inshore waters are chilled by successive blasts of the northwest monsoon and prevail widely on the continental shelf of the Sea and result in a profound affect on the Tsushima

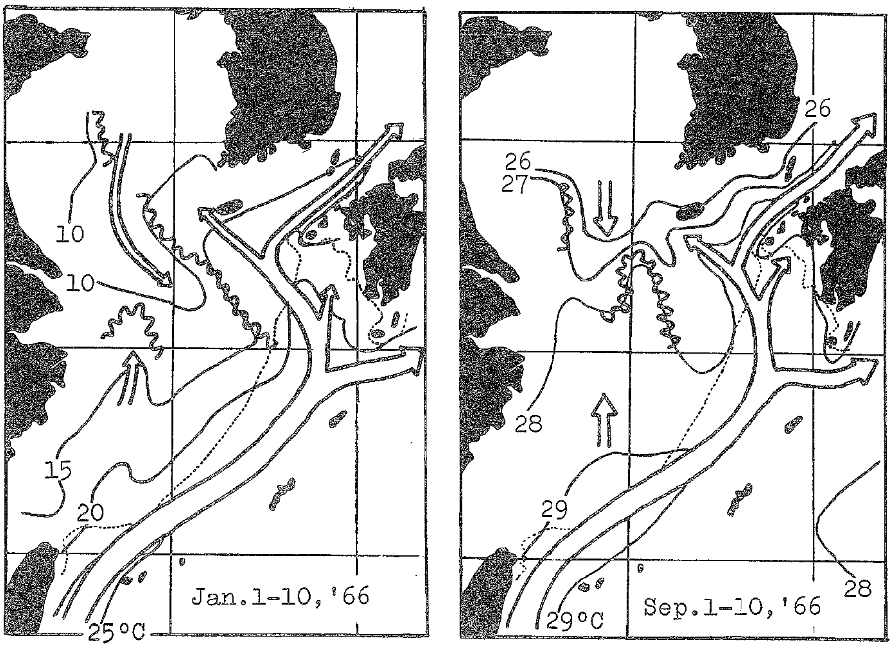

Fig. 45. Schematic representation of the water systems in the East China Sea and its adjacents (Nagasaki Marine Observatory[63]). Dotted line, 200 meter isobath; wave line, current rip.

Current. On the other hand, the cold and less haline waters are found in the basin of the Yellow Sea nearly year around and sometimes stretch out to the shelf.

c) The Tsushima Current: After ramifing from the Kuroshio in the western waters off Yaku, this current flows north at 0.5 ~ 1.0 knot. The Yellow Sea Warm Current branches from the Tsushima Current northwest of Danjo Islands. The main body of this current shows seasonal wandering, swinging westward in August to February and eastward in March to July. These water systems in the East China Sea and adjacent waters are schematically shown in Fig. 45.[63]

Then, the Tsushima Current, which advances north along the western waters off Kyushu, enters into both eastern and western canals of the Strait, though much less into the western canal. The northern major portion of the warm current through these canals shows prominent, seasonal variation, showing the maximum in August to October and the minimum in January to March (Fig. 46).[64] In the period from June to November, when the warm current predominates, the water passing the eastern canal of the Strait is clearly distinguished from the one which passes into the western canal (Fig. 47). The former water is lower than $\sigma_{15} = 25.20$ and is considered the oceanic surface water mixed slightly with the coastal waters of the East China Sea, while the latter is composed of the oceanic surface water mixed with a large amount of the coastal water of the East China Sea (lower than $\sigma_{15} = 25.20$) and the western North Pacific Central Water indicated by SVERDRUP et al. (higher than $\sigma_{15} = 25.20$ in Fig. 47).[65,66]

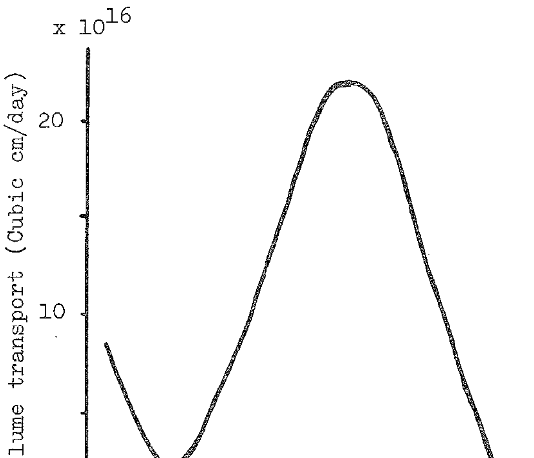

Fig. 46. Seasonal change in the northward volume transport of the warm current through the Tsushima Strait in 1936-1940 (After MIYAZAKI[64]; slightly modified).

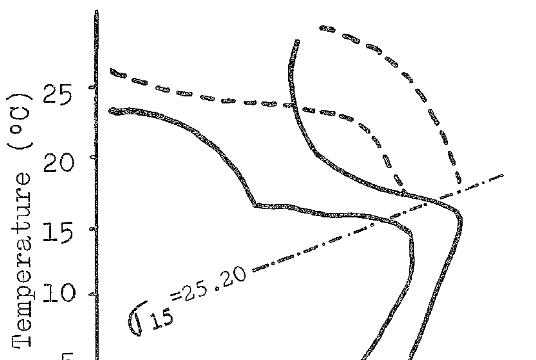

Fig. 47. T — S diagram at the eastern and western canals of the Tsushima Strait in September in 1927-1941 (After MIYAZAKI and ABE[65]; slightly mondified). Dotted line area, eastern canal; solid line area, western canal.

This Central Water seems to advance toward the north-west along the bottom of the sea valley west of Kyushu and flows into the Japan Sea. However, in the period from December to May, both waters passing the eastern and western canals are never discerned each other to form homogenized water from the surface to the bottom.[65] This seems to indicate that in the sea west of Kyushu, lateral mixing is particularily dominant between the oceanic water and the coastal water of the East China Sea in this season, possibly being induced by the successive blasts of the northwest monsoon.

Passing through the Strait, the Tsushima Current shows a tendency to flow in two or more branches (first, second and third branches from the coastal to the offshore waters of the Japan Sea) with the maximum speed of 2 ~ 3 knots. Vertically, the main region of this sea seems to consist of two major layers of distinct water systems in winter, the upper and lower waters.[3,12,20,45,62-64] The upper water is confined to the shallower levels of the region south of the Polar Front or subarctic convergence. In summer superficial water covers these upper and lower waters. One of the most outstanding features of the Japan Sea is a powerful southern surface current from the continental side to Honshu in the winter months; this is a type of drift current induced by the northwest monsoon.[12,20,45,67]

(3) Analysis of the process of stranding

In the previous sections the general distribution of the stranded animals and the oceanographical structures of the waters concerned were revealed to a certain extent. The migration process of these animals to the beaches of northern Kyushu should be presented in relation to these oceanographical structures as well as the geographical and meteorological features of these waters.

Migration process of the southern and offshore animals to the coastal waters of northern Kyushu. As was already stated, the southern constituents such as *Diodon*, *Boesemanichthys*, *Canthidermis*, etc. which originate in the waters south of the East China Sea are transported by the warm current through the Tsushima Strait into the Japan Sea, possibly during the summer season (at the peak of the Tsushima Current). This can be stated from the appearance of the larvae of *Diodon* in the water off Luzon or Taiwan.[6,7] Epipelagic members in the southern waters, *Thysanoteuthis*, *Argonauta* and *Tremoctopus* (cephalopods), *Physalia* and *Porpita* (jellyfishes), and *Violetta* (floating shellfish), are also considered to pass the Strait during the summer months.[6,7,41,47] In the summer of 1967, considerable numbers of *Tremoctopus* and *Thysanoteuthis* were driven ashore on the beaches of northern Kyushu after bad weather.[47] They were considered to be members of the northern migrating population due to their small size as compared with the stranded specimens on the beach during winter. Moreover, *Brama*, *Aciancea*, *Trachypterus*, etc. among fishes, and *Cranchia*, etc. of cephalopods, which may be assorted to the meso-or bathy-pelagic fauna of the western North Pacific Central Water, [41,45,67] are likewise supposed to pass mainly the Strait during the summer season when the Central Waters advance along the bottom of the sea valley west of Kyushu and flows into the Japan Sea, exclusively through the western canal (Fig. 47). Young *Trachypterus ijimai*, 35 centimeters in the total length driven ashore on Tsuyazaki in May, 1967 and *Brama raii*, 12 centimeters, scooped beneath the floating sargassums off Tsuyazaki in July, 1964, seem to be members of the northern migrating population. These animals transported into the Japan Sea through the Tsushima Strait appear again in the coastal waters of northern Kyushu and adjacent area during late autumn and winter to perish. In late autumn when the northwest seasonal winds induce the southward current on the surface of sea, these members of the northern migrating population are subject to southern drift currents and are driven frequently in large numbers toward the west coast of middle to southern Honshu or northern Kyushu for one or two months.[45]

Macrorhamphosus, an offshore pelagic fish larva, is considered to spawn in the East China Sea or its fringing waters and is conveyed to the coastal waters of northern Kyushu by the warm current like the southern constituents mentioned above. However, it is interesting to note that this larval fish is supposedly transported into our waters by the Tsushima Current, not during the summer season as in the case of *Diodon* for instance, but during late autumn and winter. This supposition is supported by the offshore ditribution of *Macrorhamphosus* larva which are restricted to southern part of Oki Islands of Shimane Prefecture in November to March.[12] *Synagrops* and Myctophidae larvae may indicate the same ecological characteristics as in the case of *Macrorhamphosus* because of their limited appearance period in winter. As for leptocephalus larvae, since we can find them in plankton samples taken from the East China Sea and adjacent area almost year around, their introduction into our waters is considered to be in two processes. The one is the summer transportation from the East China Sea to the Japan Sea and then the southern drift to our waters during the winter (*Diodon* type), and the other is the direct transportation into our waters in winter by the Tsushima Current (*Macrorhmphosus* type). The stranded leptocephlus larvae were probably brought into the coastal waters of northern Kyushu by both processes. In accordance with the offshore appearance of Bothinae larvae, these stranded larvae were likewise carried to their destiny by both transporting processes mentinoned above.

The approaching processes to our waters of benthic crustaceans found mainly in the East China Sea such as *Lophogaster, Plesionika, Chlorotocus*, etc., are thought to be the direct result of the warm current just like in the case of *Macrorhamphosus*. In their habitats, the vertical and horizontal mixing between the coastal waters and the oceanic waters may be particularly accelerated by the successive blasts of the northwest monsoon in late autumn and winter. As a result of forming the homogenized waters from the surface to the bottom, these crustaceans may be forced to take the pelagic mode of life when taken from their benthic habitats; then, they are probably conveyed to our waters by the warm current. In fact, most of *Lophogaster* and *Plesionika* are less than 2.5 centimeters in total length and *Chlorotocus*, less than 1.5 centimeters in total length, is exclusively young specimens. *Lophogaster* collected by plankton net towing in the middle layers of the waters west of Kyushu in November, 1970 are considered to be a part of this floating population (Y. SHOJIMA, personal communication).

Glossanodon and *Maurolicus* which are inhabitants restricted to the edges and slopes of the continental shelf of the Japan Sea indicate another striking migration process to our waters. As is evident from Figs. 6–A, 41 and 42, these fishes approach our coastal waters mainly in February–March when the northern volume transport of the warm current through the Strait reaches a minimum level of seasonal variation. This may be evidence that the southern current of the bottom or lower layers, which conveys these poor swimmers to our coastal waters, prevails in the westernmost region of the Japan Sea at the minimum of the Tsushima Current. *Solenocera*, a penaeid shrimp, is supposed to belong to the same migration pattern as that of *Glossanodon*, because this shrimp have

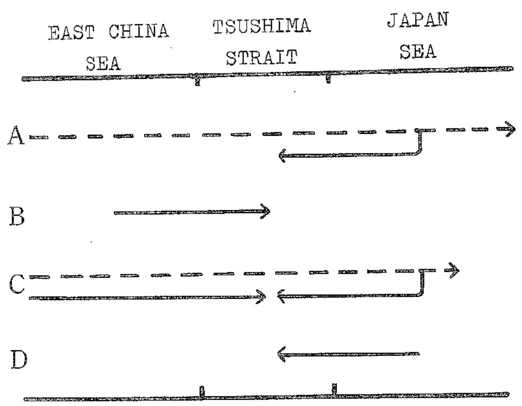

Fig. 48. Schematic representation of approaching to our waters of southern and offshore animals. Solid line, winter migration; dotted line, summer migration.
A) *Diodon* type.
B) *Macrorhamphosus* type.
C) Leptocephalus type.
D) *Glossanodon* type.

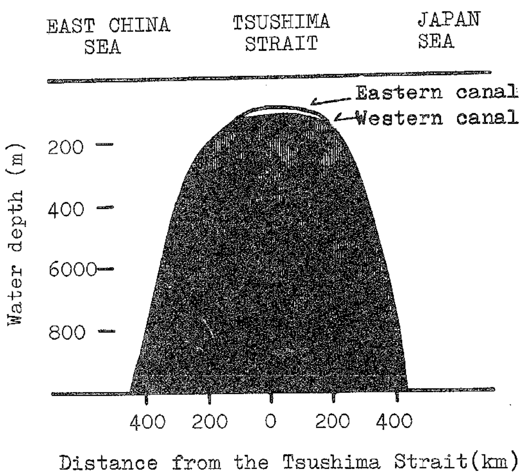

Fig. 49. Bottom topography of the Tsushima Strait.

never been found in the East China Sea, even in the samples of trawlers or dredgers carried out at more than ten thousand sampling stations throughout the continental shelf of the East China and Yellow Seas. Therefore, this shrimp is considered to be an inhabitant of the waters north of the Tsushima Strait, although nothing has ever been recorded in the Japan Sea except for the stranded specimens on the beach of northern Kyushu and the specimens collected by MIYAKE et al. (Fig. 44). These migration processes of southern and offshore animals are schematically shown in Fig. 48. Besides these patterns, there are the species (*Cololabis*, etc.) which are commonly found in our offshore waters in the winter season and are conveyed to the coastal waters under peculiar conditions to this area.

Thus, the southern and offshore animals may be transported into the waters of the Tsushima Strait by the warm current (*Macrorhamphosus* and leptocephalus types), by the southward surface drift current (*Diodon* and leptocephalus types) or by the southward deep current (*Glossanodon* type) in the late autumn and winter months. Topographically, the sill of the Strait is raised to less than 150 meters from the water surface (Fig. 49). This Strait is, therefore, much shallower in comparison with the western waters of Kyushu or the westernmost Japan Sea through which the warm current flows. In this area the waters transported from the East China Sea or from the Japan Sea as the southward drift current may be easily mixed vertically: moreover, the effects of the successive blast of the northwest monsoon on the vertical disturbance of the waters should be exceedingly prominent in this shallow sea throughout the season. As is evident from Fig. 50,[33] moderately homogenized waters prevail from the surface to the bottom in winter in the eastern canal of the Strait, being different from the summer stratification.

This indicates the vertically prompt disturbance of the waters in the Strait as well as in the East China Sea where the warm Tsushima Current originates and grows. In these processes the water-temperature may drop gradually. The transported animals

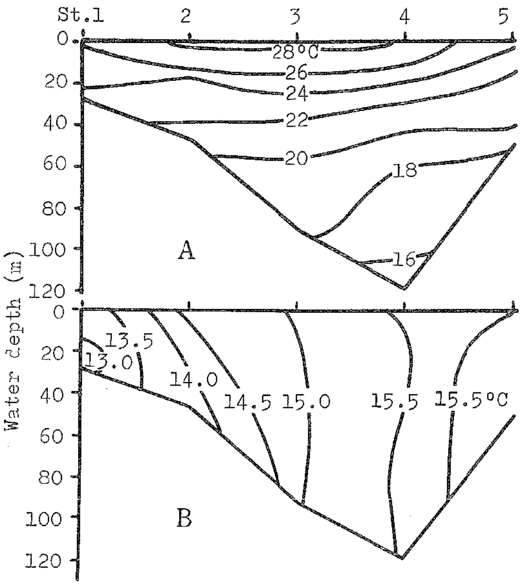

Fig. 50. Vertical distribution of temperature in the eastern canal of the Tsushima Strait in August, 1965 (A) and February, 1966 (B) (Compiled from the data of Fukuoka Pref. Fish. Exp. St.[33]).

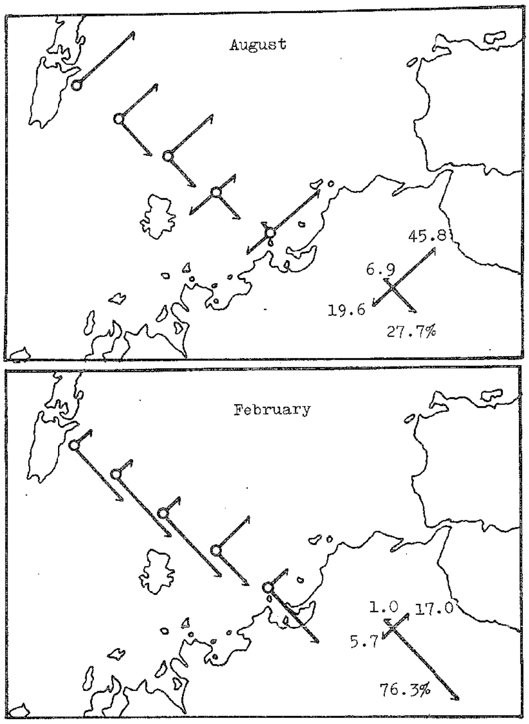

Fig. 51. Frequency distributions of the recovered drift bottles by direction division which were released in the eastern canal of the Tsushima Strait in 1954–1961 (After NONAKA[68]; slightly modified on further data).

into this area, as was stated above, may distribute uniformly in this chilled water from the surface to the bottom. In this connection, it is interesting to note that most of these stranded *Glossanodon* are not benthic adults, but young fish less than 10 centimeters. Another feature of this area, which conveys these animals into the coastal waters, is the fact that the prominent coastward drift current develops throughout the season especially during the successive blasts of the northwest monsoon (Fig. 51).[68] This current carries drift-bottles released in the waters between Iki and Tsushima Islands to the beaches of northern Kyushu within 2 or 3 days. Thus, this strong surface current should bring the animals to the coastal waters.

Process of stranding The southern and offshore animals thus transported into our coastal waters may be properly regarded in turn as constituents of the inshore planktonic or pelagic group, although within a limited period. As was indicated before, the strandings are definitely correlated with the powerful northwest monsoon and lower temperature; the strandings are exceedingly prominent during or after successive blasts of the northwest monsoon.

The supposed process of stranding is discussed in this section using a comparison of fish and crustacean with the inhabitant community of our coastal waters. The author adopted here as the inhabitant fish and crustacean community the results of the collections carried out by the small shrimp trawler specially equipped with a fish larva net. Collections were made about one kilometer off the Shingu beach (about 15 meters in depth). In addition, the results of fish larva net (130 and 60 centimeters in diameter) surveys in the three layers (surface, middle and bottom layers) of the same waters in December 1967 were used. These fishes and crustaceans obtained are listed in Table 15. As indicated in this Table, the offshore constituents such as *Macrorhamphosus*, leptocephalus and *Gonorhynchus* among fish larvae, and *Parribacus* of crustaceans are common in our coastal waters during this season (Table 15–B). Almost all of the pelagic fish larvae, crustaceans (obtained with the fish larva net), and benthic crustaceans found in the shrimp trawl fishing grounds are commonly found with the stranded community in this period (ca 20,000 specimens of 75 fishes in December, 1967) with some exceptions such as *Blennius*, *Sebastes* and *Parribacus* in the pelagic group (Table 15–B). No significant differences were observed in the length composition between the fish larvae and crustaceans of the collection and the stranded ones. However, the bottom fishes are assorted to the following two groups in comparison with the stranded fish group:

Fishes common to both communities (21 species): *Sillago, Aseraggodes, Evynnis, Engraulis, Gobius, Apistus, Rudarius, Callionymus doryssus, C. richardsoni, Paralichthys, Enedrias, Fugu v. vermicularis, F. poecilonotus, F. niphobles, Apogon, Dasson, Chelidonichthys, Stephanolepis, Syngnathus, Trachnocephalus, Hypodytes.*

Fishes peculiar to the shrimp-trawl community (13 species): *Engyprosopon, Tarphops, Pleuronichthys, Paraplagusia, Cynoglossus, Zebrias, Limanda, Conger, Squatina, Raja, Inimicus, Platycephalus, Trachonotus.*

Upon further analysis and comparison of body length composition between the inhabitant and stranded fishes, it can be seen that the fishes common to both communities may be subdivided into *Sillago*- and *Engraulis*-types (Fig. 52). The former has a distinct difference in body length composition, and appears in the larva or young stage alone in the stranded populations, and the latter has the same body length composition in both populations. Therefore, the adult or young of such fishes as *Sillago, Aseraggodes, Evynnis, Apistus, Paralichthys, Trachynocephalus,* and *Hypodytes,* which belong the former group, are ecologically regarded as fishes peculiar to the inhabitant community mentioned above. Thus, the stranded animals consist of pelagic organisms (Table 15–B), benthic crustaceans (Crustacea in Table 15–A) and infant fish (*Sillago*-type fishes above-mentioned) together with the coastal fishes which are mainly restricted to the *Sargassum* region or *Zostera* region flourishing one kilometer south of the beach or to the floating sea weeds (*Rudarius, Enedrias, Fugu, Apogon, Dasson, Stephanolepis, Syngnathus, Hypodytes,* etc.) or coastal bottom fishes such as *Callionymus.* Besides the species mentioned above, the animals carried far from shore (*Diodon, Lophogaster,* etc.) are seen in the stranded community. On the contrary, coastal flatfishes (*Aseraggodes, Engyprosopon, Tarphops, Pleuronichthys, Paralichthys, Paraplagusia, Cynoglossus, Limanda,* etc.), large swimmers (Squatina, *Raja,* etc.) or coastal bottom fishes such as *Conger, Inimicus, Platycephalus, Trichonotus,* etc.,

Table 15. Mean occurrence (catch/effort) of fishes and crustaceans in the waters one kilometer off the Shingu beach obtained by the small shrimp trawler specially equipped with a fish larva net (A) and by the fish larva nets (B) on December 6 and 18, 1967.

A*

No.	Species name	C/E	Length (cm)	No.	Species name	C/E	Length (cm)
	Fishes						
1	*Sillago japonica*	267.0	3.1 - 9.5	18	*Callionymus richardsoni*	3.0	9.3 - 17.5
2	*Aseraggodes labensis*	199.5	3.7 - 13.6	19	*Apogon lineatus*	3.0	2.9 - 3.9
3	*Engraulis japonica*	161.0	3.5 - 6.5	20	*Dasson trossulus*	2.0	3.6 - 4.9
4	*Evynnis japonica*	147.0	1.7 - 4.4	21	*Fugu pocilonotus*	2.0	9.3 - 22.0
5	*Engyprosopon multisquama*	73.5	2.1 - 13.3	22	*Chelidonichthys kumu*	2.0	2.1 - 19.0
6	*Tarphops oligolepis*	55.0	2.6 - 8.7	23	*Stephanolepis japonica*	1.5	5.2 - 6.7
7	*Gobius pflaumi*	15.5	2.3 - 5.8	24	*Syngnathus schlegeli*	1.5	13.5 - 14.5
8	*Pleuronichthys cornutus*	13.0	9.6 - 14.1	25	*Trachnocephalus myops*	1.5	12.5 - 18.8
9	*Apistus carinatus*	11.5	3.6 - 15.8	26	*Trichonotus* sp.	1.0	7.3, 7.9
10	*Rudarius ercodes*	9.0	1.5 - 3.8	27	*Limanda yokohamae*	1.0	23.7, 26.0
11	*Callionymus doryssus*	8.5	3.0 - 26.2	28	*Conger myriaster*	1.0	29.5, 30.0
12	*Paralichthys olivaceus*	8.0	5.2 - 20.0	29	*Hypodytes rubripinnis*	0.5	3.1
13	*Paraplagusia japonica*	7.0	16.2 - 27.7	30	*Squatina japonica*	0.5	47.0
14	*Cynoglossus*	4.5	3.2 - 13.2	31	*Fugu niphobles*	0.5	12.1
15	*Enedrias nebulosus*	4.0	10.8 - 11.2	32	*Raja kenojei*	0.5	33.2
16	*Fugu v. vermicularis*	4.0	10.6 - 26.0	33	*Inimicus japonicus*	0.5	8.1
17	*Zebrias zebra*	4.0	17.1 - 22.7	34	*Platycephalus indicus*	0.5	9.0
	Crustaceans						
	Mysidacea				Caridaea		
1	*Neomysis*	135.5		8	*Processa*	56.0	
2	*Acanthomysis*	65.5		9	*Leptochela*	37.5	
3	*Gastrosaccus*	11.5		10	*Latreutes*	12.5	
	Penaeidae			11	*Pontophilus*	2.0	
4	*Metapenaeopsis*	2161.0		12	*Chlorotochela*	1.0	
5	*Trachypenaeus*	11.0		13	*Crangon*	1.0	
6	*Sicyonis*	2.5		14	*Alpheus*	1.0	
	Galatheidae				Portunidae		
7	*Galathea*	1.0		15	*Portunus*	12.5	

*Towed for one hour.

B*

No.	Species name	C/E	Length (cm)	No.	Species name	C/E	Length (cm)
	Fishes						
1	*Engraulis japonica*	1.85	1.0 - 2.3	6	*Macrorhamphosus*	0.33	0.5, 0.7
2	*Cololabis saira*	1.33	1.0 - 1.8	7	Leptocephalus	0.33	1.7, 2.0
3	*Goniisteus*	0.67	0.7 - 1.0	8	*Gonorhynchus*	0.17	2.0
4	*Hexagrmmos*	0.50	0.8 - 1.0	9	*Sebastes*	0.17	1.5
5	*Blennius yatabei*	0.50	1.6 - 1.8	10	Labridae	0.17	1.3
	Crustaceans						
1	Mysidacea	26.45	0.6 - 1.2	4	*Oxycephalus*	1.67	0.8 - 2.0
2	*Leptochela*	18.35	1.0 - 1.5	5	*Alima* larvae	0.50	0.4 - 1.5
3	*Lucifer reynaudi*	6.18	0.8 - 2.1	6	*Parribacus antarcticus*	0.33	1.0

*The nets used are 130 and 60 centimeters in diameter and towed in three layers for 20 minutes with 2 knots.

which are generally found in deeper waters than *Callionymus*, were not found in the stranded fish community during December, 1967. Thus, the successive blasts of the northwest monsoon had little effect on the bottom fish community (flatfishes, sharks, etc.) living at or within the shallow waters about one kilometer off the Shingu beach, but it showed an effect on the shallow water nekton such as *Engraulis*. In this connection, it is particularly noticeable that neither *Diodon*, etc., among fishes, nor *Lophogaster*, *Chlorotocus*, etc. of crustaceans, which are seen frequently in the stranded community in this season, were obtained by the shrimp trawler or fish larva nets in this coastal water; this suggests the ecological properties of these animals in their course approaching the coastal waters.

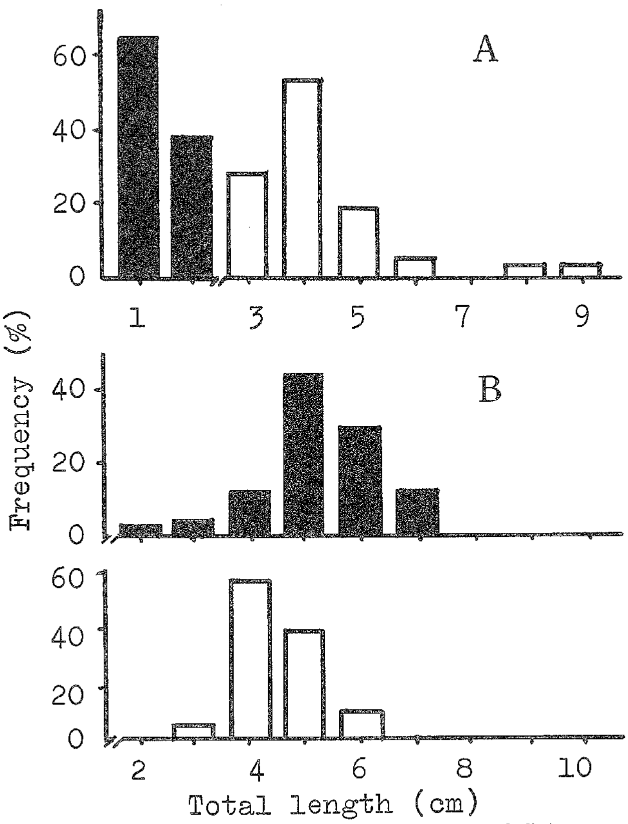

Fig. 52. Total length compositions of fishes caught with the shrimp trawler in the experimental fishing on December 6, 1967 (white) and stranded on the beach on December 1-10, 1967 (black). A) *Sillago japonica*: white, 476 specimens; black, 25. B) *Engraulis japonica*: white, 319 specimens; black, 90.

Culminating all of the above analysis in the section, the author postulates the process of stranding as follows:

(1) The stranded animals originating in the southern or offshore waters are transported into the area of the Tsushima Strait by the Tsushima Current, the southward surface

drift current, or the southward deep current. At the same time they are conveyed to the coastal waters of northern Kyushu by the powerful drift current as a result of the northwest monsoon in late autumn to winter. In the course of this process, the successive blasts of the northwest monsoon bring about lower air- and water-temperatures which may make these tropical warm-water animals inactive.

(2) Thus, the exotic southern and offshore animals brought into our coastal waters may now be regarded as the pelagic or planktonic animals of the inshore type from distributional and ecological viewpoints; therefore, the mechanism of stranding will be the same as that of the inshore type. Due to the shallow coastal water, successive northwest monsoons cause much water disturbance becoming progressively greater and greater. The resultant water disturbance forces the marine life to drift ashore as a result of wave action brought about by these monsoons.

(3) This water disturbance or wave action may force the separation of the community in the *Sargassum* or *Zostera* regions and temporarily brings about some elements of the community to the inshore pelagic group as in the case of the conveyed pelagics. Besides the conveyed animals, the coastal benthic crustaceans such as *Metapenaeopsis*, are forced to leave their habitats by direct wave action or other water disturbances. Then, these animals are cast ashore with the pelagic animals mentioned above during the northwest monsoon period.

Consideration

Although southern marine life migration such as *Diodon* in the Japan Sea and the resultant destruction due to the bad conditions or stranding have been reported,[6,14] transportation and stranding of southern or offshore fish larvae are poorly understood because of a limited account of the facts. The transporting area of these larvae may mainly be limited within the waters south of the Polar Front formed in winter in the Japan Sea and these animals may not give rise to viable young or adult in this marginal sea, if they are not stranded on the beaches.[45] Thus, each year they are subject to death migration or forced migration by currents which carry them to the above-mentioned waters. Namely, such transportations of southern marine life from the southern seas into the Japan Sea by the warm current through the Tsushima Strait have continued since the days of openning the land bridge between western Japan and the continent in the beginning of the last post-glacial epoch. But, most constituents of the Japan Sea fauna consist of the northern elements, and the southern elements are rather rare.[45] Zoogeographically speaking, therefore, the destruction of marine life in this shallow Strait by stranding may be regarded as the first barrier for the southern marine life to settle in this marginal sea.

As was stated before, southern and offshore animals are the major portion of the stranded community. The reason why they appear mainly in the early period of December and January is due to the fact that they cannot tolerate the cold conditions of winter; also the spawning seasons of offshore fishes such as the southern migrating population of *Cololabis, Macrorhamphosus,* etc. are concentrated mainly during the early period of the stranding seasons.[12,56] On the contrary, inshore fishes (*Engraulis, Plotosus,* *Fugu*, etc.) and fish larvae (leptocephali, etc.) found nearly year around in the offshore waters are seen to be stranded for a long period of time (Fig. 5).

The animals belonging to the *Glossanodon*-type migration process appear later in the season peaking in February-March and are very scarce in species and specimens (*Glossanodon, Maurolicus, Coelorhynchus*, etc. of fishes and *Solenocera* of crustaceans). *Arctoscopus*, which was trammeled in January to April, 1970 at Tsuyazaki, is considered to be assigned to this transporting group.

For stranding of the pelagic fish larvae such as leptocephali, *Cololabis*, etc., it is considered that not the inactivation of these animals due to chilling, but the disturbance of waters, coastward drift current and wave actions casting on the beach are indispensable. The appearance of congrid leptocephalus was limited to the winter period and that of *Cololabis* larva to the offspring of southward migrating population, while both the early autumn population of the leptocephalus and the offspring of the northern migrating *Cololabis* were not observed to be stranded on the beach (Figs. 6–A, 39 and 40). The intermitent northwest monsoon, however, sometimes prevails even in October or April during which this non-stranding population of leptocephalus or Cololabis larva is found in the waters off the beach. This indicates that the strandings are strongly affected by the successive blasts of the monsoon which induce powerful, water disturbances, coastward

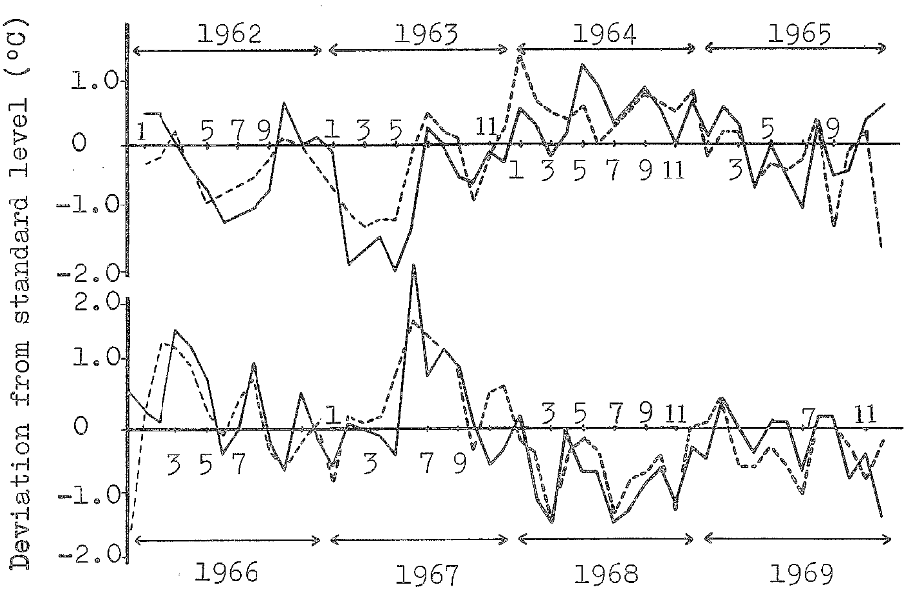

Fig. 53. Deviation of water - temperature in the Tsushima Strait (34°00' N, 129°30' E; solid line) and Danjo Islands (32°00' N, 128°00' E; dotted line) in 1963 - 1969. Standard temperature used is obtained from the data of monthly average temperature in 1960 -1969. Numerals indicate the month in each year.

drift current, etc. On the other hand, it is impossible to neglect the important effect of inactivation by the winter chill on larger southern and endemic constituents. The strandings of the so-called species peculiar to the Tsushima Current [12,45,46] (such as *Oxycephalus, Phyllosoma* larva, *Calanus, etc.* among crustaceans, arrow worms of *Chae-*

tognatha and salpa of Protochordata) may be regarded as similar to that of *Cololabis* larva mentioned above, and those of *Clypeaster* of Echinodermata or coastal brachyurans, to the case of coastal shellfishes or coastal benthic crustaceans (*Metapenaeopsis*, etc.).

As was mentioned before, the northwest wind and temperature index, which correlates highly with the direct stranding of fishes upon the beach, indicates seasonal trends (Fig. 37). On the other hand, an annual change of fish strandings is clearly recognized and this is principally influenced by the massive appearance species (Fig. 15). According to the annual change of water-temperature of the Tsushima Current, the temperatures in August–October, during which the northward volume transport of the Current attains its peak (Fig. 46) were to be higher in 1964 and 1967, lower in 1965, 1966 and 1968 (Fig. 53). Thus, the amount of northern water movement in the Current (1964 and 1967) is considerable greater than that of normal years. The massive appearance of the southern puffer, *Boesemanichthys*, in the beginning of 1965 and the landings of *Thysanoteuthis* at the Tsuyazaki Fish Market, which were stranded on the beach and caught with set net, highly correspond to these mass volume transports of the warm current (Figs. 17–C, 53 and 54). *Tremoctopus*, *Thysanoteuthis* and *Trachypterus* which were driven

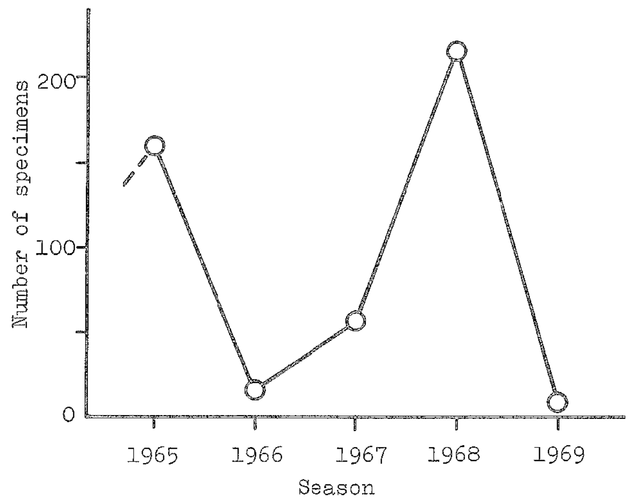

Fig. 54. Annual change of *Thysanoteuthis rhombus* landed at the Tsuyazaki Fish Market, near Shingu beach, in 1965-1969.

ashore on the beaches of northern Kyushu in the summer of 1967 are considered as the northward migrating population transported by this massive warm current. In these seasons southern constituents such as *Auxis*, *Thunnus*, etc. are also observed to migrate more abundantly into our waters than in normal years.[21] However, these southern migrants (*Boesemanichthys*, *Diodon*, etc.) did not always appear in enormous quantities in our waters during the prominent warm current years. Among them, *Thysanoteuthis* was transported in massive quantities into the Japan Sea in 1959[23] when the Current retained high temperatures. Therefore, this southern epipelagic squid is considered to be one of the most important indicator species of the northern volume transport of the

Tsushima Current.

The author can not clearly explain the relationship between the annual occurrence of *Glossanodon* on this beach and the southward deeper current from the Japan Sea which is believed to convey this poor swimmer to our waters. But, it is probable that the year to year change of stranded *Glossanodon* indicates an aspect of the annual trend in this southern current. Massive occurrences of leptocephali in January, 1967, and *Macrorhamphosus* and *Cololabis* larvae in January, 1968 seem to have no relation with the annual change of the warm current. Moreover, *Sagitta, Iasis & Pegea, Lophogaster* and *Oxycephalus* (Table 5), peculiar to this warm current, are stranded yearly in mass quantities regardless of the annual change in the current. The various trends in the appearance of marine life may rely on immediate environmental conditions as well as specific individual biological properties which could not be explored here.

VIII. Conclusion

In this chapter the author discusses the importance of this study from the fisheries viewpoint based on the results obtained from field observations, although many problems remain yet unsolved. The following points are made clear and concise from the present study.

(1) The stranded animals belong to all phylums inhabiting in and migrating into these waters. They range in size from less than one millimeter to several meters in body length. Of these, allogenetic species from the southern waters are prominent together with autogenetic endemic ones, while northern elements are very scarce.

(2) The period of stranding ranges from October to May, during which more than 90% of the fishes appears in December–January, crustaceans in January, and cephalopods and jellyfishes in December and March. The annual amount of fish stranding varies greatly, being affected by the massive appearance species. On the other hand, the invertebrates do not show so drastic year to year variation in stranding.

(3) The species number of the stranded community is high in the inshore benthic constituents, whereas the specimen number is high in the pelagic fish larvae and young, smaller crustaceans, jellyfishes, arrow worms, salpas and *Clypeaster*. The good swimming, torpedo-shape animals are very scarce in comparison with the inhabitant community. Ecologically, the stranded community consists mainly of southern and offshore planktonic and pelagic constituents. Of these, exotic fish larvae, such as some of the leptocephali, and Bothinae larvae, *Lestidium*, *Synagrops*, etc. (which were hitherto unknown in our waters), are seen to be transported into our waters each year.

(4) Such *Cololabis* larva and eggs, leptocephalus, *Macrorhamphosus*, etc. among fishes, *Lophogaster, Oxycephalus,* etc. of crustaceans, and others are sometimes destroyed in enormous numbers by stranding on the beaches during winter. Thus, in this area death by stranding is considered to be one of the most important natural mortalities of these animals including commercially important fish larvae.

(5) These stranded animals, which mainly originate in the southern and offshore waters, are i) transported through the Tsushima Strait into the Japan Sea in summer by the Tsushima Current and again conveyed to this Strait area by the southward surface drift current in late autumn and winter, ii) transported from the East China Sea into this area by the Current in winter, iii) transported into this area from the Japan Sea by the southward deep current in late winter, and iv) transported into this area by both the first and second processes mentioned above.

(6) The animals transported into the Strait area are carried to the coastal waters of northern Kyushu by the powerful coastward drift current induced by the successive northwest monsoon in winter, and then, they are cast on the beach together with the inshore animals. The successive blasts of the northwest monsoon, which result in water disturbance, drift current, chilled water, etc. may be more effective on the stranding phenomenon in the shallow waters of the Strait than in the adjacent water. This is why more strandings are observed in the beaches of northern Kyushu.

(7) The environmental conditions directly effecting the stranding show seasonal trends which are alike each year, and any noticeable variation in the conditions is not recognized in January when the strandings reach their peak every year. However, the amount of volume of water transported northward by the Tsushima Current shows a marked annual variation. The annual variations of strandings of some of the southern constituents (*Boesemanichthys*, *Thysanoteuthis*, etc.) show identical variations with those of the Current by which they were transported.

(8) The effects of the northwest monsoon resulting in water disturbance, chilled water, and wave action on stranding of inshore animals do not apply to the bottom fish community (living at or within about one kilometer off the Shingu beach), but effect the shallow water nektons such as *Engraulis*.

(9) The southern and offshore animals, which account for the main portion of the stranded community, are transported into the Japan Sea and are stranded on the beaches and there perish, or do not rise to any progeny in this marginal sea due to the unfavorable environmental conditions. This study has revealed that there are many animals subject to death or forced migrations each year, and that zoogeographically, this shallow Tsushima Strait may be considered to be the first barrier for the southern marine life to settle in the Japan Sea.

As pointed out before, stranding of marine life on the beaches of northern Kyushu is common each winter. The fishermen and early-morning strollers collect a considerable number of the stranded squids (*Thysanoteuthis, Argonauta,* etc.) and fishes (*Aluterus, Girella, Brama,* etc.) every rough weather morning in winter. A part of these collections are sold at the local fish markets. The author considers it very important to survey this phenomenon from the standpoint of exploration of the animal community and of oceanographical structure, for the following main reasons:

(1) This phenomenon provides invaluable information concerning the distribution of fish larvae, etc. in our water. As mentioned before, some exotic fish larvae, such as

several of leptocephali and Bothinae larvae, etc. which have never been found in the local plankton- and fish larva-net samples have been recorded for the first time in this stranding survey. Moreover, we come to a more precise understanding of the seasonal distribution of congrid leptocephalus, etc. by observing the results of the stranding surveys in addition to those of the fish larva-net survey (Fig. 39).

(2) The stranding survey is one of the most useful methods for approaching early life-history studies of fishes. Fish larvae, such as some leptocephali and Bothinae larvae (Plate I, A and C), Myctophidae, etc. are possibly more clear to science due to this survey. In addition, some fish larvae, such as *Hime, Sillago,* etc., having missing growth stages previously not found using fish larva-nets or other fishing gears, are frequently stranded on these beaches.

(3) This phenomenon clarifies the transportation or movement of water from the southern and northern area of the Tsushima Strait. This transportation or movement of water deeply influences local water systems. The present studies have shown *Thysanoteuthis* to be the most proper and valid indicator species of the warm southern current, and *Glossanodon* to be that of the northern deep current (Figs. 41, 42 and 54).

Therefore, the author considers this survey, in addition to the methods hitherto adopted, as a method of exploring the relationship between the animal community and the oceanographical structures of our waters. In order to achieve the expected results it is necessary to survey the stranding phenomenon on these beaches after the successive blasts of northwest monsoon in December–March, and to consult with the reliable fishermen or early-morning strollers on the beaches or the local fish markets. In order to arrive at a more presice understanding of the phenomenon, it is indispensable to investigate the origin of southern migrants, their physical transporting processes in relation to sea current, and their northern migration through the Tsushima Strait during summer. The cause for the annual variation of the summer migrations through the Strait is most important in predicting stranding in the following winter, but it remains almost undetermined. Furthermore, the relationship between the relative abundance of the local population and the stranded population is not fully understood. In regard to population abundance offshore and inshore constituents must be investigated.

IX. Summary

The author made an ecological study during 1964—1968 on stranded fishes and other animals found on the Shingu beach, northern Kyushu. Special attention was paid to the understanding of this stranding phenomenon as a method of approaching fishery biology in the future.

In Chapter II, a short historical review of previous works concerning the stranding phenomenon on the beaches along the Tsushima Current is made. This history is chronologically divided into the following three periods: the period of record (from the beginning of the record to about 1900), the period of accumulation of the record

or description (from 1900 to the decade of 1950) and the period of considering the mechanism and trying to utilize its information for fishery science (the decade of 1950 onward). In Chapter III, the materials and methods of the present survey are indicated with a description of the survey area. In Chapter IV, the stranded animals are described making clear their faunistic characters. Its conclusions are that the stranded community is composed of endemic as well as allogenetic southern or warm water elements previously unknown in our waters and that the northern elements are scarce both in species and specimens. In Chapter V, the seasonal and annual change of the phenomenon is shown. The stranding animals appear mainly during the period from October to May with the peak in January. Drastic year to year changes are not observed in each taxonomical group, excepting for fishes which vary rather abruptly, being affected by the appearance of the massive species. In Chapter VI, the stranded animals are analyzed distributionally and ecologically in regard to developmental stage and body form. The species number of the stranded community is numerous in the inshore benthic constituents, while the specimen number is high in the pelagic fish larvae and young, small crustaceans, jellyfishes, arrow worms, salpas, etc. The good swimmers such as torpedo-shape animals are very scarce in the stranded community as compared with the inhabitant community. Ecologically, the stranded community consists mainly of southern and offshore planktons and pelagics. In Chapter VII, environmental conditions and the process of stranding are discussed. It is concluded that these stranding animals, which mainly originate in southern and offshore waters, are i) transported through the Tsushima Strait into the Japan Sea during summer by the Tsushima Current and again conveyed to this area by the southward surface drift current in late autumn and winter, ii) transported from the East China Sea into this area by the Current in winter, iii) transported into this area from the Japan Sea by the southward deep current in late winter, and iv) transported into this area by both the first and second processes mentioned above. At the same time, the animals thus transported into the Strait area are carried to the coastal waters of northern Kyushu by the powerful coastward drift current induced by successive monsoons in winter, and then, cast on the beach together with the inshore animals. In conclusion, the author offers this kind of survey of these phenomena as a method of exploring the relationship between the animal community and the oceanographical structure of the waters.

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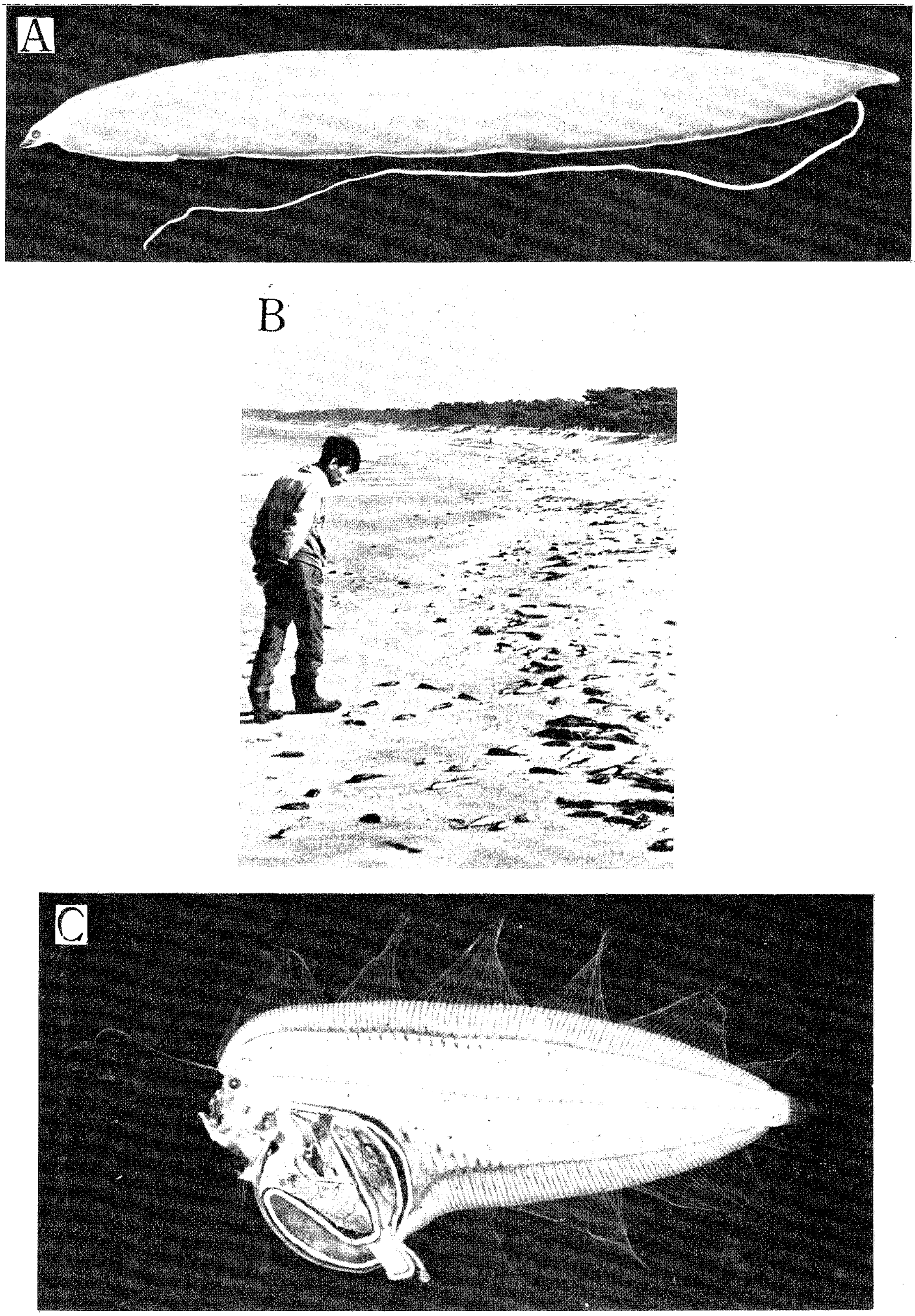
PLATE

Explanation of Plate I.

A. Leptocephalus larva (Congridae) stranded upon the Shingu beach, northern Kyushu, on January 2, 1966 (natural size).

B. *Boesemanichthys firmamentum* stranded upon the same beach on January 21, 1965.

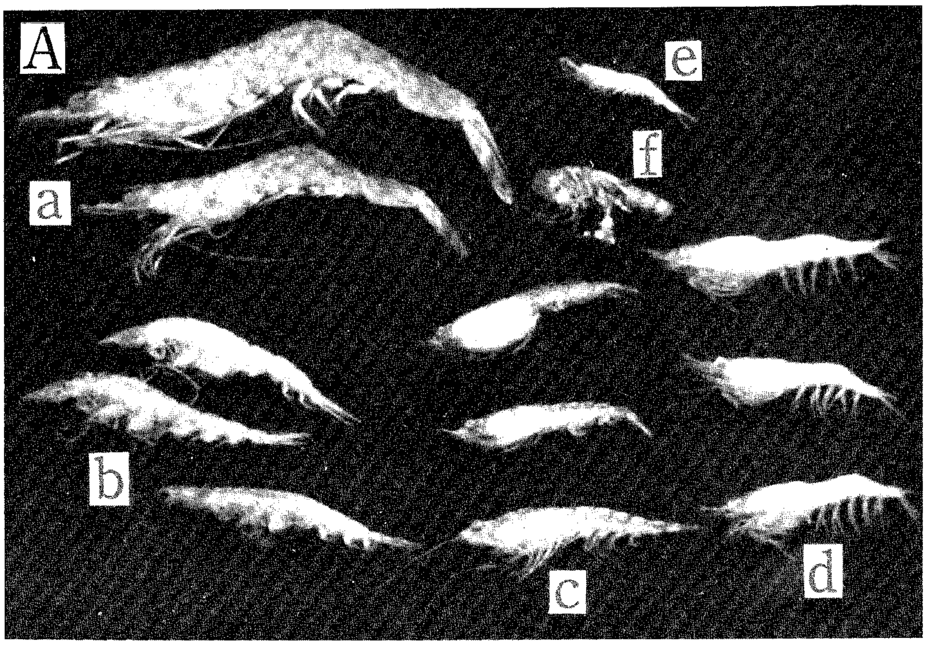
C. Bothinae larva (*Chascanopsetta*) stranded upon the same beach on December 25, 1967 (natural size).



Explanation of Plate II.

A. Crustaceans stranded upon the Shingu beach on December 25, 1965 (natural size).
  a. *Metapenaeopsis* (2 specimens).
  b. *Oxycepahlus porcellus* (3 specimens).
  c. *Lophogaster pacificus* (3 specimens).
  d. *Icotopus* (3 specimens).
  e. Mysidacea.
  f. *Phronima sedentaria.*

B. Floating shellfish and jellyfish stranded on the same beach on December 1, 1965 (natural size).
  a. *Violetta globosa.*
  b. *Physalia physalis* (3 specimens).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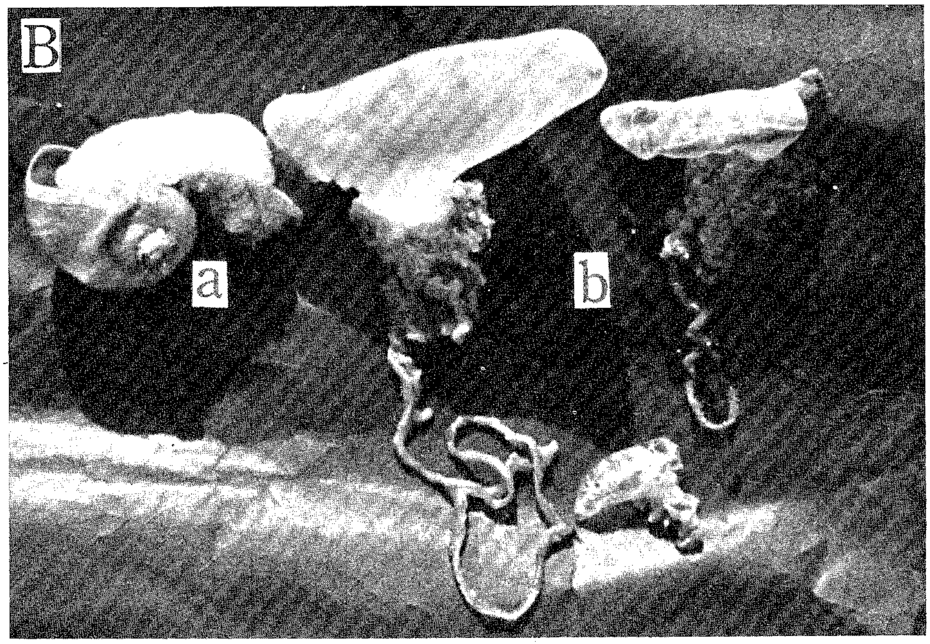
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a
b

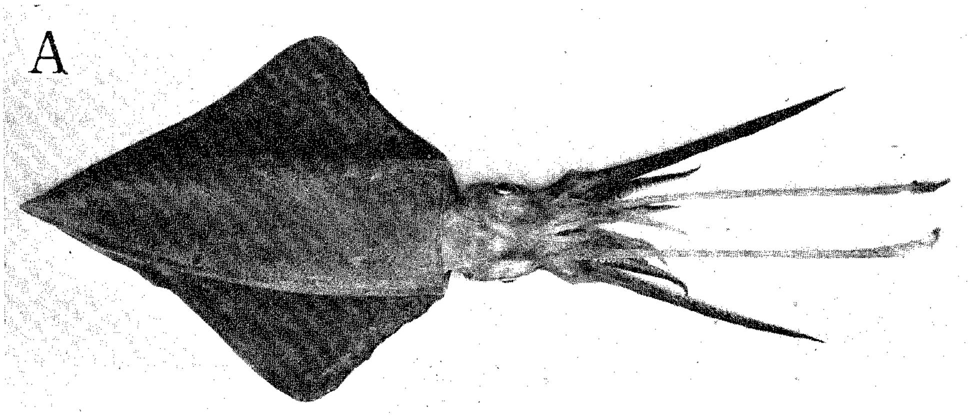
Explanation of Plate III.

A. *Thysanoteuthis rhombus* stranded upon the Shingu beach on December 25, 1966 (65 centimeters in mantle length).

B. *Argonauta argo* stranded upon the same beach on December 12, 1965 (15 centimeters in shell height).

C. *Tremoctopus violaceus* stranded upon the same beach on November 6, 1966 (70 centimeters in total length).

A



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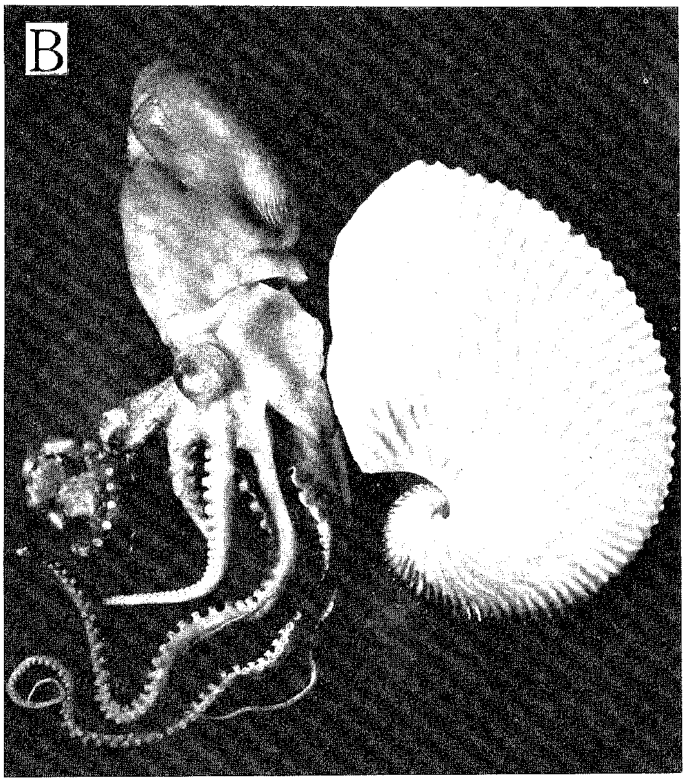

C