II. SCIENTIFIC PAPERS SUBMITTED FROM SESSIONS

2. Fisheries and Biology Sessions

A. Communities of the Okhotsk Sea and adjacent waters: composition, structure and dynamics
B. Abundance, distribution, dynamics of the common fishes of the Okhotsk Sea
C. Salmon of the Okhotsk Sea: biology, abundance and stock identification

Exogenous Succession of the Southwestern Sakhalin Algal Communities

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The southwestern Sakhalin is a traditional harvesting region for *Laminaria japonica*. Recently, the commercial importance of this region decreased due to a reduction of the area occupied by algae. Shifts in species distribution have resulted in a change of the species mix from the past.

MATERIAL AND METHODS

Data was collected and processed using the method of Kalugina-Gutnick (1975). Photo surveys were carried out in 1965-1967, 1990, and the data was analyzed using VNIICAM (Sorokin and others, 1987). Algal samples were also collected by divers in 1963 (Sarochan, 1963), 1988-1944 (SakhTINRO, SakhNIRO).

RESULTS

Macrophytobenthos of southwest Sakhalin consists of 242 species, 41 species related to Chlorophyta, 70 to Phaeophyta, and 131 to Rhodophyta (Klochkova,1994). Macrophyte distribution depends on bottom type near the southwestern coast of Sakhalin where abrasion terraces or "benches", all without alluvium are found on the underwater shore slope. Bare rocky surfaces are zones of active hydrodynamic processes. Benches are found along all the southwestern coast of Sakhalin but interrupted by bays and inlets at river mouths where a thin layer of alluvium is observed. The southwestern littoral zone had little alluvium because the rivers and streams are small. Soils, mainly sand, which is moved some kilometres occurs near the Cape of Slepikovsky and the Cape of Lopatino.

Hydrological conditions of southwest Sakhalin littoral zone are generally determined by two currents, the West Sakhalin and the Tsushima. Waters of the Tsushima Current enter into the Tatar Strait around Moneron Island from the west and swung to the south along the coast into the La Perouse Strait. Waters of the Okhotsk Sea enter into the Japan Sea and move along the north coast creating a tidal current of cold-water near southwest Sakhalin (up to the Cape of Windis) (Budaeva, 1981).

The algae habitat is along the coast at depths of 0.5-15 m. Three algal communities, two three-strata, and one one-stratum were delineated. One community is located near Sadovniki-Gornozavodsk at depths of 0.5-1.5 m (Fig. 1). The upper stratum is large brown algae (*Laminaria japonica*, *Laminaria cichorioides*, *Costaria costata*, *Cystoseira crassipes*). *Laminaria japonica* is the dominant species in both biomass (2,000 g/sq.m in avarage) and in the frequency of occurrence. This community was named *Laminaria japonica*. The species most common to the middle stratum are *Dichloria viridis*, *Rhodymenia pertusa*, *Tichocarpus crinitus*, *Ptilota filicina*, *Chondrus pinnulatus*, *Ulva fenestata*, *Monostroma grevillei* and others. The algae which dominates the lower stratum are *Bossiela cretacea*, *Corallina filifermis* and cortical algae of genus *Melobesia*. For more than a year 30 species of macrophytes were found in this community.

A second community was located near Gornozavodsk, the Cape of Krilyon at depths of 1-10 m. It contains many-stratum and differs from the first area as *Alaria marginata* and *Laminaria angustata*. *Laminaria japonica* appeared in the upper stratum. Alaria marginata is not the most abundant but we called this community Alaria. The middle and lower stratum species structure is similar to the first community.

A third community was delineated as one-stratum composed of red corallina algae of species *Corallina*, *Bossiela*, *Melobesia* and *Lithothamnion* which we called the *Corallina* community. This community is located in the littoral zone near the village Sadovniki-Town Nevelskb but deeper in the water than the *Laminaria* community at depths of 2-10 m.

Analysis of data from the southwest Sakhalin near the village of Sadovniki-town Nevelsk indicats that exogenous succession occurred. The *Laminaria* community which only occurs in the most shallow part of bench at depths of 0.5-1.5 m was replaced by Corallina. This change is clearly seen in Fig. 2 where the algae distribution at the villages Yablochnoye-Antonovo is shown. Limits of the *Laminaria* distribution were determined with great precision. Table 1 shows the reduced distribution of *Laminaria* in the zone.

Laminaria japonica is locate on the tops of ridges where spring ice can cutoff the second year thallus. This causes *Laminaria japonica* to have a one-year cycle which can adversily affect the stock state as the biomass of one-year plants is smaller than second year plants. The horizontal distribution of succession rapidly takes place in a southerly direction. In 1994 succession occurred near Sadovniki-Kalinino and in 1995 the southern limit of the Corallina community reached Nevelsk (Fig. 3).

Succession also occurs near southwest Sakhalin which could have been caused by changes in the Tsushima Current found by Komaki (1988). If this hypothesis is true, the *Corallina* species movement along the coast will continue to the south up to the Cape of Windis. Another possible explanation for the succession could be the presence of dense accumulations of urchins (Nabata and others, 1992). Near Sadovniki-town Nevelsk the urchin (*Strongylocentrotus intermedius*) is mainly phytophagous. Last year, the reproduction of *Laminaria japonica* likely exceeded the algae consumed by urchins. The most dense urchin accumulations aree at 1-5 m in the *Corallina* community and these urchins are feeding on Corallinaceae. The succession may have been caused by the intensive use of concrete to develop 12% of the shoreline of the village Sadovniki-town Nevelsk. The direct influence of concrete on the development of algae has not studied however.

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TABLES AND FIGURES

Table 1. Changes in the Laminaria community near Yablochnoye-Antonovo (sk.m).

Year	1965	1990	1995
Square	184300	95300	61000

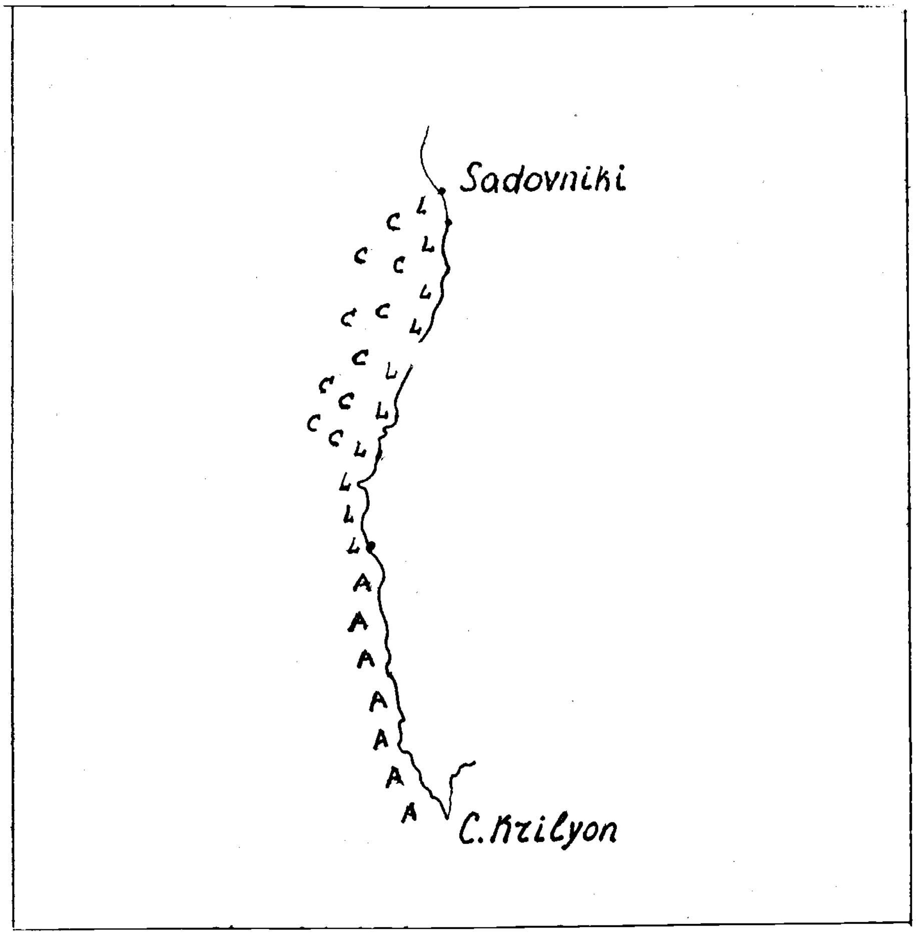

Fig.1. Scheme of algae association distribution in the area of the village Sadovniki- the Cape of Krilyon.
L- Laminaria association, A - Alaria association, C - Corallina association

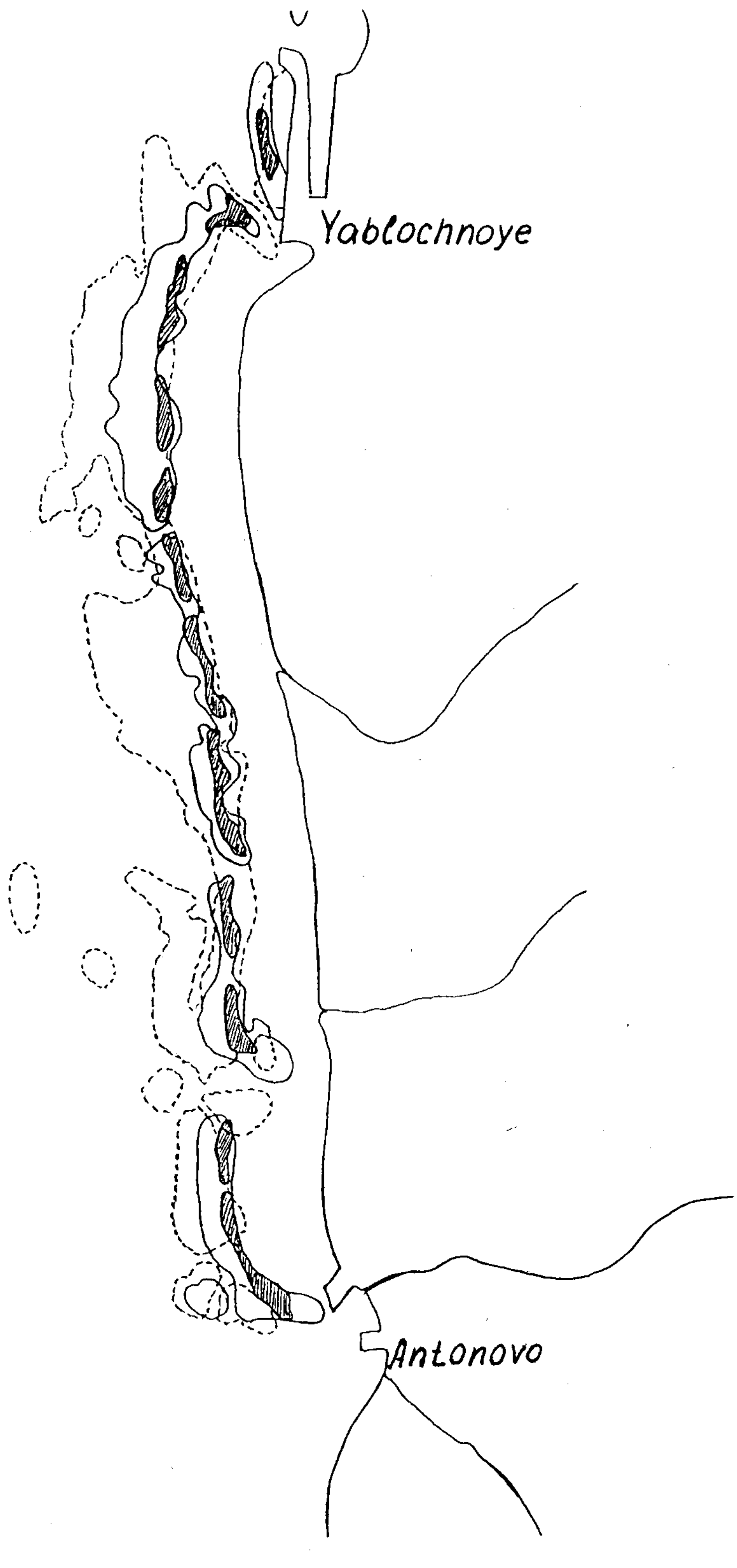

Fig.2. Map-scheme of Laminaria association area change in the region of the villages Yablochnoye-Antonovo from 1965 to 1995.

---- - 1965

____ - 1990

///// - 1995

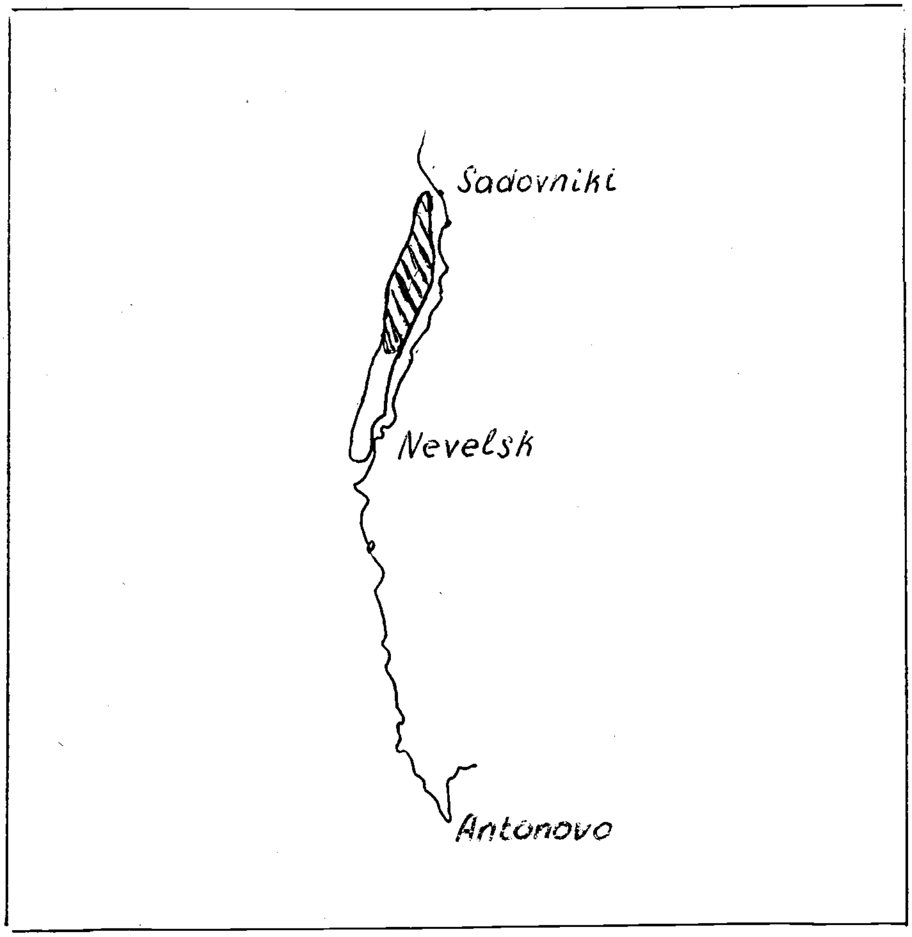

Fig.3. Scheme of Corallina association in the region of the village Sadovniki - Nevelsk in 1994-1995.

///// - 1994

— - 1995

Characteristics of Pelagic and Benthic Communities on the North Sakhalin Island Shelf

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INTRODUCTION

Sakhalin Island shelf is an area where a number of fisheries for bottom and pelagic species occur. The region also has a great potential for oil and gas exploitation and needs to have an ecological monitoring system developed to monitor exploration and production to prevent possible negative effects on marine organisms. Five expeditions to the North Sakhalin Island shelf have been carried out by FERHRI scientists in 1990, 1991 and 1994. Background data on pollutant concentrations and the characteristics of the benthos and phyto and zooplankton were collected (Tkalin, 1993; Tkalin and Belan, 1993).

Phytoplankton samples were collected from the surface layer and zooplankton was sampled from the bottom to surface during the daytime using a large Jeday net. Two benthos samples were taken at each station using a Van-Veen grab (0.11 m^2) or modified Petersen grab (0.25 m^2).

PHYTO AND ZOOPLANKTON

In 1990-1991, twenty four species of diatoms and flagellates were collected; 23 species are typical of marine waters and one (*Glenodinium pilula*) of brackish waters. The spatial distribution of phytoplankton is not uniform. In 1990, the maximum values of phytoplankton biomass and abundance (7,907 mg/m^3 and 454,500 ind/l) are in the northern part of study area and minimum values (262 mg/m^3 and 7,700 ind./l) are at the southern periphery. In 1991, high values of biomass and density of phytoplankton are in the northern part of study area (1,046 mg/m^3 and 22,100 ind/l) as well as in the south (2,082 mg/m^3, 16,600 ind/l). In 1990 and 1991, the diatom *Nitzshia seriata* is dominant (biomass) in the northern periphery and the flagellates *Protoperidinium granii* and *Gyrodinium lacryma* are dominant in the southern part of study area.

Zooplankton in the study area is mainly copepods (up to 88% from total abundance). The biomass and abundance of zooplankton decreases from the north to the south. In 1990, maximum values are about 1,660 mg/m^3 and 17,789 ind/m^3 and the minimum values are about 745 mg/m^3 and 11,315 ind/m^3 respectively. In 1991, the spatial distribution and abundance of zooplankton is the same as in 1990 but the seston biomass was three times lower.

In general the status of the plankton community is considered to be normal except for an area where the zooplankton is affected by an oil spill that caused a reduction of more than 40% of plankton (B.M. Borisov, personal communication).

BENTHOS

Benthos samples were collected along the North Sakhalin Island shelf in 1990-1991 and in 1994. In 1990 and 1991, the highest biomass (1,600 $g/m^{2})$ is in the northern part of study area, with the average biomass being more than 500 g/m^2. The sea urchin *Echinarachnius parma* (*Echinodermata*) is the most abundant. Minimum values of biomass (13 g/m^2) were detected in the southern part of study area where *Polychaeta* and *Actiniaria* dominated. In general *Echinodermata* and *Bivalvia* are the most abundant (biomass) in the investigated area.

In 1994, benthos samples were collected from four polygons along the North Sakhalin Island shelf (Table 1). Data on the distribution of the benthos biomass are presented in Table 2. Polygon A is situated in the Sakhalin Bay, close to the Amur River mouth and the average biomass is 56 g/m^2. *Echinodermata* is absent except for *Stegophiura brachyactis* (*Ophiuroidea*) and the *Crustacea*, *Polychaeta* and *Bivalvia* are the most abundant (Table 3). Macrobenthic fauna is typical of brackish waters.

Polygons B, C and D were situated along the Northeast Sakhalin Island shelf. The biomass in polygon B ranged from 300 to 8,000 g/m^2 with an average of more than 1,300 g/m^2. Sea urchin *Echinarachnius parma* are the most abundant (Table 3). At some stations *E. parma* biomass exceeds 1,000 g/m^2 and at one station reached 8,000 g/m^2 (abundance 360 ind/m^2). The average biomass in polygon C exceeded 1,500 g/m^2, varying from 298 to 2,700 g/m^2. *E. parma* is dominant at all stations in this area comprising of up to 80% of the total benthos biomass (Table 3). At some stations the density of *E. parma* abundance and biomass reached 280 ind/m^2 and biomass 3,000 g/m^2 respectively. The average biomass in polygon D was 732 g/m^2. Sea urchin *E. parma* is dominant, but the percentage of the total biomass and frequency of occurrence decreased to 75% and 85% respectively (Table 3). The percentage of the *Bivalvia* increased to 13% and the mollusc *Tridonta borealis borealis* dominated at two stations.

CONCLUSION

Several expeditions were carried out in 1990-1991 and in 1994 to determine the abundance of species on the Sakhalin Island shelf. Data collected of benthos and phyto and zooplankton along the shelf off North Sakhalin Island before commercial oil and gas extraction shows high productivity and variability of pelagic and bottom communities. Continuous ecological monitoring during the exploitation of mineral resources is required to determine if negative changes in the marine environment quality occurs in order to take remedial action if necessary.

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TABLES AND FIGURES

Table 1. Polygons along the north shelf of Sakhalin Island.

Polygon	Latitude (center)	Longitude (center)	Average depth, m	Number of stations
A	52°58'	142°19'	25	10
B	52°55'	143°52'	67	20
C	52°31'	144°04'	83	15
D	52°26'	143°41'	32	13

Table 2. Benthos biomass in the study areas (g/m^2).

Polygon	n	min	max	X	(S_{n-1})
A	10	< 1	134	56	(50)
B	20	300	8248	1339	(1809)
C	15	298	2700	1503	(744)
D	13	24	2656	732	(701)

Table 3. Average biomass of benthos (g/m^2) and the percent of total biomass.

	Polygons			
Benthos	A	B	C	D
Actiniaria	< 1 (< 1)	50 (4)	57 (4)	43 (6)
Bivalvia	10 (18)	------	99 (7)	93 (13)
Crustacea	16 (29)	31 (2)	31 (2)	35 (5)
Echinoidea	------	1146 (86)	1195 (80)	552 (75)
Gastropoda	7 (12)	8 (< 1)	20 (1)	1 (< 1)
Ophiuroidea	7 (12)	------	44 (3)	1 (< 1)
Polychaeta	15 (27)	15 (1)	19 (1)	8 (1)

Fishery and Oceanographic Database of Okhotsk Sea

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The specific feature of resource research and especially in commercial fishery forecasting is that field work costs are augmented by the processing of data from commercial and unexploited stocks. The requirement for providing marine resource data to researchers includes the following:

- planning, organizing and carrying out the vessel cruises;
- collecting data to allow the short and long term forecasting of stocks abundance;
- creating a data base management system for storing, assembling and processing oceanographic and biological data that can be easily used;
- developing programs to provide analytical and forecasting ability;
- preparing data for analysis and for monthly, quarterly and annual forecasts and for other practical recommendations.

These requirements are inter related to form a linear sequence of events; a sequential method for solving problems is a necessity for developing the technology for complex research on ocean bio-resources. It is possible to solve a number of questions using specialized computer systems developed for keeping the data with access channels and using the technical and research potentiality of staff to analyze the data. The data base should be available at all times for the data processing and analyses and "friendly" programs for complex data analyses should be available. These programs should allow for simple adaptation to new data and methods, etc. Thus, it should be possible to use an interactive process where a researcher can obtain current information quickly, process and present the data in a convenient form, make formal and expert analysis and repeat any stage of the data processing using new data etc. This paper deals with the state of data management and processing capability for the Okhotsk Sea resources. Bioproductivity of the Okhotsk Sea is at a high level from analysis of the data from long-term investigations carried out by TINRO research cruises.

By the early 1980s the monitoring of fishery resources were well developed by TINRO. The exploratory stage of investigating the North and South Pacific Ocean from Arctic to Antarctic was completed and the qualitative and quantitative composition of commercial fishing became the central activity. The main purpose of research is to focus on the establishment of rational fishing practices by the fishing fleet. A system of regular surveys was introduced to monitor pollock, herring, halibut, crabs and other species in the Okhotsk Sea.

The ecosystem investigations of 1980s in the Okhotsk Sea developed a better understanding of the biocenosis, food availability and the interaction of fishery resources. Since 1965, more than 160 cruises in the Okhotsk Sea contribute to the development of a large database that is available for analysis. The long-term monitoring data make it possible to better understand the dynamic processes which occur in the Okhotsk Sea and to estimate the influence of fishing pressure on the dynamic processes and to look at the effects of climate change, etc. Moreover, retrospective analysis of the data has become more important recently, due to funding shortages.

From early 1981 all data have been saved in a single format in the appropriate database. The most common formats are:

- trawl log
- specimen
- length frequency
- hydrological

A large amount of data is kept in the database as shown in Fig. 3. One data base deals with the distribution of hydrological stations in the northwest parts of Pacific ocean and adjacent seas and another with the coincident distribution of research trawls in Okhotsk Sea. More than 50,000 trawl logs were collected from esearch cruises; data on the results of biological analysis of 110,000 species; 7,000 samples of general analysis (one sample consists of 100-200 species) and more than 52,000 hydrological stations are held in the Okhotsk Sea database. The distribution of the biological data on fished species is shown in Table 1 and the distribution of monthly hydrological observations are shown in Table 2.

Fisheries statistics are collected in a special database. Monitoring of commercial fishing is ensured by a special automatic system for data collected from 60-80% of the commercial fleet. The captains provide daily information about the fishing operation. The monitoring of fishing has been in place for 12 years and it has resulted in the development of a unique data base on the main fishing areas. Data from 400,000 fishing trips dealing with fishing for pollack, cod, halibut and herring are kept in the database which include catches and other parameters for all areas. The Software allows analysis of each parameter for all fishing areas and to study the changes of the parameters with time, analyze stock density effects and solve a number of other problems related to the fishery. Since 1960, the data on catches have been kept in the database as annual observations. The database can be used to solve simple questions with unrestricted selection of time and space scales to complex analysis of population state.

The following analyses are the most popular: analysis of the cartography of unstudied parameters, contouring the size-mass frequency distributions using the annual data, calculating the climatic norms according to definite squares and calculating anomalies using different characteristics. The best result of our work is the creation of a Fishing Areas Catalogue. The Catalogue includes more than 400 fishing charts of the main areas and parameters of Okhotsk Sea. The Catalogue can be used, not only by scientists, but by captains of fishing vessels. Using fish distribution charts on board of vessels can allow captains to fish more effectively by selecting the best fishing grounds to improve catches while saving time and fuel. The creation of a Catalogue of Far Eastern Seas is possible using data available for all fish species from each research cruise. The surveys are often carried out through international cooperation by combining the efforts of scientists from interested countries to include their information sources, computer techniques, funding and printing facilities.

The information available on computers could be doubled if data collected in the 1960-80s period is added to the current data base. Our plans, for the near future, are to increase our efforts to put this data on the computer. In conclusion, it should be noted that developing the fishery biological database continues to be an ongoing process.

Species	Quantity of trawl logs	Quantity of specimen forms	Quantity of length frequency forms
Pollack	9274	70733	4408
Cod	3216	1690	153
Navaga	2152	2725	160
Herring	1694	4472	251
Flounder	14090	5649	920
Pacific Salmon	982	1819	36
Greenling	1240	1880	42
Halibut	4348	13687	427
Capelin	1269	2504	130
Saury	9	67	3
Mackerel	23	600	2
Goby	11710	1470	76
Sardine	277	5102	159
Smelt	1170	50	35
Rockfish	1690	-	34
Sea Bream	4	-	-
Jack Mackerel	10	-	-

Table 1. Distribution of biological data, collected during the trips of scientific and commercial vessels (Okhotsk Sea).

Depth (m)	MONTH												Number of measurments
	1	2	3	4	5	6	7	8	9	10	11	12	
0	801	1021	1184	2375	3720	7923	9545	10409	6390	4503	2269	1467	51607
	259	429	408	961	2218	5318	6724	7693	4172	2896	1644	1082	33798
100	443	646	684	1017	1741	4009	4157	4103	2723	2147	1293	973	23936
	185	337	303	462	1395	3228	3289	3083	1845	1471	1048	879	17525
200	240	447	492	528	1023	2638	2361	2215	1536	1190	766	644	14080
	129	283	260	313	863	2343	1905	1700	1119	866	663	585	11029
500	74	106	119	115	449	1015	980	920	478	571	279	242	5348
	73	96	113	108	415	953	852	740	353	455	268	243	4668
1000	39	7	48	36	155	439	320	286	132	187	167	121	1936
	42	7	47	68	155	317	303	262	116	160	159	115	1751
1500	23	3	27	11	73	207	96	158	51	68	56	75	846
	23	3	25	23	72	200	95	122	51	63	48	59	784
2000	10	-	7	1	46	134	27	39	14	33	30	37	378
	10	-	5	2	44	122	24	37	15	33	27	29	348
3000	-	-	-	-	17	32	8	10	2	16	4	8	97
	-	-	-	1	17	31	8	10	1	16	5	8	97

Table 2. Distribution of hydrological observations in Okhotsk Sea.

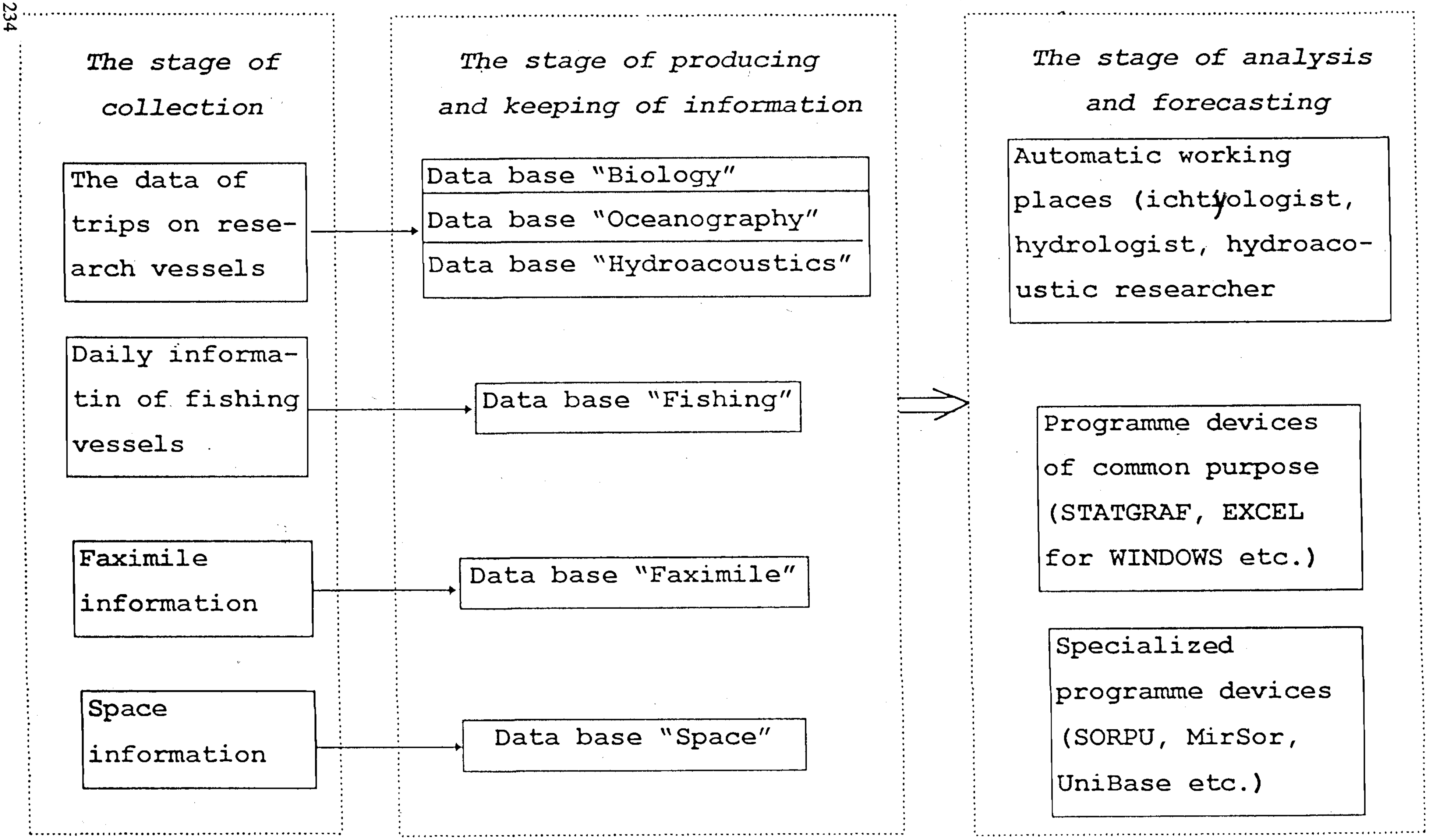

Fig. 1. The main stages of information technology (TINRO).

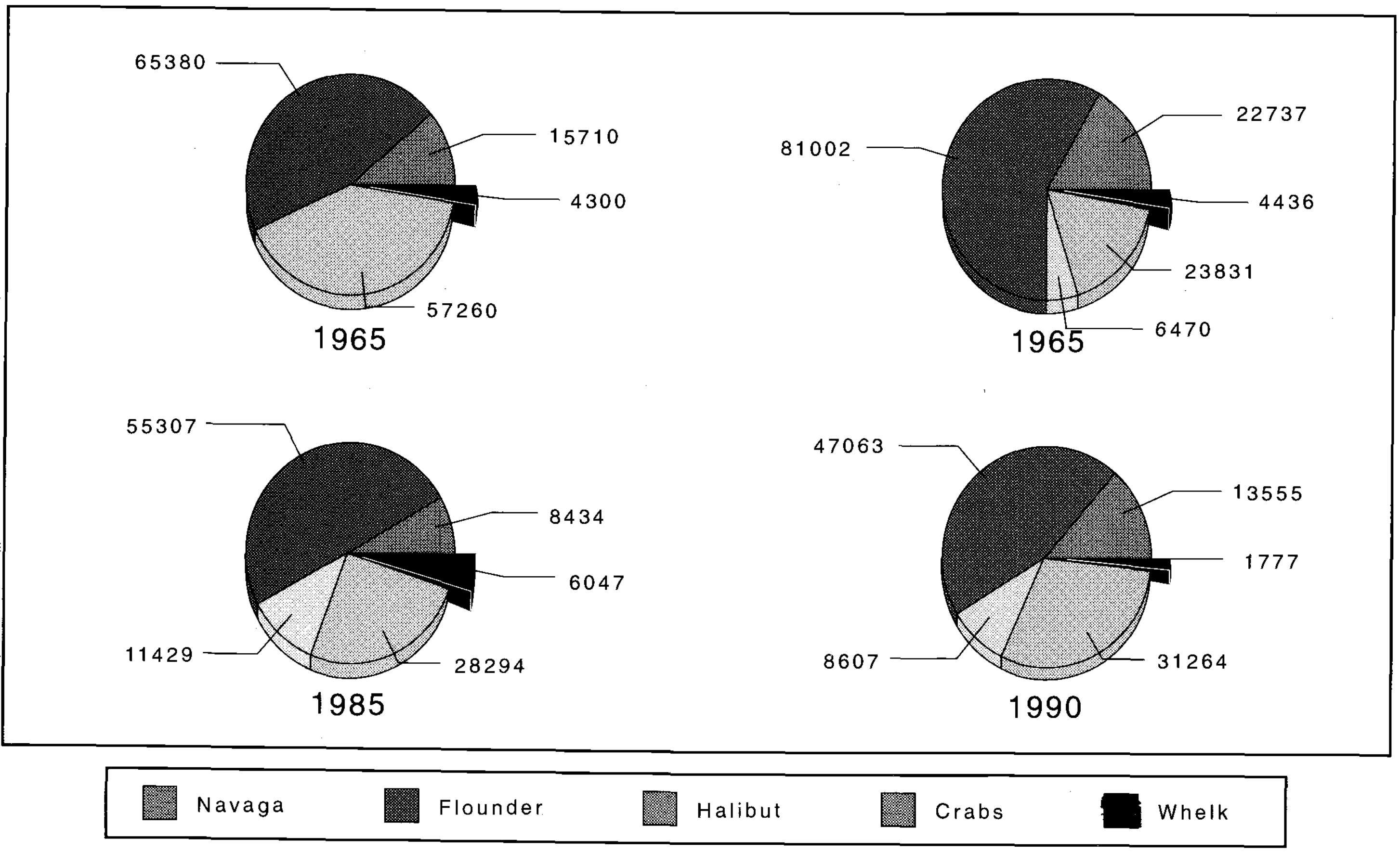

Fig. 2. Dynamics of catch structure of the main groundfish in tons.

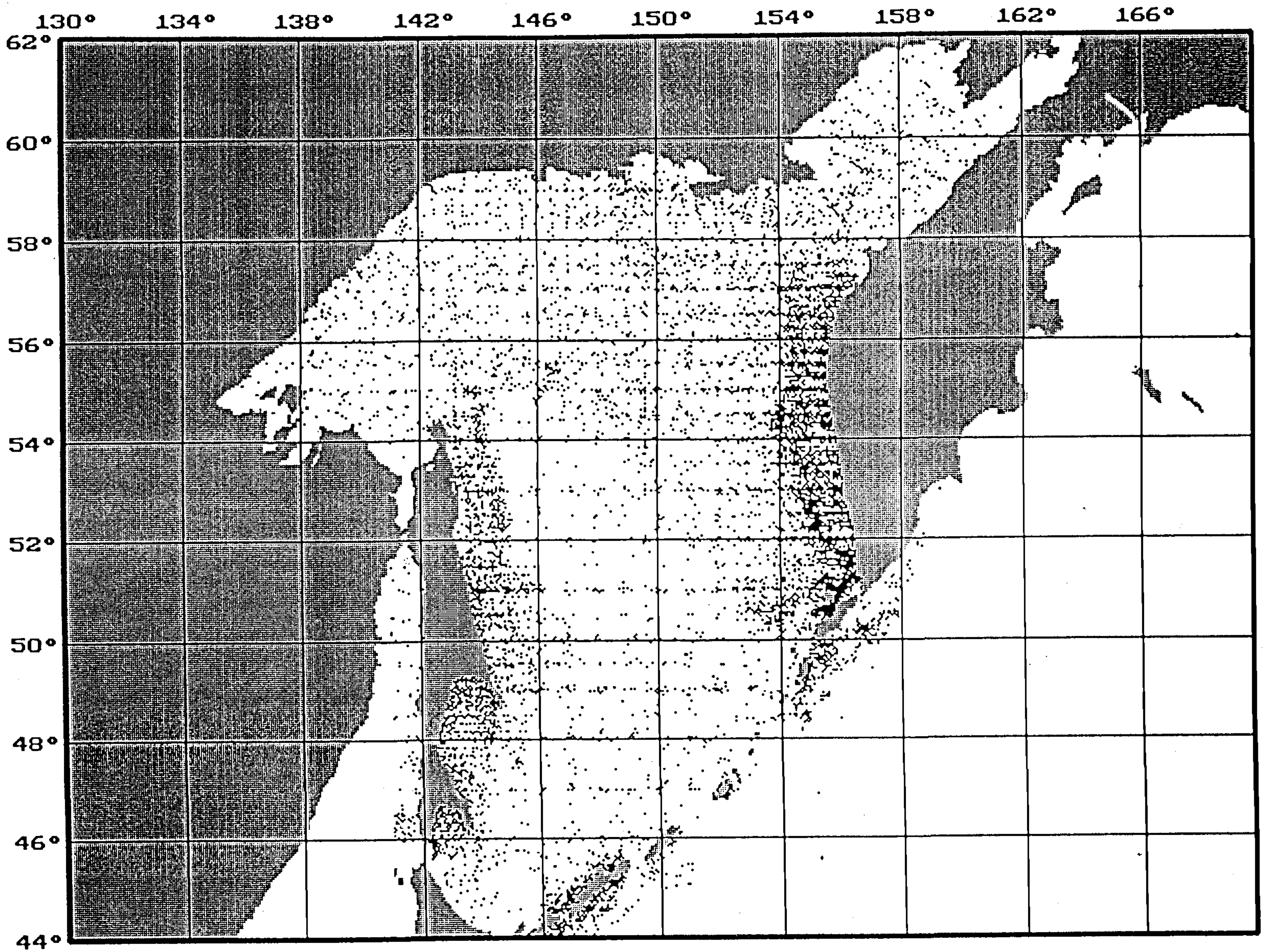

Fig. 3. Locations of research trawlings (1980-1994).

Interannual Dynamics of the Epipelagic Ichthyocen Structure in the Okhotsk Sea

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From the beginning of the 1990s, the oceanography changes in the northern Pacific due to changes in the level of water exchange between the Okhotsk Sea and Pacific Ocean and, consequently, the sea current intensity. The abundance of common species changes and these fluctuations differs from the long-term interannual variability. The present time period is interpreted as "cold" similar to the 1940-60s cold period (Shuntov et al.1996).

Climate change in the Sea of Okhotsk is thought to have resulted from a long-term change of atmospheric circulation over the northern Pacific and a decrease in the intensity of water exchange between Okhotsk Sea and Pacific Ocean. The West Kamchatka and East Sakhalin Currents which indicate water inflow and outflow are weaker than in the previous ten years. The influence of the cold dichothermal layer becomes more apparent as a consequence of the decrease in the warm Pacific water inflow. Taking into consideration this reasoning, the present period is thought to be cold and the impact on the epipelagic fish community was found to be as follows:

1. the walleye pollock abundance decreases 2-3 times;
2. the herring abundance increases 4-5 times;
3. subtropical fishes such as pacific sardine and anchovy discontinue migrating into the southern Okhotsk Sea in summer;
4. the abundance of the pacific salmon increases over the last two years.

Increases in abundance of some fish species did not compensate for the decreases in walleye-pollock, thus, the total fish biomass in the epipelagic layer is still approximately 1.5 times lower (Table 1). A number of studies have been carried out on changes in the nekton composition but little is known about changes in the community structural. Data collected during the last combined surveys allow estimates of the total consumption of fish, the composition of food and the long-term dynamics.

The epipelagic fish community of the Okhotsk Sea consists of walleye-pollock (about 6.0 mln.t), herring (2.5 mln.t), capelin (0.08 mln.t), salmon (pink and chum, 0.48 mln.t) and northern smoothtongue (deep-sea smelt 1.2 mln.t). In comparison with the 1980s the main changes in the fish community composition occurs due to a decrease in abundance of walleye pollock while the herring increases. In previous years, walleye pollock in the southern deep basin is about 1.5-2.0 mln.t in the summer. Subtropical fishes such as sardine and anchovy stopped migrating to the southern Okhotsk Sea. Salmon and northern smoothtongue are the only abundant species there. The total fish biomass in the epipelagic layer, in the southern Okhotsk Sea, decreases approximately 2-3 times. In the northern Okhotsk Sea, the total fish biomass decreases insignificantly (15-20%) because both walleye-pollock and herring remain comparatively abundant. Therefore, fish distribution in the epipelagic layer increases northward relative to the long-term trends in species abundance.

The data show that the species composition has significantly changed and total fish daily diet decreases insignificantly from 568 th.t to 511 th.t in comparison with the 1980s (Fig. 1). Euphausiids decrease from 57 to 28% due to T.longipes, while amphipods increase from 7.5 to 17.3%, pteropods from 0.8 to 9.2%, and copepods and forage fish stay at about the same level of abundance. The walleye pollock share of food resources stays stable while the capelin share increases two times and the mesopelagic fishes decreases six times. Other hydrobionts consume less than 1% of the total available food. Such changes in the total diet are due to the affect of fluctuations of key species in both the plankton and nekton. Thus, the trophic structure including fish distribution throughout Okhotsk Sea is influenced by the oceanographic conditions. Further, Walleye pollock eat about 80% of the total daily diet in the 1980s. Currently, in summer, walleye-pollock and herring consume almost equal amounts 48 and 44% respectively (Fig. 2). Although the condition of each species differs, as herring had a higher ration value of about 9% of body weight in comparison with about 4% for pollock.

CONCLUSION

Currently, walleye-pollock and herring are key nekton species utilizing most of the organic matter in the epipelagic layer of Okhotsk Sea, though the walleye pollock abundance has declined considerably. Taking into account that these two species are more abundant in the northern Okhotsk Sea, availability determines the total diet composition. In comparison with the 1980s, the total consumption decreases insignificantly throughout the whole epipelagic layer of the Okhotsk Sea, but recently a difference between the north and south appears to be because of the northward shift of fish species biomass. Though the total fish biomass in the epipelagic layer decreases by about 1.5 times, the quantity of organic material passing through fish remains almost the same.

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TABLES AND FIGURES

Table 1. Biomass of common fishes (thousand tonnes / %) in epipelagic layer (0-200 m) in Okhotsk Sea in summer

	1980-s		1993 - 95	
Walleye pollock	11300	78.3	6000	58.4
Herring	500	3.5	2500	24.4
Deep-sea smelt	2457	17.0	1200	11.7
Salmon	150	1.0	480	4.7
Capelin	15	0.1	80	0.8
Total	14422		10260	
Concentration, tonnes per km^2	9.6		6.8	

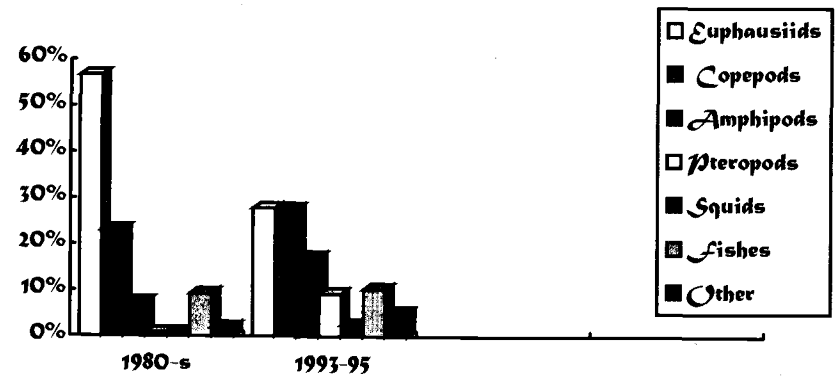

Fig. 1. Composition of total daily diet of all fishes in epipelagic layer of Okhotsk Sea in summer.

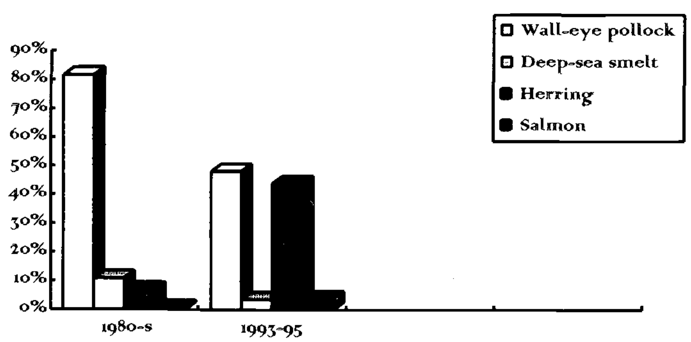

Fig. 2. The shares of common consumers in the total daily diet.

Quantitative Seasonal and Year-to-Year Changes of Phytoplankton in the Okhotsk Sea and off Kuril Area of the Pacific

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Data from 1353 Jady plankton net samples collected over 4 years from the upper layer of the Okhotsk Sea and adjacent Pacific Ocean areas were analysed (Fig. 1). The net is made of kapron with a mesh size of 0.168 mm and mouth diameter 37 cm. Tows were carried out in the 0-50 m and 0-200 m (bottom) levels. Phytoplankton was separated from zooplankton by a set of sieves ("Recomendations...",1984). The data were averaged by 1-degree squares and biostatistical areas (Fig. 1) (Volkov, 1986; Shuntov et al., 1993). The organisms sampled were separated into the different genera for analysis.

During the period of the investigation diatom algae are the most abundant. The "bloom" is caused by intensive development of *Chaetoceros* and *Thalassiothrix*. *Peridinium* is noted as single cells.

In 1993, three overlapping surveys are carried out by 3 vessels to estimate seasonal phytoplankton distribution (Fig. 2) and biomass (Tables 2, 3 & 4). Anomalous oceanographic condition were found due to a lack of water influx into the Okhotsk sea through the northern Kuril Straits (Shuntov, 1994), which causes sea surface temperatures of 9-10 degrees, 1-1.5 degrees lower than in 1991.

In area 13-a (above shelf water of the central and southern Kuril Islands), the phytoplankton abundance within the 50 m layer is the richest. The average phytoplankton biomass for all three surveys is at a maximum in the area and concentrations increase 4.2 times between July and August from 1,242-4,980-5,250 mg/m^3. The total phytoplankton concentration in the area increases from 4.6-18.3-19.3 bln.t. The same is observed in area 12 where the biomass of plankton during the second survey is 1.7 times higher than the first (2,050 and 1,242 mg/m^3). At the same time the quantity of silicon in both areas decreases from 10-20 to 5-6 mg-at./l and phosphates from 0.8-1.0 to 0.2-0.4 mkg-at/l. The difference in phytoplankton biomass between areas is most evident in the third survey. For instance, in areas 10 and 11 phytoplankton is almost non existent, in area 12, it is more than 1,000 mg/m^3 and in area 13 more than 5,000 mg/m^3.

In the Pacific, maximum biomass of phytoplankton occurs during the second survey (7,320, 8,152 and 5,800 mg/m^3) but the average biomass gradually increases between July and August, from the first survey to the third from 819 to 1,390 and to 1,470 mg/m^3.

In 1993, the biomass of phytoplankton in the Okhotsk sea and in the Pacific is 2-5 times higher than in other years.

In conclusion, the distribution of plankton is patchy which is caused by the complex oceanographic conditions. The highest biomass of phytoplankton is in areas above the shelf and in upwelling zones. The data confirms that the Sakhalin-Kuril region continues to be a highly productive area. Seasonal Bogorovs index varies from 0 to 4,540, thus, the plankton community appears to be in a different stage of seasonal succession in different parts of the region from spring to mid-summer.

Changes in abundance continues from April through to September - October depending on environmental condition in the main part of the Okhotsk Sea.

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TABLES AND FIGURES

Table 1. Samples collected.

R/S	Year	Month	Number of samples in layer		
			200 - 0 m	50 - 0 m	Total
1. "Mlechny put"	1988	VI - VIII	187	-	187
2. "Pr. Levanidov", "Pr. Kaganovsky"	1991	VII - VIII	181	-	181
3. "Pr. Kaganovsky", "Novouljanovsk"	1992	VII - VIII	216	212	428
4. "Pr. Kizevetter"	1993	VII - VIII	35	36	71
"TINRO"	1993	VII - VIII	107	119	226
"Pr. Soldatov"	1993	VII - VIII	131	129	260
Total:			857	496	1353

Table 2. Biomass of phytoplankton in different areas of Sakhalin-Kuril region, July 1 - 28, 1993.

Area	Number of stat.	Square, t. km²	Layer 50 - 0 m			Layer 200 - 0 m		
			Biomass, mg/m³	Biomass, t/km²	Stocks, thous. t	Biomass, mg/m³	Biomass, t/km²	Stocks, thous. t
Okhotsk Sea								
8	7	35.0	106	5.3	185.5	48	9.6	336.0
9	15	121.0	695	34.8	4210.8	157	31.4	3799.4
10	9	35.0	1580	79.0	2765.0	556	99.0	3465.0
11	8	56.0	49	2.5	140.0	22	2.7	151.2
12	15	154.0	1242	62.1	9563.4	349	69.8	10749.2
13[a]	14	73.5	1242	62.1	4564.4	396	79.2	5821.2
13[b]	3	24.5	104	5.2	127.4	41	8.2	200.9
Total:	71	499.0	717	35.9	21505.0	224	42.8	24522.9
Pacific Ocean								
7	27	150.0	1189	59.5	8925.0	465	90.7	13605.0
8	31	242.0	609	30.5	7381.0	170	34.0	8228.0
8[a]	8	83.0	176	8.8	730.4	37	7.4	614.2
9	8	38.5	1951	97.6	3757.6	523	95.7	3684.5
10	13	135.0	171	8.6	1161.0	68	13.6	1836.0
Total:	87	649.0	819	41.0	21955.0	253	48.3	27967.7

Table 3. Biomass of phytoplankton in different areas of Sakhalin-Kuril region, July 20 - August 7, 1993.

Area	Number of Stations	Square t. km^2	Layer 50 - 0 m			Layer 200 - 0 m		
			Biomass, mg/m^3	Biomass, t/km^2	Stocks thousand t	Biomass mg/m^3	Biomass t/km^2	Stocks thousand. t
Okhotsk Sea								
9	22	170.0	476	23.8	4046.0	174	34.8	5916.0
10	9	35.0	1071	53.6	1876.0	556	98.4	3444.0
11	8	56.0	49	2.5	140.0	22	2.7	151.2
12	22	154.0	2050	102.5	15785.0	692	138.4	21313.6
13[a]	10	73.5	4981	249.1	18308.9	2313	462.6	34001.1
13[b]	6	24.5	71	3.6	88.0	28	5.4	132.3
Total:	77	513.0	1450	72.5	40243.9	631	123.7	64958.2
Pacific Ocean								
7	14	150.0	1107	55.4	8310.0	317	63.4	9510.0
9	11	38.5	2912	145.6	5605.6	827	148.0	5698.0
10	3	40.0	150	7.5	47.5	39	7.8	312.0
Total:	28	228.5	1390	69.5	13963.1	394	73.1	15520.0

Table 4. Biomass of phytoplankton in different areas of Sakhalin-Kuril region, August 2 - 17, 1993.

Area	Number of stat.	Square, t. km^2	Layer 50 - 0 m			Layer 200 - 0 m		
			Biomass, mg/m^3	Biomass, t/km^2	Stocks, thous. t	Biomass, mg/m^3	Biomass, t/km^2	Stocks, thous. t
Okhotsk Sea								
9	9	170.0	507	25.4	4318.0	149	29.8	5066.0
10	7	35.0	+	+	+	24	3.8	133.0
11	9	56.0	1	0.1	5.6	17	1.2	67.2
12	14	154.0	1118	55.9	8608.6	632	126.4	19465.6
13[a]	13	73.5	5250	262.5	19293.8	2001	400.2	29414.7
13[b]	4	24.5	87	4.4	107.8	39	7.8	191.1
Total:	56	513.0	1161	58.0	32333.8	477	94.9	54337.6
Pacific Ocean								
7	13	150.0	1977	98.9	14827.5	669	133.8	20070.0
9	8	38.5	962	48.1	1851.9	624	124.8	4804.8
Total:	21	188.5	1470	73.5	16679.4	647	129.3	24874.8

Table 5. Interannual changes of biomass (mg/m^3) of phytoplankton in Sakhalin-Kuril region during summer. Layer 200 (bottom) - 0 m.

Area	Years			
	1988	1991	1992	1993
Okhotsk Sea				
1	140	-	-	-
2	3	-	39	-
3	41	-	-	-
4	588	-	-	-
5	126	-	10	-
6	37	200	14	-
7	20	925	35	-
8	+	415	5	-
9	423	210	5	160
10	95	22	135	379
11	103	35	45	20
12	275	176	30	558
13[a]	401	207	113	1570
13[b]	401	-	-	-
Total:	173	247	93	444
Square: thousand km^2	1502	690	864	513
Stocks, billion t	69.1	28.3	5.0	65.0
Pacific Ocean				
7	-	510	109	484
8	-	114	-	-
9	-	55	64	658
10	-	309	80	54
Total:	-	247	84	431
Square: thousand km^2	-	527	236	229
Stocks, billion t	-	22.7	3.6	15.5

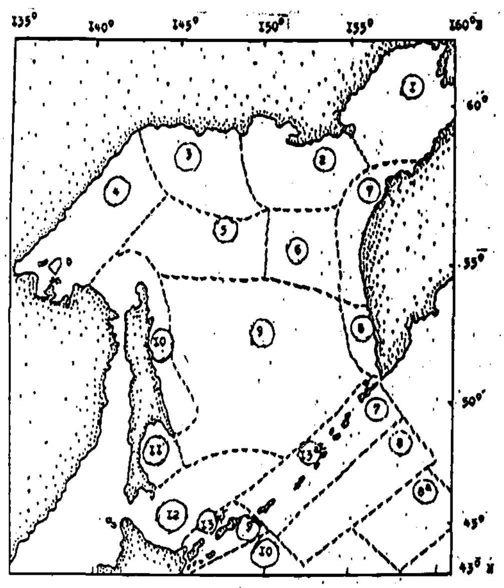

Fig. 1. Biostatical areas of Okhotsk Sea and adjacent waters to Pacific.

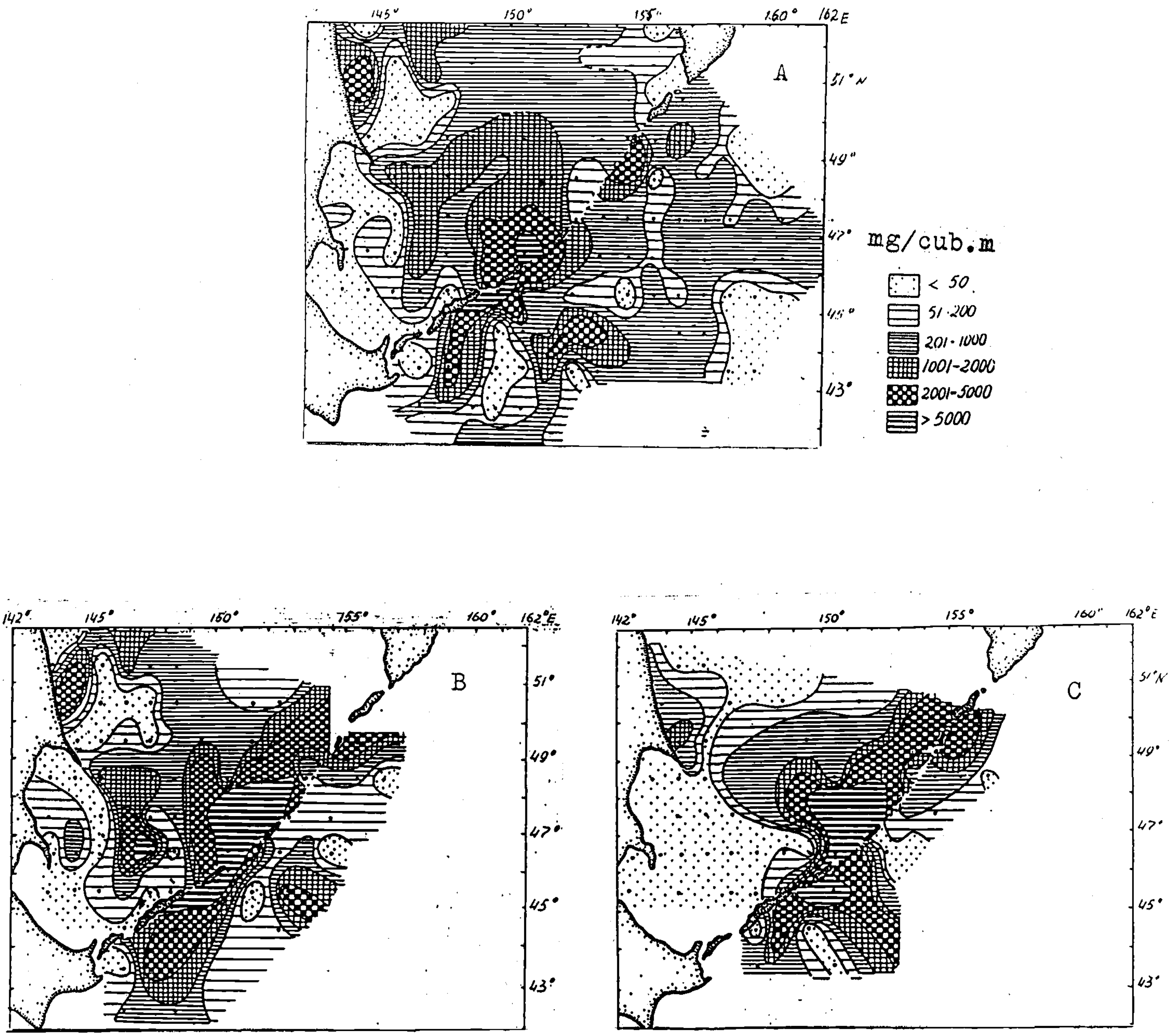

Fig. 2. Distribution of biomass of net phytoplankton (mg/cub.m) of Sakhalin-Kuril region in summer 1993. Layer 50-0 m.

A - first survey (July 1-28) B - second survey (July 20 - August 7)
C - third survey (August 1-17)

Biological Productivity in Anomalous Mercury Conditions (Northern Part of Okhotsk Sea)

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In August 1993 (24^{th} cruise of the R/V " Alexander Nesmeyanov") the contents of mercury in the water, plankton and bottom sediments in some regions of the Okhotsk Sea were investigated. The research was conducted on the western Kamchatka shelf at the entrance to Shelikhov Bay and in the Tauisky Sakhalin region. Mercury is estimated using cold vapor atomic absorption spectrophotometry (Hatch and Ott, 1968). The mercury level in the sea water is determined following Virtsavs et al., 1974 and Mercury ..., 1979. The determination of mercury in plankton and bottom sediments is based on using standard methods (Oradovsky, 1977; GOST ..., 1986).

Analysis of the data indicates that mercury in the upper layer of the water column is rather homogeneous and the concentration ranges from 0.000 to 0.042 mcg/l (average 0.019 mcg/l) (Fig. 1). The relatively low mercury content of the water is observed in all regions. The upper microlayer of water had 1.6 times the mercury content of the lower layer (Fig. 2). The maximum concentration of mercury (0.070 mcg/l) is found in the entrance to Shelikhov Bay. Abnormally high concentrations of mercury (0.600 mcg/l) is found in the bottom layer of water of the entrance to Shelikhov Bay which was 6 times more than in marine fisheries waters (The collection ..., 1991) (Fig. 3).

In the bottom sediments, the concentrations of mercury ranges from 0.006 to 0.028 mcg/g of dry mass in association with the granulometric composition. The concentrations of mercury in plankton ranges from 0.036 to 0.121 mcg/g of dry mass. In the high mercury concentration 1 m bottom layer of water, similar increases in the concentration of mercury is found associated with bottom sediments and plankton.

The data suggest that a spatial mercury anomaly coincids with the location of a strong cyclonic eddy of the Jamsky current moving out from Shelikhov Bay. The surface waters are to a high degree satiated with oxygen (up to 138%) as a result of the high biomass of the diatom *Thalassiosira*. This diatom has the highest mitotic index for the area.

The maximum concentrations of organic carbon, carbohydrates, organic and mineral forms of biogenic elements are also found in the region. The maximum amount of chlorophyll "a" and abnormally high values of primary production are observed. The maximum biomasses of bacteria and infusoria and a large amount of zooplankton (99% of it were larvae of crab) are found along with large amounts of pollock. The size of algae and zooplankton are unusually large. Similarly, hydrological and hydrochemical conditions are observed over the Kashevarov Bank where the mercury content in the water is low. Upwelling of cold bottom waters are enriched by the biogenic elements which are in higher concentrations than in the entrance to Shelikhov Bay but the biological productivity is lower.

High biological productivity is found in areas where there is upwelling to the surface as the bottom waters are enriched with nutrients. In these zones, high biomass of phytoplankton and zooplankton occur along with fish species who feed on the plankton (Natarov, 1966).

In the region between the Tauisky Gulf and the entrance to Shelikhov Bay an inter-structural hydrological front is formed as a result of the interaction between the two currents which move in opposite directions (Chernyavsky, 1970). In the narrow zone between the flood, the upwelling of cold deep nutrient rich waters occurs. The constant exchange of nutrients produces an intensive, long development period of phytoplankton and a large accumulation of zooplankton in the entrance to Shelikhov Bay (Afanasyev, 1981). Most of the herring stocks and pollock stocks in Okhotsk Sea are found in the region. A number of studies have found that this area has an extraordinary high stable biological productivity (Kotlyar, 1970; Chernyavsky, 1970).

A very high abundance and biomass but simplification in the complexity marine organisms can be found in a polluted environment. The hyper development of some species and the decrease of species composition are a reaction to extremely high levels of nutrients and high levels of pollutants that favors only some species. Organisms living near volcanic activity on the sea-bottom where high levels some chemicals (including mercury) can cause a decrease of biological activity and reproduction (Tarasov et al., 1985).

Some levels of mercury may increase the length of hydrobionts life, stimulate their activity and cause strengthening of exchange processes (Weis et al., 1985; Weis et al., 1987). Natural selection may cause some organisms, that live in high concentrations of mercury, to become more resistant to pollution stress (Baker et al., 1985). The above experiment shows that the interaction of natural geochemical anomalies as well as antropogenic influences may cause an adaptation of populations of hydrobionts to allow them to live in a polluted environment.

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FIGURES

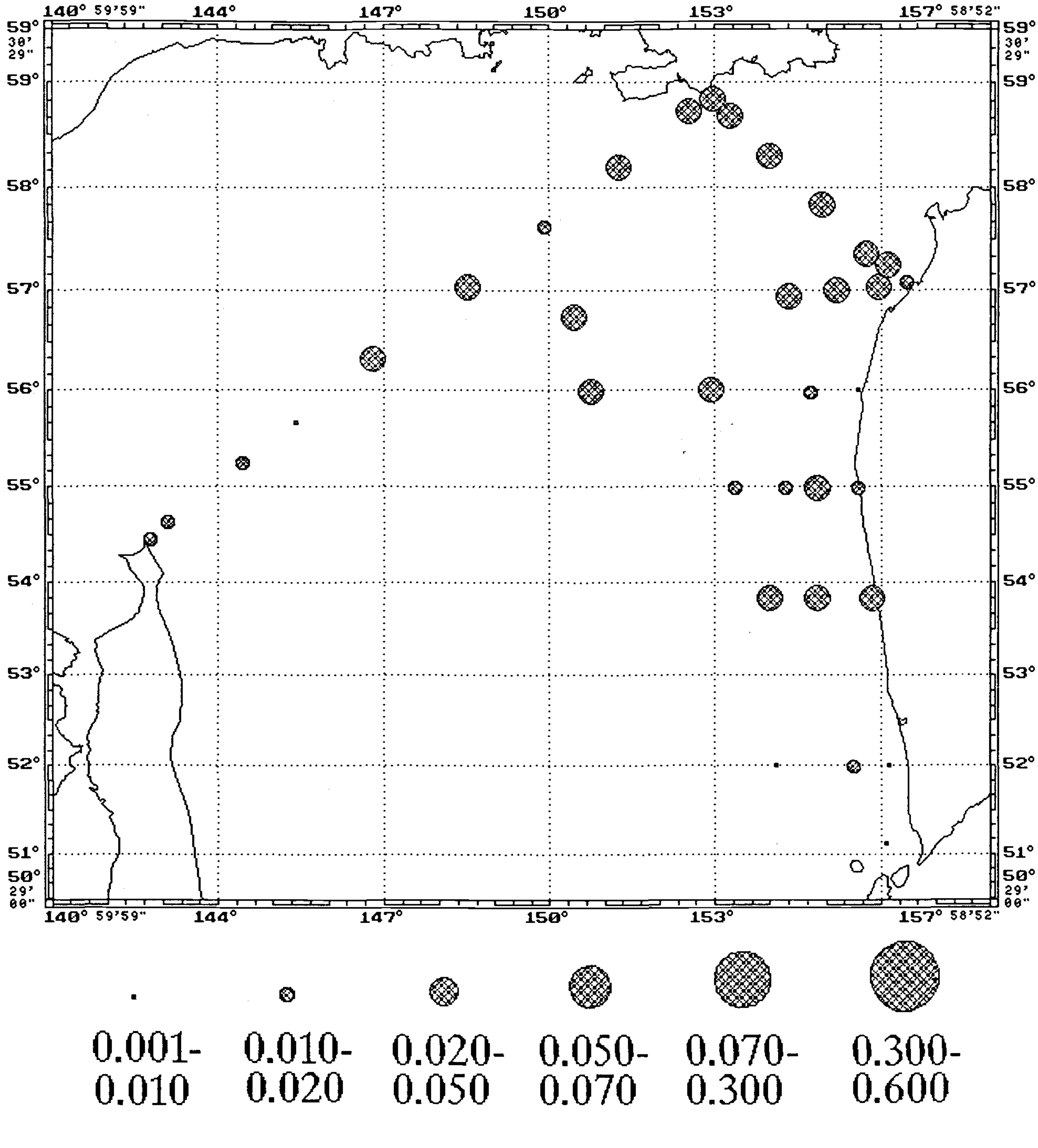

Fig. 1. Distribution of mercury concentrations (mcg/1) in the surface layer of water.

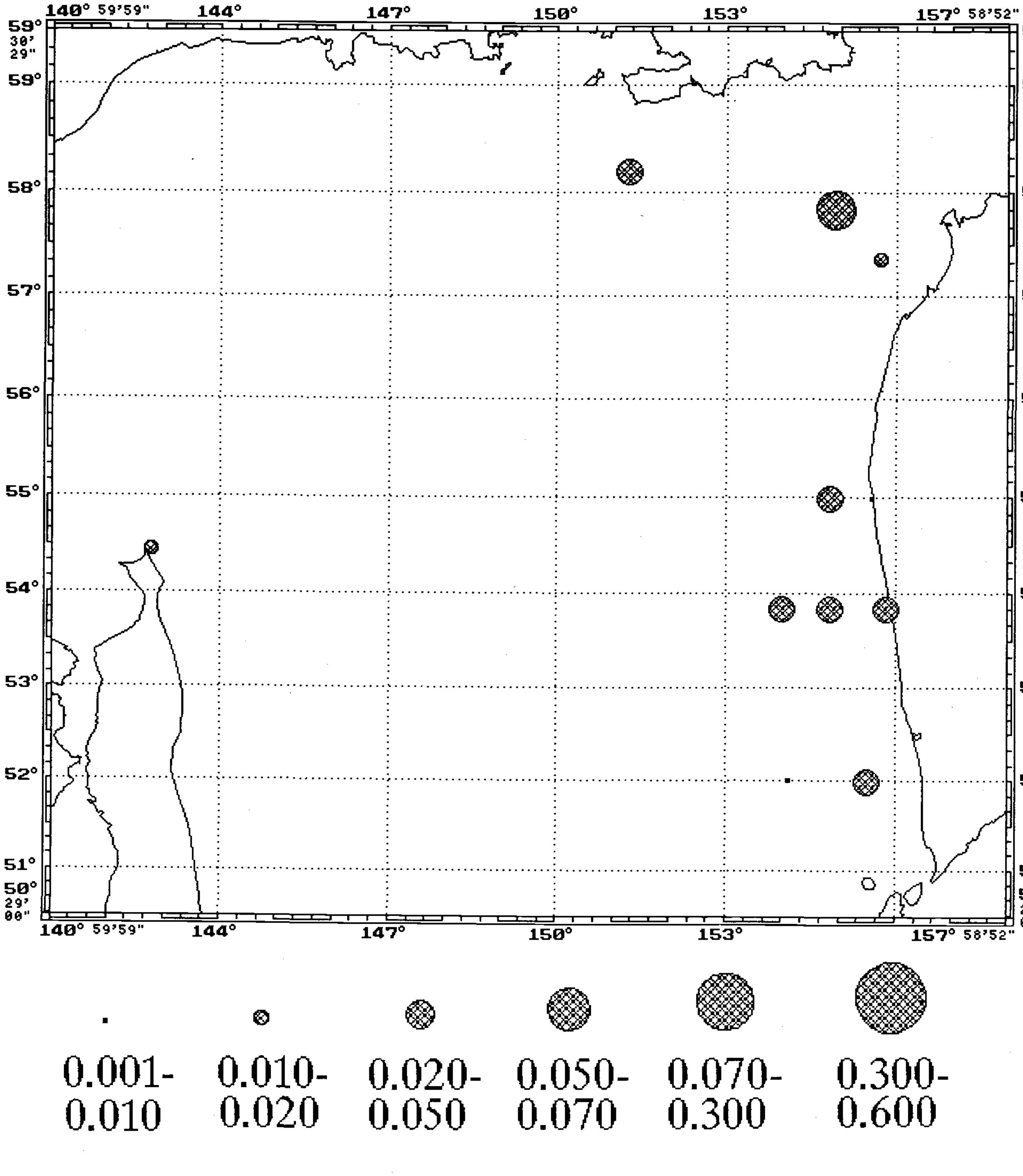

Fig. 2. Distribution of mercury concentrations (mcg/1) in the upper microlayer of water.

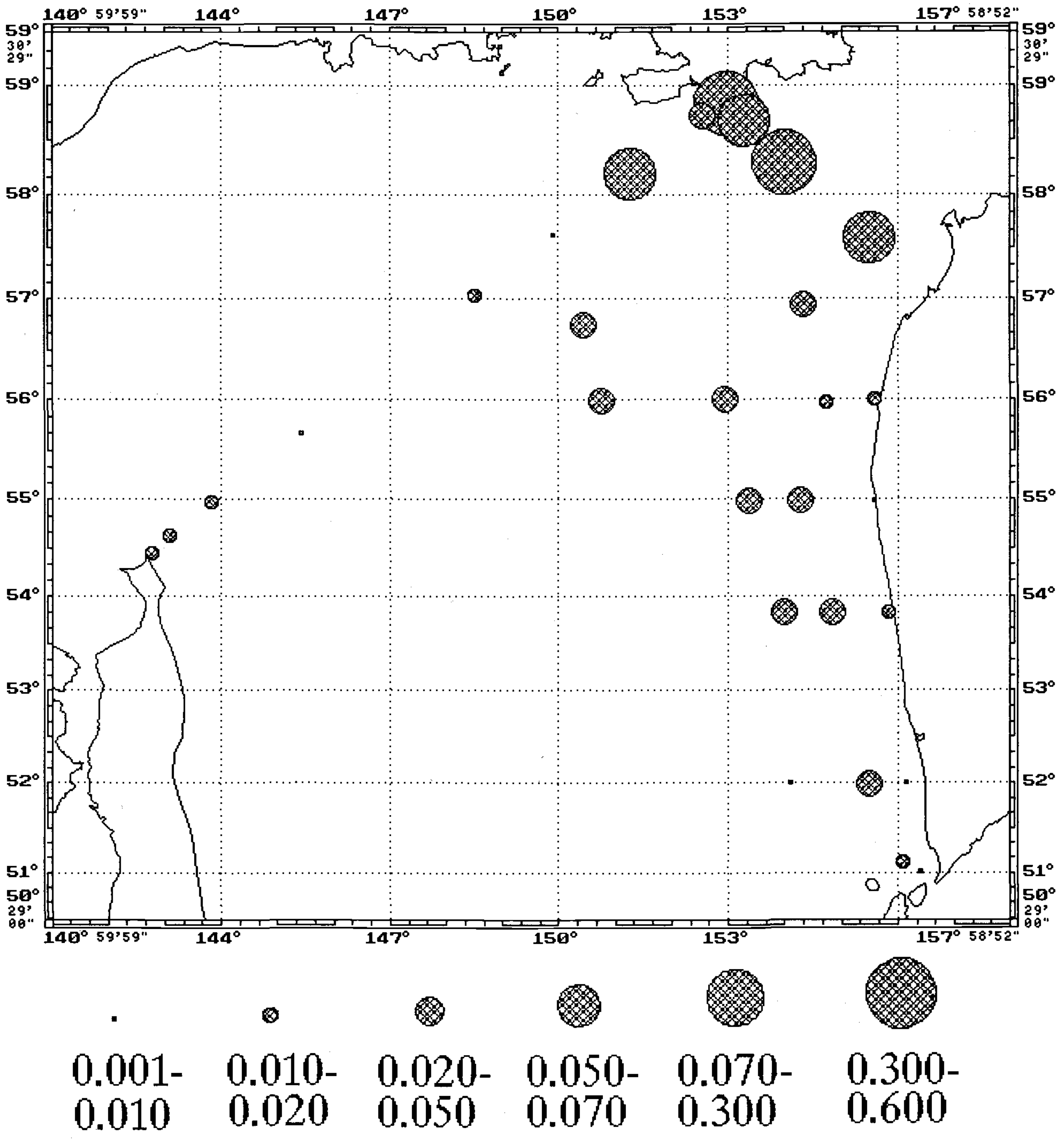

Fig. 3. Distribution of mercury concentrations (mcg/1) in the ground layer of water.

Origin of Hydrocarbons in the Ecosystem of Coastal Region of the Okhotsk Sea

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The industrial development of oil and gas deposits at the Okhotsk Sea shelf has been started recently. Authentic information about distribution and origin of hydrocarbons (HC) is necessary to evaluate both the oil and gas development prospects and ecological rates setting of anthropogenic pressure on marine environment.

Our study included investigations of the concentration and composition distribution of dissolved and particulate aliphatic hydrocarbons (AHC) and polycyclic aromatic hydrocarbons (PAHC) in the surface waters and bottom sediments. The observations were carried out near the Kuril Islands, along the east coast of the Okhotsk Sea, in the Gulf of Sakhalin and on the N.E. Sakhalin Island shelf in August 1993 aboard the R/V *Academic Alexander Nesmeyanov* (cruise AN24). The last two areas were surveyed repeatedly during the 23rd cruise of the R/V *Academic Mikhail Lavrentev* in the fall of 1994. The purpose of this research is to establish the background characteristics and level of petrogenic hydrocarbons in these coastal zones.

The average concentration of dissolved aliphatic HC in surface waters collected from different regions of the Okhotsk Sea varied within a relatively narrow range: from 15 to 19 μg/1 in summer, 1993, and from 21 to 33 μg/1 in autumn, 1994; the degree of enrichment in the surface microlayer (ML) changed from 1.2 to 6.6 (Table). As have been shown earlier (Tkalin, 1993) the HC content in the water column and bottom sediments is not very high and comparable with the other regions of the N.W. Pacific. Along the N.E. Sakhalin Island shelf, the average AHC concentrations were from 9 to 15 μg/l in different seasons, with maximum value of 44 μg/1. The state of the benthic and pelagic environments appeared to be normal except for the area affected by a local oil spill.

The mean level of dissolved PAHC in the surface coastal waters was 8 μg/1, with the degree of their enrichment in the ML from 2 to 3. Naphthalene and fluoranthene dominated in PAHC composition whereas pyrene and benzo(a)pyrene remained minor components.

These data probably represent the background concentrations for the Okhotsk Sea. The removal from the coast in the offshore direction and from the river-sea boundary in the Gulf of Sakhalin did not significantly affect the distribution of dissolved HC, but their suspended (particulate) form. The distribution pattern of alkanes in waters near the Kuril Islands and the eastern shelf of the Okhotsk Sea indicated the natural origin of HC with various ratio of autochthonous and allochthonous components.

Bottom sediments in the coastal regions of the Okhotsk Sea are characterized by low concentrations of aliphatic HC in comparison with less productive aquatories. In the surface layer of the bottom sediments the average content of AHC changed from 3.8 to 19.6 μg/g (calculated on dry weight) and represented from 0.07 to 0.80% of organic carbon (C_{org})

whereas the average PAHC content varied from 2.2 to 43.1 μg/g and from 0.3 to 14.3×10^{-4}% in C_{org}. These values remained within the range of concentration (1.5 to 52 μg/g) found in bottom sediments of the Bering Sea by Venkatesan and Kaplan (1982). The reported concentrations of HC can be explained by comparatively low organic matter contents in the sediments which, in turn, can be related to the short vegetative period of diatom algae, as well as to the rapid biogenic decomposition of particulate organic matter dominated by proteins and carbohydrates (Romankevich, 1984). It is apparent that biological production of the region and lithology of sediments influence the distribution and composition of hydrocarbons.

In summer 1993 along the N.E. Sakhalin Island shelf (in the region of oil deposits) the aliphatic HC concentration in surface waters exceeded the background level sevenfold (on average), and the PAHC content surpassed the background level by 19. The bottom sediments indicated an increased portion of hydrocarbons in organic matter and a varied HC distribution pattern. In autumn 1994, in the Gulf of Sakhalin concentrations over 50 μg/1 were observed in surface as well as in near bottom waters.

The spatial distribution of hydrocarbons and the distribution pattern of alkanes in some samples suggest the existence of a local source of petroleum pollution on the Sakhalin Island shelf. However, comparison of the abnormal chromatograms of alkanes from water and bottom sediments in this area with chromatograms of the Sakhalin petroleum indicates some basic differences. Even if the Sakhalin petroleum is subjected to weathering (such as would occur 30 days after a spill on marine waters), alkanes C_{17} - C_{18} will dominate in the low molecular area (Mishukov et al., 1987). According to our chromatograms the homologous compounds up to C_{23} were practical absent.

Therefore, it is more likely that there is an endogenous source of the abnormal hydrocarbon concentrations in the bottom core (such as fluid flow). These data were obtained from the marginal regions which are connected with oil and gas-fields. They are restricted to very small areas (<1 m^2) with a limited depth of oil stratum bedding and with favorable tectonic and lithology situations (Venkatesan and Kaplan, 1982; Nesterova and Nemirovskaya, 1988). The analysis of fluid hydrocarbons has shown a high degree of similarity with crude oil and the HC composition observed in the bottom sediments.

On the other hand, migration of small quantities of low molecular hydrocarbons from the bottom core with fluid fluxes can promote intensive development of bacterial communities. This can lead not only to the appearance of the oil oxidizing bacteria, but also the bacteria which re-synthesize the high molecular alkanes, as was discovered in bottom water samples collected from the Bering Sea (Nesterova and Nemirovskaya, 1988).

It is quite likely that a natural distillation of petroleum in fluid fluxes takes place in deep water layers along the Sakhalin shelf, causing the selective accumulation of high molecular hydrocarbons. The transition of the transformed HC from the bottom sediments to the water column in shallow areas results in their accumulation in the surface waters. This assumption is supported by the similarity of alkanes distribution patterns in water and bottom sediments, as well as by high concentrations of PAHC at specific stations of this region.

Apparently, the ecosystem of the Okhotsk Sea can endure these natural fluxes of petroleum hydrocarbons, as evidenced by the background concentration and composition of HC in the South Sakhalin Island shelf. In addition, there is a high natural rate of the hydrocarbon biodegradation (mean value 540 μg/1 per day), reflecting a high assimilative capacity for petroleum hydrocarbons (Anikiev et al., 1992).

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TABLES

Table 1. Concentration of dissolved hydrocarbons in the Okhotsk Sea

Region	Depth	number of samples	aliphatic HC, µg l^{-1}			PAH, ng l^{-1}		
			mean	ranges	σ	mean	range	σ
			Summer 1993					
Kurily Islands	ML	27	44	18-108	22	15	20-14	10
	surface	42	15	6-40	5	6	3-8	2
Eastern Okhotsk Sea Shelf	ML	11	37	30-55	10	12	8-15	4
	surface	24	18	12-23	3	6	2-8	3
Okhotsk Sea	ML	2		16-34		-	-	-
	surface	9	18	11-23	3	5	2-8	2
Gulf of Sakhalin	surface	16	16	6-23	4	9	4-15	5
East Sakhalin Shelf north part	ML	1	-	574	-	-	5032	-
	surface	14	202	15-2172	548	145	8-338	214
south part	surface	10	19	11-26	5	12	6-14	5
			Autumn, 1994					
Gulf of Sakhalin	surface	11	33	13-60	17	10	5-18	8
	near bottom	8	28	12-75	20	9	4-17	7
Northeast shelf of Sakhalin Island	surface	17	21	9-33	5	9	5-13	8
	near bottom	18	19	12-29	5	9	6-17	9

Elements of the Pacific South Kuril Area Ecosystem

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ABSTRACT

This paper examines the interannual variability of water temperature and atmospheric circulation as well as their effect on the distribution of plankton, saury and sardine. In cold years (1980-1988), the abundant growth of phytoplankton was observed to negatively affect saury entering the area because of the florescence but affected sardine positively as it feeds heavily on phytoplankton. "Warm" years (1970-1979) were characterized by low plankton biomass and rich saury abundance.

INTRODUCTION

Recently (1960-1994), Northwest Pacific saury catches fluctuated up and down while in 1976-1988 sardine catches underwent a period of increase followed by a decline. In 1960-1969 there was a periods of medium and small catches of saury in the South Kuril Area (SKA), while in 1970-1979 catches were large and from 1980-1988 catches were extremely poor for saury but good for sardine. Factors that affect growth and abundance of saury and sardines are water temperature and the state and distribution of plankton that is the main food of pelagic fish and squid. In turn, the production of these species are affected by the variability of atmospheric circulation.

METHODS AND MATERIALS

The atmospheric circulation over the Far-East can be analyzed from meridional and zonal forms of circulation and types of synoptic processes. These processes can be followed from the atlas for 1949-1985 (Kalachicova and Nikolayeva, 1985). The atlas includes atmospheric circulation from Ilyinsky (W, C, E, Z) as well as types of atmospheric processes (W, M, E, S). Using the atlas, the anomalies of atmospheric circulation (in days) and of ground synoptic process types from May to August, 1978-1985 can be accounted for.

W - western, E - eastern, C - central, M - mixed, Z - zonal, S - southern.

To estimate the long-term variability of the water thermal regime in the SKA, data from the coastal hydrometeorological stations for 1961-1989 was used. Decadal data on water temperature distribution near the sea surface and at a depth of 50 m as well as data on plankton within a layer of 0 to 100 m for seven years (July through September 1979-1981, 1983, 1984, 1987 and 1988) were analyzed.

RESULTS

In accordance with the earlier findings of Bokhan et al (1989), the area is divided into five sites associated with the heterogeneity of the water masses and of plankton distribution: Site 1; the South

Kuril shallows, Site 2; coastal waters adjacent to the Pacific shores of Iturup Island; Site 4; Southwestern Pacific and Site 5, Southeastern Pacific (Fig. 1).

From the August distribution of plankton in different years for different sites it is evident that there were differences in the plankton biomass distribution (Table 1). High value of plankton biomass for the years is observed northeast of the coastal waters of Iturup Island and Friz Strait. The smallest values of plankton biomass are observed in the South Kuril shallows and in the ocean .

The interannual variations of plankton biomass over the area was significant. In coastal waters of Iturup Island and Friz Strait, the plankton biomass is 1,000 to 7,000 mg/cub.m early in August 1981, and 200 to 1,000 mg/cub.m in August 1978-79.

It is well known that June is the last month of phytoplankton development and August is a period of the majority of zooplankton development. The maximum zooplankton development came, as a rule, 1.5-2 months after the completion of phytoplankton development in a boreal area (Kun,1985). We observed an extension of plankton productivity cycle except in August 1978-79 when plankton development was typical and fit the "biological summer" concept.

The variations in plankton distribution was reflected in the saury and sardines fishery conditions in the SKA. 1978 and 1979 were characterized by good saury catches (50,000-70,000 t), whereas in 1980-1988 there were extremely poor (0-10,000 t). At the same time the 1980s were marked by good catches of Pacific Sardine (250,000-300,000 t). The different responses of saury and sardine to plankton distribution can be explained by differences in their nutrition. Saury avoided areas of good phytoplankton development by migrating far from the South Kuril Islands into the ocean, northeast to the Central Kuril. The sardine diet included a wide variety of both zooplankton and phytoplankton as was observed in the 1980s (Kun, Shatilina, 1989).

To determine thermal conditions in the SKA, water temperature variation profiles of the surface and at the 50 m level were developed. An extremely warm year occurred at all sites in 1978. By early August the water temperature on the coastal of Iturup Island and Friz Strait was 11 and 13°C, being 5-10°C in 1980, 1981, 1987 and 1988 (Fig. 2). At the two ocean sites an abnormally high water temperature of 22°C occurred early in August 1984 and the lowest temperature was 13°C in 1980. In the South Kuril shallows, water temperature was 14-17°C. Late in July 1979 the water temperature was 10°C but rose to 16°C by mid August. In the 1980s the water temperature remained below 15°C.

Fig. 3 shows average monthly water temperature anomalies at the Kurilsk and Yuzhno-Kurilsk hydrometeorological stations in the summer. Two cold periods occurred, the first cold was observed from 1963 through 1971 and the second from 1980 to 1988. The temperature began to rise in August 1989 and continues to the present.

Variations in the seasonal and interannual plankton biomass were observed in relation to water temperature variations at all the sites of the SKA. The highest values of plankton biomass (phytoplankton bloom) are observed in cold waters of Iturup Island and near Friz Strait (Table 1). The least values of biomass is observed in the South Kuril shallow waters and at the ocean sites. In cold years, in coastal waters of Iturup Island and Friz Strait, the plankton is characterized by a late biological spring (extension of biological processes in plankton).

Table 2 shows the data of anomalies in types of bottom processes in 1978-1984. In the years when water temperature in the coastal waters of SKA is above normal, processes of the western type dominated over the Sea of Okhotsk and the South Kuril Islands. Thus, in July 1978, the western-type process comprised 25 days and in August 1979 it was 16 days. The high western-type process, with cyclone activity dominates the Far-Eastern sea and a high pressure field observed in the Northwest Pacific provides a transfer of warm air in the area of the Sea of Okhotsk and the Kuril Islands. In years of low temperature in coastal waters of Kunashir and Iturup, a southern-type process is intensified providing cold northeastern air masses.

Table 3 represents the data of anomalies of circulation forms by Iliinskiy (1965). From these data, in 1978, zonal circulation dominates with a high-altitude frontal zone (HFZ) being located to the north of 40°N. In 1979, a western-type form dominated in the 1980s reiteration of the C and W forms became important. In May 1983 and 1984 the Z form reiteration is elevated but the HFZ was located to the south of 40°N. In June and July of 1984 and 1985 the reiteration of the high altitude depression is abnormally elevated over the Sea of Okhotsk and caused the intensification of an arctic invasions. In 1980 the C form reiteration was abnormally high which was related to the intensification of the Okhotsk invasion.

DISCUSSION

A cold type of thermal regime, and therefore an abundant development of plankton depends on the frequency and intensity of cold arctic invasions. Warm types are formed when zonal processes are intensified causing quick development of plankton.

One of the ways of determining SKA food availability is by forecasting water temperature which depends on atmospheric processes.

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TABLES AND FIGURES

Table 1. Average values of plankton biomass (mg/cub.m) in the South-Kuril Area of the Pacific Ocean in the mid-August 1978-1988.

Year	I South Kuril I shallow I waters	Waters of the Iturup Island	Waters of the Friz Strait	Southwestern ocean area	Southeastern ocean area
	I 1	2	3	4	5
1978	I 500	500	200	700	200
1979	I 195	1148	1076		657
1980	I 639	2678	1103	1373	441
1983	I 284	1723	1121	1170	448
1984	I 749	1823	3448		
1987	I 717	1102	793		427
1988	I 1175	1082	1008		878

Table 2. Anomalies of bottom processes, western- (w) and southern (s) types in 1978-1984.

Month	1978		1979		1980		1981		1982		1983		1984	
	w	s	w	s	w	s	w	s	w	s	w	s	w	s
June	4	-7	8	-6	12	-13	-4	-4	6	-5	-5	6	4	-7
July	21	-15	-2	-5	-8	2	3	3	1	-3	5	-4	-2	8
August	8	-10	17	-10	-6	1	-4	11	6	5	6	5	9	-1

Table 3. Anomalies of atmospheric circulation forms in June 1978-1985.

Form	I 1987	1979	1980	1981	1982	1983	1984	1985
Zonal (Z)	I 2	-1	-8	4	0	4	-4	-3
Mixed (M)	I 4	3	2	-2	-3	-3	5	7
Eastern (E)	I -2	0	-2	-1	-3	1	5	3
Western (W)	I 5	4	-1	1	-3	3	1	-2
Central (C)	I -7	-5	8	-2	2	-3	-8	-8

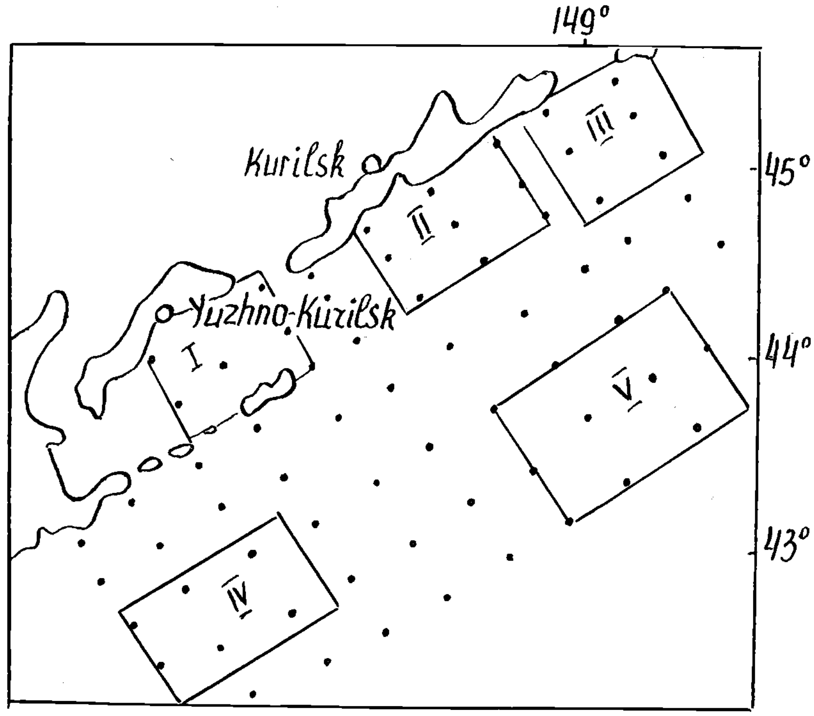

Fig. 1. The plot of the surveys according to the program "Poligon".

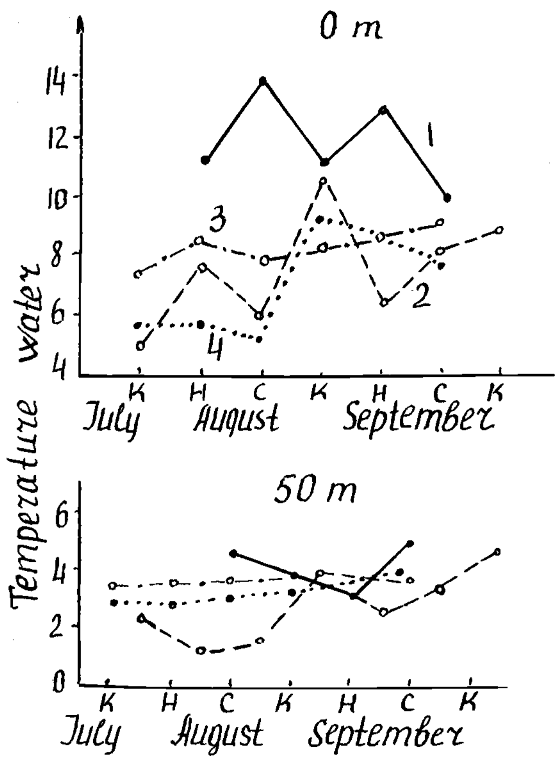

Fig. 2. Seasonal variability temperature water of the Friz Strait.

1 - 1978 2 - 1980 3 - 1984 4 - 1988

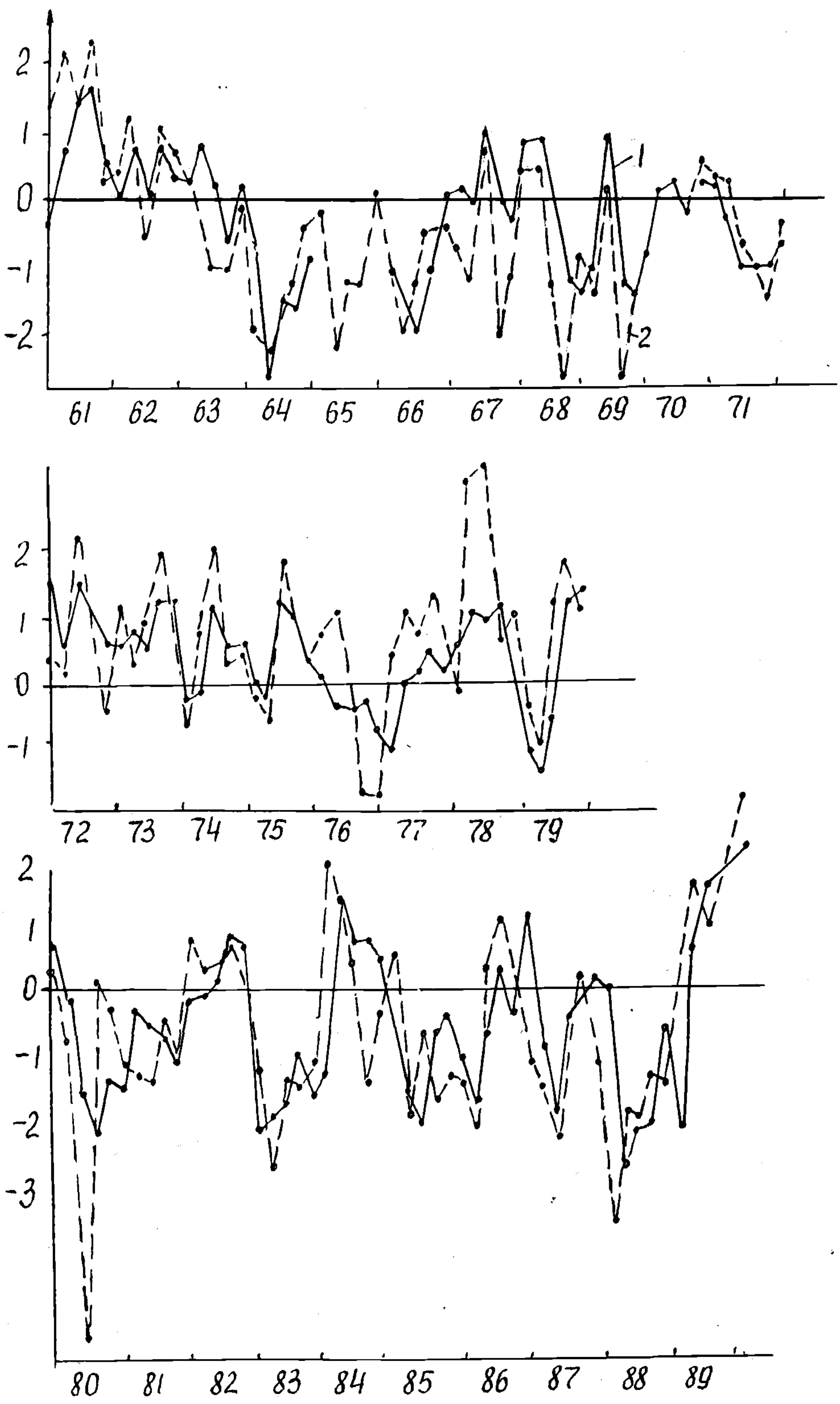

Fig. 3. Anomalies of temperature water in the South Kuril (SKA) in June-October, 1961-1990

1 - HMS Yuzhno-Kurilsk 2 - HMS Kurilsk

Biota of the Okhotsk Sea: Structure of Communities, the Interannual Dynamics and Current Status

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The biological resources of the Okhotsk Sea are of great importance to the Russian fishery. The size of the biological resources is related to the high productivity and lead to increased research activity on behalf of fishermen. Unfortunately, only TINRO has been engaged in regular research on the biological resources of the area and these studies are a summarization of a number of papers including reviews (Shuntov, 1985; Shuntov and Dulepova, 1993; Shuntov et al.,1993). This paper focuses on the characteristics of the biota during the 1990s. In order to evaluate the long-term dynamics in the biological phenomena a comparison of the new information with data of the previous year is necessary. These data were obtained from combined surveys conducted between 1980-1990 and from the literature.

In 1980, the relative stability of the composition and structure of the Okhotsk Sea communities and the biomass and production of major groups of hydrobionts is evident (Table 1). Based on these data, the energy balance requirements are calculated and diagrams of the partitioning of the energy flow between the different levels within the Okhotsk Sea ecosystem have been constructed (Fig. 1). The results are approximate and can be only considered as one of a number of possible variants.

The exchange of energy between the different levels of the food web cannot be explained unless the detritus cycle is included. The energy obtained from dead organic substance exceed by 1.5 times that from direct consumption of primary production. The greatest flow of energy passes through the bacteria and protozoa which are consumed by zooplankton and non-predatory zoo-benthos (Fig. 1). The energetic expenditure of bacterial plankton and protozoa exceed 85% of total respiration of all heterotrophs of the Okhotsk Sea ecosystem.

The non-predatory zooplankton mainly consist of copepods and euphausids (third in importance) which are a major energetic reserve for other higher trophic levels. Over 10% of the total energy flow and heterotrophic production is dependent on this link. The predatory zooplankton consume up to 65% of the energy and non-predatory zoobenthos, nekton and nektobenthos also depend on this component of the foodweb. Twenty five percent of the production of non-predatory zooplankton, which became part of the detritus component, replenish the energy reserve of the ecosystem from which the consumption by non-predatory zooplankton is more than two times. Predatory zooplankton consume 27% detritus in their diet. The rest of the ecosystem components are less important in utilizing detritus although they contribute a considerable share of their production to the cycle.

The demersal fauna (predatory and non-predatory benthos, nektobenthos) of the Okhotsk Sea consume slightly more than 1% of the total energy flow. These components of the ecosystem subsist, mainly, on microflora of the sediments, detritus , protozoa and bacterial plankton, although the pelagic animals are part of the nekton benthos ration, the greater part is consumed by demersal fishes and crabs (bentophags and predators) (Dulepova and Borets,1994). Taking into consideration fishing effects, the transformation of the demersal fauna production into detritus is much higher than for zooplankton: non-predatory, zoobenthos more than 40%, predatory zoobenthos more than 80% and nektobenthos more 50%. Thus, a considerable part of the production of the ecosystem components (20 to 63%) is not utilized and turns into detritus but a lesser amount of organic substance goes to detritus than is consumed. The Ohkotsk Sea produces excess detritus which is related to the high level of phytopankton and protozoa production.

In the early 1990s, a climatic change took place in the pelagic zone of the Far-Eastern Seas analogous to a period from 1940s-1960 as changes from 1970-1980s is analogous to a period from 1920-1930s (Shuntov, 1993; Shuntov et al.,1993). In the 1990s, the pelagic community was considered to be in transition.

ZOOPLANKTON COMMUNITIES

Data on zooplankton for 1980-1990s was mainly only available from the southern Okhotsk Sea (Tables 1-2). In the early 1990s, the number of predatory plankton and euphausids increased but the number of copepods declined. The decline of the plankton communities in the early 1990s was likely from high concentrations of plankton feeding pollock and sardine. In 1994, the biomass of euphausids remained high and the biomass of copepods increased as the number of sagittas decreased. These changes were related to the beginning of the stabilization of the composition and structure of the plankton community under new conditions.

The plankton community of West Kamchatka was quite different to other areas of the Okhotsk Sea due to a pronounced reduction of the biomass of pollock, the most important plankton feeding fish. In 1994, the number of predatory plankton in Kamchatka waters was maximum but the levels remained high (Table 3). Such a high level of predatory plankton was abnormal in communities and was likely the result of decreased predation. It was likely that the process of succession occurred as was found in the southern part of Sea. New information about the Okhotsk Sea plankton also supported the conclusion that the plankton community was in a transition but the reorganization occurred at different rates in different areas.

NEKTON COMMUNITIES

In 1993, simultaneous to the decreased sardine and pollock biomass in the southern Okhotsk Sea, there was an increase of squids abundance which was unexpected (Table 4). In 1994, the biomass and abundance of the fish concentrations increased due to the increased number chum and pink salmon which came into the Okhotsk Sea for part of the year. In the southern part of pelagic zone there was no change in the number of some epipelagic fish after the pollack and sardine decreased. It was thought that herring from Sakhalin, anchovy, saury, arabesque, greeling and squids might have replaced the pollock. At the present time, changes in abundance of fish species in the north Okhotsk Sea is no longer synchronous (Table 5). In 1994, for the first time, more than one third of the fish biomass in the epipelagic zone was herring.

DEMERSAL ICHTIYOCENOSIS

Most populations of demersal fishes and invertebrates which were reduced by fishing in the 1950s-1960s, began to recover due to better management measures in allocating the catch (Shuntov, 1985). In the early 1980s, when fish and crab stocks grew, the production of the benthos was evidently under-exploited by fishes and invertebrates (Table 6). It was concluded that benthos stocks would further increase (Dulepova and Borets, 1990). In the late 1980s, the biomass of demersal fish and crab on the West Kamchatka shelf increased approximately two times (Dulepova and Borets,1994). As a consequence, the consumption of benthos organisms approached the value of production (trophic capacity) if one considers that not all the benthos organisms were food for fish and crab. In this case under moderate fishing, such a situation can, evidently, be indefinitely continued.

FISHING

By the early 1960, the total catch in the Okhotsk Sea reached approximately 1 mln tons (Fig. 2). Herring, flatfish, salmon and crab were the most common species in the catch. In the second half of the 1960s, the volume of the catch of salmon and flatfish decreased but the catch of herring and, especially, pollock increased. The pollock became the most abundant of the species caught of all the fish species taken together. After the 200 mile fishing zone was introduced the access of foreign fleets to Russian waters was limited and the catch in the Okhotsk Sea decreased by approximately two times. By the mid-1980s, the Russian fishery had increased and stocks increased as a consequence of raising the natural reproduction efficiency as well as relaxation of the fishing pressure in the second half of the 1970s, the total catch in the Okhotsk Sea reached 2.6 mln. t., almost the 1975 level. This increase was related to the increased pollock catch and, to lesser degree, from other stocks which were, at the time, at a good level (salmon, cod, flatfish, crab).

In the early 1990s, fishery conditions worsened in most of areas of the Russian economic zone. In the Okhosk Sea, the catch remained stable until 1993 when the level declined from a maximum of 2.5-2.6 mln. tons to the present reduction of the catch by approximately 0.5 mln. t which was largely related to decreased pollock abundance. It is not inconceivable that the lost income from the pollock fishery can not be replaced by other species such as herring, cod, flat fishes, safron cod, crab, capelin and other species. Total catch in the Okhotsk Sea could be maintained at about 2 mln. t or somewhat higher if an increase of the Gizhigin and Sakhalin herring stocks were to take place. The Okhotsk Sea and adjacent waters will remain a major fishing area of Russia.

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Table 1. Elements of annual energetic balance (kkal/sq.m) of the Okhotsk Sea ecosystem.

Elements	Biomass mln.tons	Production mln.tons	Production g/sq.m.	K kkal/g	K_2	U	Elements of energetic balance P	A	C	R	F
Phytoplankton	-	15,100	9,450	0.7	-	-	6,615	-	-	-	-
Bacterioplankton	-	5,200	3,307	1	0.32	-	3,307	10,334	10,334	7,027	-
Protozoa	-	2,100	1,350	0.9	0.55	0.6	1,215	994	2,209	3,618	1,472
Non-predatory zooplankton	314	2,520	1,678	0.7	0.4	0.6	1,174	2,235	4,891	1,761	1,965
Predatory zooplankton	115	480	320	0.8	0.35	0.8	256	731	914	535	205
Non-predatory zoobenthos	208.6	318	201	0.3	0.3	0.5	60.3	201	402	141	201
Predatory zoobenthos	21.4	22.1	14	0.3	0.3	0.5	4.2	14	28	9.8	14
Pelagic fishes	31.5	1.7	9.9	1	0.3	0.8	9.9	33	41.3	23.1	8.3
Demersal fishes	3.5	1.7	1.08	1	0.2	0.7	1.08	5.4	6.8	4.3	1.4
Demersal invertebrates	1.5	0.5	0.32	0.5	0.35	0.8	0.158	0.45	0.56	0.58	0.2
Squids	2	7	4.4	0.8	0.35	0.8	3.5	10	12.5	6.5	2.5
Marine birds	0.012	0.004	0.003	1	0.15	0.8	0.003	0.02	0.025	0.017	0.005
Mammals	0.5	0.1	0.07	1	0.15	0.8	0.07	0.47	0.58	0.4	0.1

Note: K - calorific value

K_2 - net growth efficiency

U - digestion efficiency

P - annual production

A - assimilated part of annual ration

C - annual ration

R - respiration

F - non-assimilated part of annual ration

Table 2. Biomass (g/sq.m) of dimensional fraction of zooplankton in the epipelagical of the southern part of Okhotsk Sea (to south of 51°N) during summer in 1980-1990s.

Dimensional groups of plankton (fractions)	1986	1987	1988	1991	1992	1993	1994
Small	8.4	35.0	26.0	19.0	17.5	9.8	15.1
Middle	20.0	18.6	40.0	10.1	25.0	20.0	12.5
Large (macroplankton)	208.9	122.8	194.8	144.8	186.9	178.8	188.2
Total	237.3	176.4	260.8	173.9	229.4	208.6	215.8

Table 3. Biomass (g/sq.m) of major groups of macroplankton in the epipelagical of the southern part of Okhotsk sea (to south of 51°N) during summer in 1980-1990s.

Groups	1986	1987	1988	1991	1992	1993	1994
Euphausids	48.0	34.0	26.7	77.8	23.7	76.8	77.9
Copepods	120.0	53.0	113.7	31.2	52.0	26.6	63.4
Hyperiids	11.4	4.4	4.9	5.1	18.2	12.2	13.1
Saggitas	28.0	24.1	45.8	29.5	87.6	53.0	32.6
Other	1.5	7.3	3.7	1.2	5.4	10.2	1.2
Total	208.9	122.8	194.8	144.8	186.9	178.8	188.2

Table 4. Biomass (g/sq.m) and production (g/sq.m) of zooplanktonal fraction of predatory plankton (%) in the West Kamchatka Area in summer, 1980-1990s.

Indices	1986	1987	1988	1991	1992	1993	1994
			to the north 54 N				
Total biomass	278	243	532	80	183	-	315
Fraction of predatory zooplankton	15.5	22.6	19.6	23.0	31.0	-	42.0
Production of unpredatory zooplankton	1591	990	2699	472	501	-	533
Production of predatory zooplankton	121	171	372	61	222	-	501
			to the south of 54 N				
Total biomass	212	136	235	198	252	220	340
Fraction of predatory plankton	21.0	32.0	32.0	41.0	26.0	27.0	56.0
Production of unpredatory plankton	654	348	481	486	645	442	726
Production of predatory zooplankton	120	123	293	284	264	186	717

Table 5. Density of nekton (t/sq.m) in the upper epipelagical (0-50m) in Okhotsk Sea (to the south of 53°N) in 1990s).

Nekton groups	1991	1992	1993	1994
Fishes	1.70	1.76	1.0	1.29
Squids	0.10	0.06	0.16	0.08

Table 6. Biomass (thousand tons) and ratio (%) of fishes in the epipelagial of the northeastern part of Okhotsk Sea in September-October 1994.

Species and groups	Thousand tons	%
Salmons	40	0.63
Alaska pollack	3336	52.70
Herring	2276	35.90
Capellin	79	1.22
Spiny lumpfishes	18	0.30
Smooth-tonque	517	8.20
Other mesopelagic fishes	25	0.39
Sakhalin flounder	23	0.36
Other fishes	19	0.30
All fishes	6333	100.0

Table 7. Biomass and production (mln.tons) of the demersal fishes and invertebrates on the West Kamchatka shelf in 1980s (Dulepova and Borets; 1990,1994).

Index	The early 1980s	The late 1980s
Biomass of:		
Fishes	0.82	1.9
king crab	0.3	0.5
predatory benthos	3.1	3.1
unpedatory benthos	17.1	17.1
Production of benthos	27.0	27.0
Consumpion of benthos by fishes and predatory invertebrates	16.0	22.0

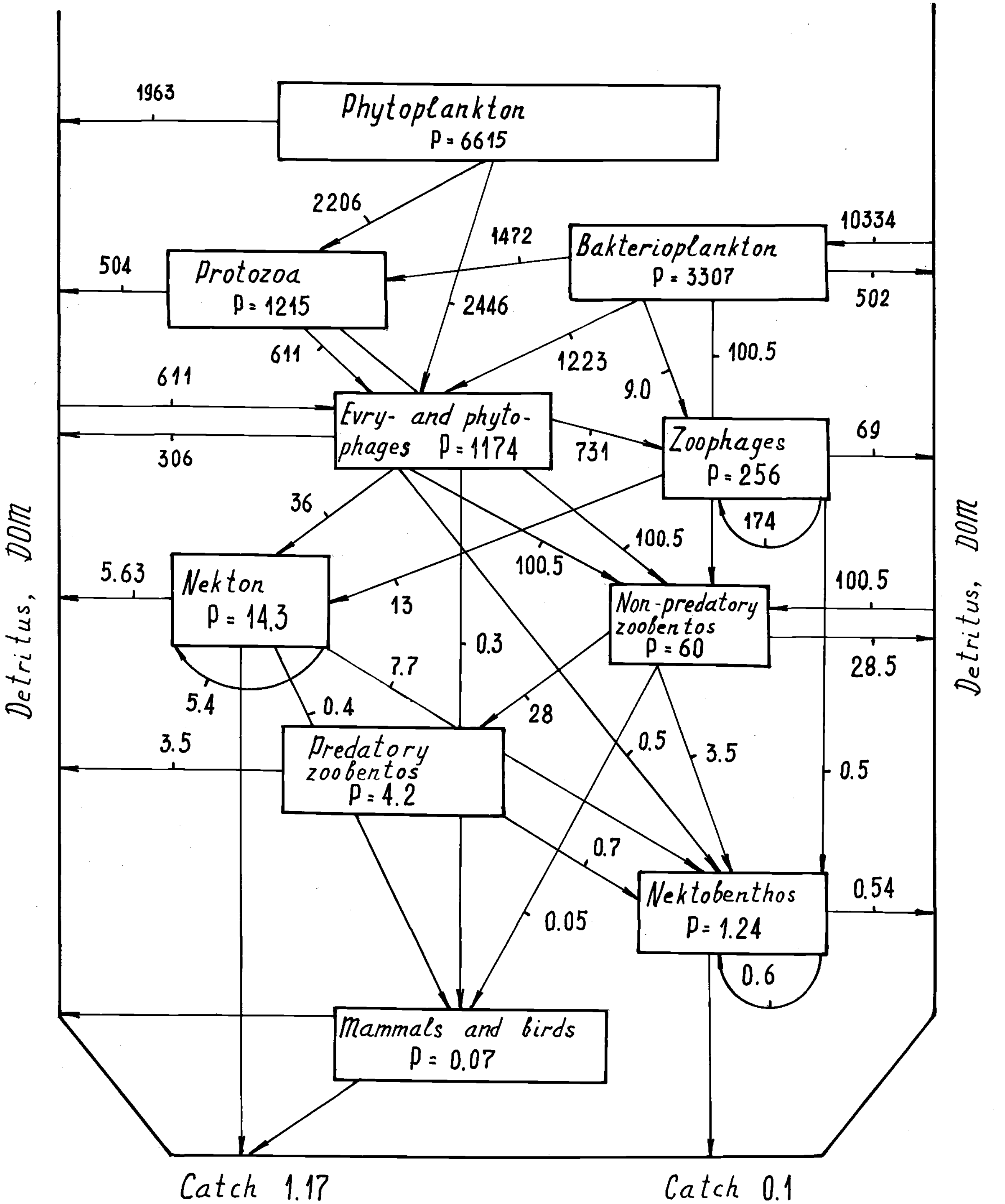

Fig. 1. Scheme of the substance flows (mln.t) in the Okhotsk Sea ecosystem in 1980s.

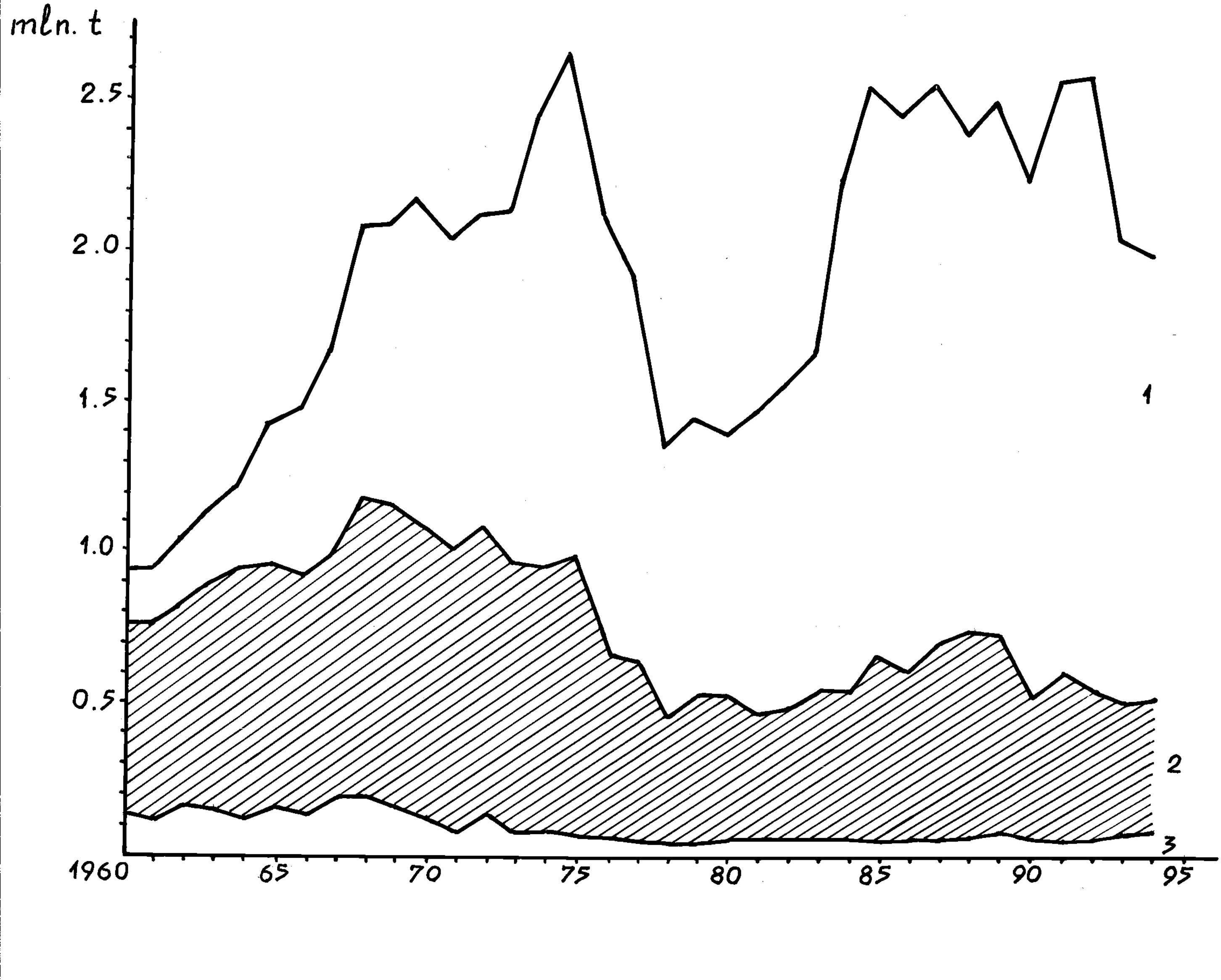

Fig. 2. Dynamic of catching (mln.t) of fish and other objects in the Okhotsk Sea after 1960.

1 - Alaska pollock 2 - other fishes 3 - other objects

Influence of some Abiotic Factors on Spatial Population Dynamics of the West Kamchatka Flounders (*Pleuronectidae*)

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Flounders, inhabiting the waters of West Kamchatka are currently the most important commercial species. The total catch increased from 30 to 55 thousand tons in an unregulated fishery. The commercial species of flounders, except halibut, are yellowfin sole, Alaska plaice, Sakhalin flounder, longhead dab, flathead sole, starry flounder and rock sole. Often inhabiting in the same regions, these species form a complex group. Various interspecific relationships and common biological features are tipical for the group.

The dynamic characteristics of flounder populations (distribution, migrations) are explored by many investigatiors (Moiseev, 1953; Polutov, 1958; Fadeev, 1971, 1987). This study estimates the influence of dynamic factors on fish distribution and migration on the annual cycle.

Two aspects of distribution of the above species are considered in the paper:

1. To define the influence of population density of each species on depth and temperature in different seasons, and to recognize the influence of these factors on fish distribution.
2. To determine the degree of habit coincidence of flounder which will give the opportunity to explore their interspecific competition. The results allow estimates of directed catch for certain species and to develop methods to determine commercial aggregations.

MATERIALS AND METHODS

Samples were collected by a bottom trawl survey on the shelf of West Kamchatka in 1973-1990. About 1,200 trawls samples were collected during the period. To ascertain population density, fish catch per unit effort is transformed into a relative number. The number is represented as the percent of the total catch per effort in a certain month and a year. Later a corresponding average value for each month for the years of the survey is estimated. The information obtained was used to characterize fish aggregation density in connection with three factors: depth (interval - 20 metres), temperature of water on the bottom (interval - 0.5°C) and latitude (interval - 15`).

RESULTS AND DISCUSSION

The distribution of West Kamchatka flounder in the seasonal cycle is typical of the distribution within limits of the depth and the temperature of water on the bottom. All flounder species examined were mostly concentraded at depths of 90 to 250 metres in winter (January-February) and in the shallows from 20 to 160 metres in spring due to seasonal migrations from deep waters to shoal waters. Quite different optimum temperature conditions for most of the West Kamchatka species are found during three time periods: winter-spring (January-May), summer (June-July) and summer-autumn (August-September). Four relatively stable periods of flounder distribution are found with various combination of bathymetric and thermic conditions. These periods are as follows: winter (January-February), spring (April-May), summer (June-July) and summer-autumn period (August-September).

Analysis of the data indicate that there are common and specific features of flounder distribution for various species. Regular bathymetric distribution in different seasons is typical for flatfishes examined, except for the deepwater and cold water species: Sakhalin flounder and flathead sole. In winter, the flounders density decreases gradually with the depth. The nature of the relationship resembles a normal distribution. The dependence of population density on depth changes sharply in spring-summer, summer and summer-autumn periods. The most fish aggregations are marked on the shallows and decrease gradually as the depth increases (Figs. 1 (1, 2, 4, 6, 7)). Sakhalin flounder and flathead sole did not show variations of bathymetric distribution in various seasons. Flathead sole population density change a bit but it is independent of the season and depth (Figs. 1 (5)). Sakhalin flounder extend their range of depth in summer-autumn period which is typical for the species(Figs. 1 (3)).

West Kamchatka flounders population density varies greatly in different seasons with the water temperature on the bottom. In winter and in spring, all species form the most dense aggregations in 0 - +1°C water temperature. In summer, when the water warms, flounders are found in a broader thermic range and did not appear to prefer any particular temperature. Coldwater species, Sakhalin flounder and flathead sole, however, prefer waters of -1 - +2°C (Fig. 2).

The distribution of most West Kamchatka flatfish is related to depth during spring migration. In April-May the variation of flatfish density aggregations is closely related to the bathymetric gradient. In winter as well as in summer and summer-autumn the depth affects flatfish distribution the least. This is more typical for the three shallow species: longhead dab, yellowfin sole and Alaska plaice, and less for deep water species: Sakhalin flounder and flathead sole. The dependence of aggregation density on depth is not marked for Sakhalin flounder and flathead sole. Rock sole and starry flounder did not aggregate with depth gradient in winter but are found to do so in summer.

The temperature influence on West Kamchatka flatfish population density for four species: yellowfin sole, longhead dab, flathead sole and starry flounder is defined by the temperature layer on the bottom in winter and during spring migration. The dependence of flatfish distribution on the temperature for Alaska plaice, Sakhalin flounder and rock sole greatly increases during spring months compared with the winter period. The influence of temperature on flatfish distribution decreases sharply for the summer months as catches are similar throughout the temperature range. Thus, the results indicate that West Kamchatka flatfish distribution is influenced by the variability of habitat conditions observed. If the formation of flatfish concentrations is mainly dependent on water temperature in the home range in winter and during spring migration, the role of depth increases greatly as it defines fish distribution and the distance traveled.

During summer feeding the influence of the depth and water temperature, in particular, decreases. Probably fish distribution and behaviour is more related to the of food supply abundance and distribution.

Cluster analysis is used to determine the degree of habit competition among the different species during the year. Each row of fish population density distribution is compared separately to all other rows, depending on the depth, water temperature and latitude. In order to obtain quantative values for the degree of habit coincidence, methods developed by Zhivotovsky are used to analyze morphometric characters. The pair-group method by Baily (1970) is used to determine the population habit coincidence.

Based on the analysis of the data there are three flatfish ecological nitches relative to the habit conditions using a hierarchic approach (Fig. 3). Shallow and warm water species occupy one nitche: yellowfin sole, longhead dab, Alaska plaice and starry flounder. The yellowfin sole and longhead dab which belong to the genus Limanda are closely ecologically related (Fig. 3 (1)). The other nitche includes the deep sea and cold water species: Sakhalin flounder and flathead sole (Fig. 3 (2)). And, finally, the third group is represent by rock sole (Fig. 3 (3)). Deep but limited aggregations of rock sole are found on the southwest Kamchatka shelf. Rock sole is seldom found north to 53°N.

Assuming all flounder species occupy a specific ecological nitche, then indirect evidence of the competition between them can be considered. Likely strong competition occurs among species from the same or close nitches than for species from desperate nitches. The most adaptable species will increase in this case oppressing the other ecologically similar species. Yellowfin sole is the most abundant flatfish in the first group (Fig. 3), and longhead dab which is ecologically similar is not very abundant. Alaska place and starry flounder are not abundant though they are more abundant than longhead dab.

In the second group, Sakhalin flounder is abundant on the shelf while flathead sole abundance is in deeper water. And finally, rock sole form a separate group of high abundance in the southwest Kamchatka coast as evidenced from commercial exploitation.

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FIGURES

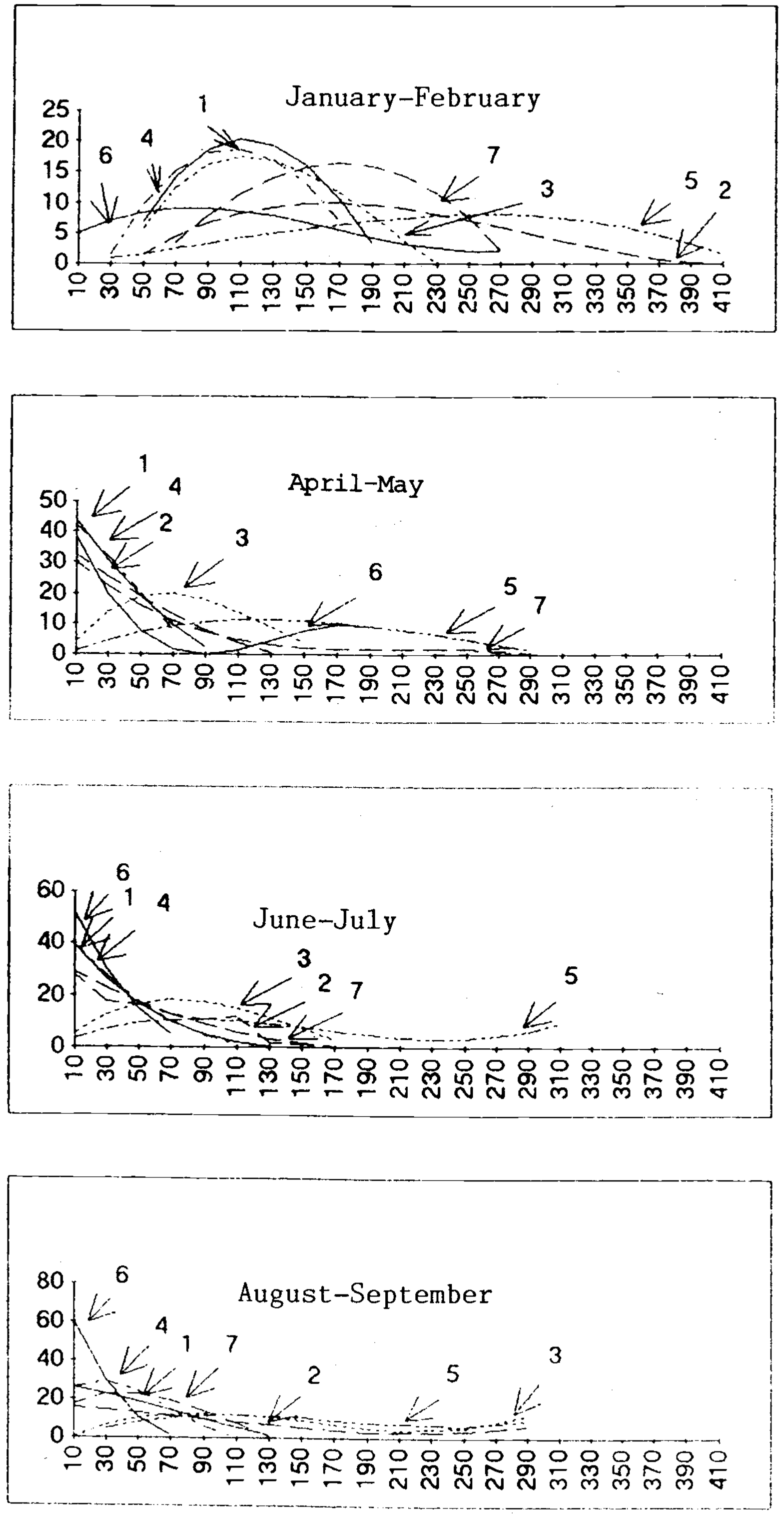

Fig. 1. Density dependence of flounder populations on depth.
1 - yellowfin sole 2 - Alaska plaice 3 - Sakhalin flounder 4 - longhead dab
5 - flathead sole 6 - starry flounder 7 - rock sole

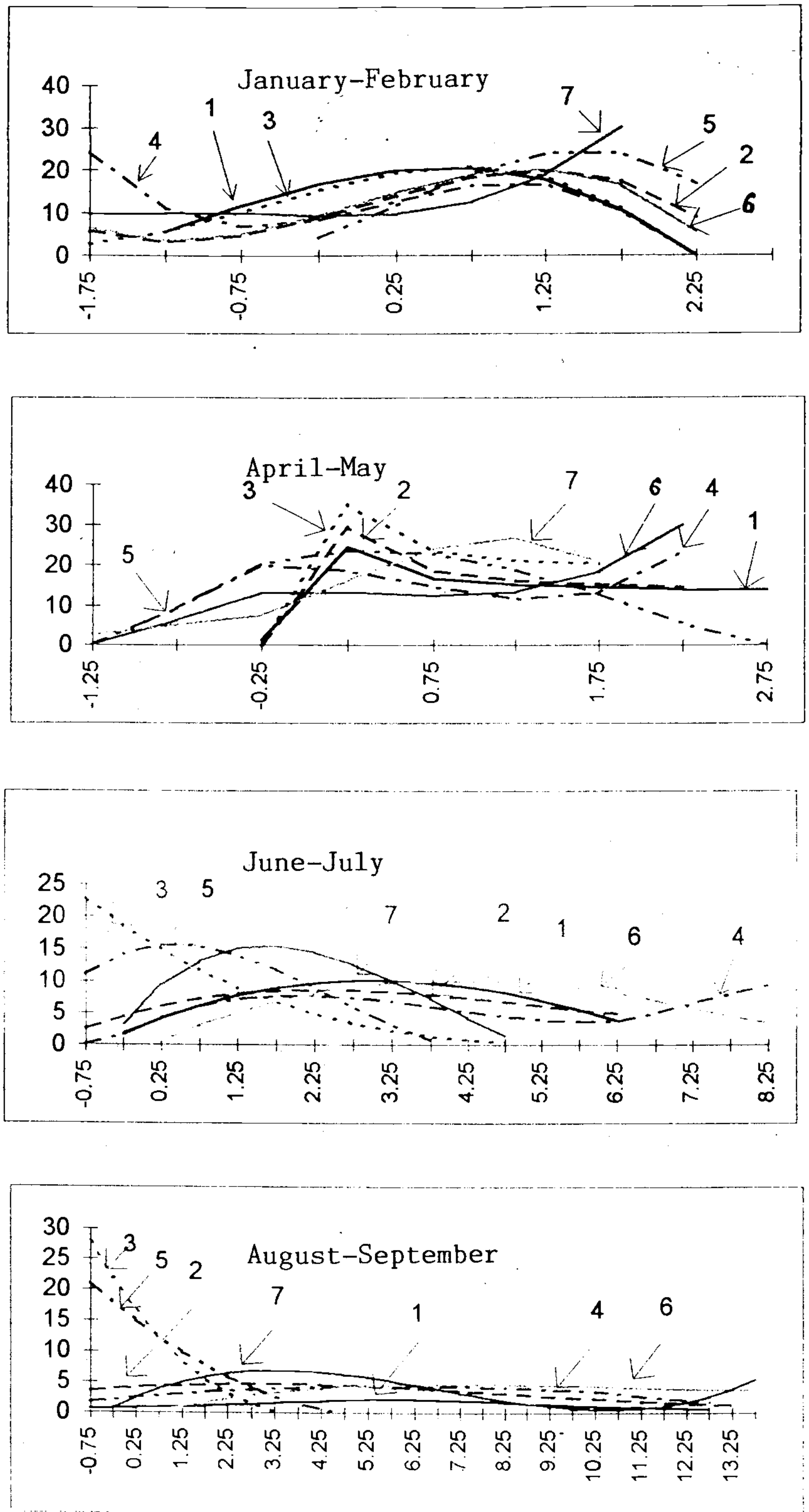

Fig. 2. Density dependence of flounder populations on water temperature.
1 - yellowfin sole 2 - Alaska plaice 3 - Sakhalin flounder 4 - longhead dab
5 - flathead sole 6 - starry flounder 7 - rock sole

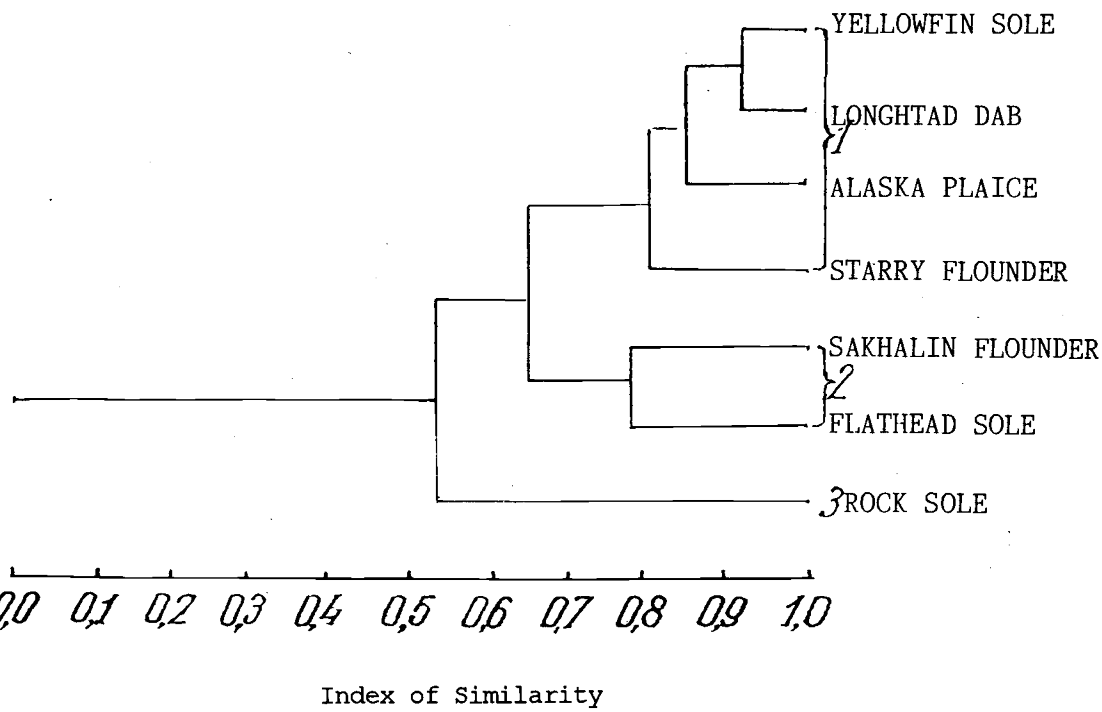

Fig. 3. The cluster of area similarity of flounders' population.

An Examination of Age Estimates of Walleye Pollock (*Theragra chalcogramma*) from the Sea of Okhotsk using the Burnt Otolith Method and Implications for Stock Assessment and Management

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ABSTRACT

In a previous study the first two authors examined age determination structures of walleye pollock, *Theragra chalcogramma*, from five stocks in the Northeast Pacific Ocean. We found that the burnt otolith section method consistently produced older age estimates. In this report we used this method to age walleye pollock sampled from the Sea of Okhotsk, and compared these results with ages estimated for the same fish using the otolith surface method. We also discuss how these estimates change our understanding of a number of biological parameters used in stock assessment, and also discuss the ecological implications.

INTRODUCTION

Up until the early 1980s age determination methodology was considered routine and accurate for aging all fish in a population. Unfortunately, few of these methods were validated. In 1983, the first two authors published a study which reviewed the accuracy of methods used to provide fish ages for fisheries stock assessment and management (Beamish and McFarlane 1983). The study was intended to emphasize the complexity of producing accurate ages and to discuss the consequences to assessments and management of relying on ages of uncertain accuracy. We found that in general fish were being underaged and that these age estimates had a substantial impact on estimates of growth and mortality that strongly influenced the development of management strategies.

In 1989 McFarlane and Beamish (1990) examined a number of structures which had been used to estimate the age of walleye pollock (*Theragra chalcogramma*) in the Northeast Pacific Ocean to determine, on a stock basis, which structure produced the most consistent pattern of growth and the most obvious annuli. In 1990, we extended this study to walleye pollock in the Sea of Okhotsk. The purpose of this report is to briefly review the results of our examination of age-determination structures from pollock in the Northeast Pacific Ocean, present the results of our examination of otolith surface and otolith cross-sections (burnt otolith method) from pollock from the Sea of Okhotsk, and comment on the implications for stock assessment and management of these stocks.

METHODS

A sample of 160 pollock was collected by trawl from the Sea of Okhotsk (off northeastern Sakhalin) in July, 1990. Each fish was measured for fork length and sex was determined. Paired sagitta otoliths were collected from each fish. Unfortunately, scales were not collected from these fish. Ages were estimated using both the surface and burnt cross section. Criteria for annulus identification are presented in Chilton and Beamish (1982). In general, an otolith surface can be aged by immersing the otolith in water on a black background and examining it with a dissecting microscope using reflected light. Some otoliths have a cloudy or chalky surface inhibiting the identification of the growth zones. These zones may be made slightly more distinct by rapidly dipping the otolith in a weak solution of HCI (usually 20%) before placing it in the water.

Otolith cross sections are aged by breaking the otolith dorso-ventrally through the nucleus and burning one of the broken surfaces in an alcohol flame and painting the burnt surface with non-toxic mineral oil to enhance the contrast between growth zones. The annulus was defined as the translucent zone or the zone of slower growth that appeared as a dark zone under reflected light.

RESULTS AND DISCUSSION

McFarlane and Beamish (1990) indicated that the most appropriate structure or method or both for age determination may vary among stocks. Pectoral fin-ray sections, otolith surfaces and burnt otolith sections are all suitable structures for stocks consisting of mainly younger fish.

Annuli on scales from all areas appeared to be distinct. However, ages estimated from scales were similar to ages determined from other structures only for the youngest fish. For most stocks, the burnt otolith section consistently produced older age fish. For example, for pollock from the Aleutian area and the international waters of the Bering Sea (Donut Hole), more annuli were identified on the burnt otolith section (Figs. 1 & 2) than on other structures. All four methods produced different age compositions (Figs. 3a & b), which resulted in different estimates of length at age, growth and mortality (McFarlane and Beamish 1990).

For the Sea of Okhotsk stock, a similar pattern was found. The burnt otolith sections consistently produced older ages than ages estimated using the otolith surface method (Fig. 4) when older fish were present in the sample. For example, when the fish is young (Figs. 4a & b), both methods produce the same estimates, however as the fish ages, and growth of the fish is reduced, otolith growth occurs almost exclusively on the ventral surface of the otolith (Figs. 4d, f & h) resulting in a thickening of the otolith.

In order to identify the annuli, the otolith must be sectioned (broken) and burnt. As with the other stocks (McFarlane and Beamish 1990), the two methods produced different age compositions (Fig. 5) and growth curves (Fig. 6).

We recognize that the age estimates for pollock have not been proven to be accurate. However, we applied the same age determination criteria to the burnt sections of pollock as we applied to other species such as rockfish and sablefish. The older ages for those species have been shown to be correct (Bennett et al. 1982; Leaman and Nagtegaal 1987; McFarlane and Beamish 1995). In our study and in other studies comparing otolith surface and section readings (reviewed in Beamish and McFarlane 1987) it was shown that otolith burnt sections do produce older age estimates than otolith surface readings.

Accurate age estimates are important for determining a number of biological parameters used in our assessment models. In particular, accurate age estimates are required to determine growth, mortality rates and identify strong year classes. If this small sample is considered representative of Sea of Okhotsk pollock, then the natural mortality estimate from this area is lower than determined using the otolith surface ages. Ensuring accurate age determination is also important in identifying and measuring the strength of year classes of the stock. Misidentification of strong year classes would lead to a misunderstanding of the precesses which regulate a population, particularly the importance of environmental factors.

We would like to conclude this report with a few thoughts on the "ecological" consequences of understanding the population dynamics of a population. For example, what is the effect of truncating the age distribution of a population? What are the long-term implications. If many individuals in the population would actually live to 25 or 30 years in an unfished stock then there had to be an advantage to a population having these old fish around ... clearly related to environment.

In an earlier paper we hypothesized that the length of life was related to the longest period of unfavourable conditions that the species encountered. Just the fact that pollock can live this old means there were such environmentally unfavourable periods. If this is true then our management strategies must consider that at some point these environmental conditions leading to poor survival of pollock will reoccur. If we truncate the age structure then we are becoming the agents of natural selection - and we are selecting for fish that optimize their survival under heavy fishing pressure as opposed to natural selection which selects for survival of the species in an environment that has extreme fluctuations in the physical or biological conditions.

What happens to these "truncated" stocks when the extreme environmental changes occur. Notice we said when, not if. It is inevitable that these changes will occur. We believe that accurate ages of walleye pollock will indicate that in general our management of fisheries must be conservative both because mortality rates are lower (stocks less productive) and there needs to be enough fish to survive periods of poor conditions.

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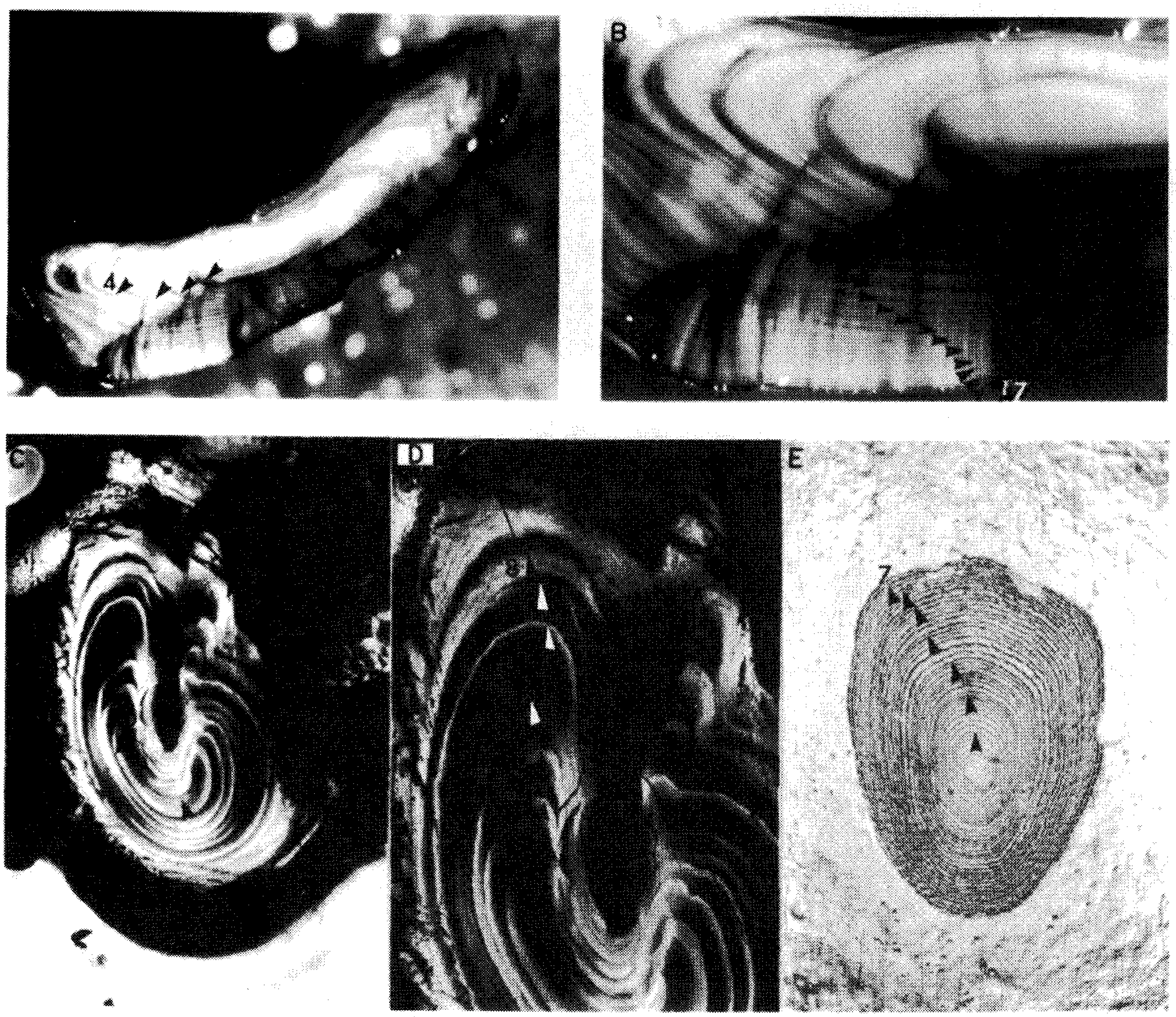

Fig. 1. Structures used for age determination collected from a 49 cm walleye pollock captured in the eastern Bering Sea (Aleutian area). A and B: Burnt otolith section showing 17 annuli. C and D: Pectoral fin ray showing 8 annuli and a large area between 8th annulus and the edge where annuli could not be identified. E: Scale showing 7 annuli. The otolith surface age was 10+.

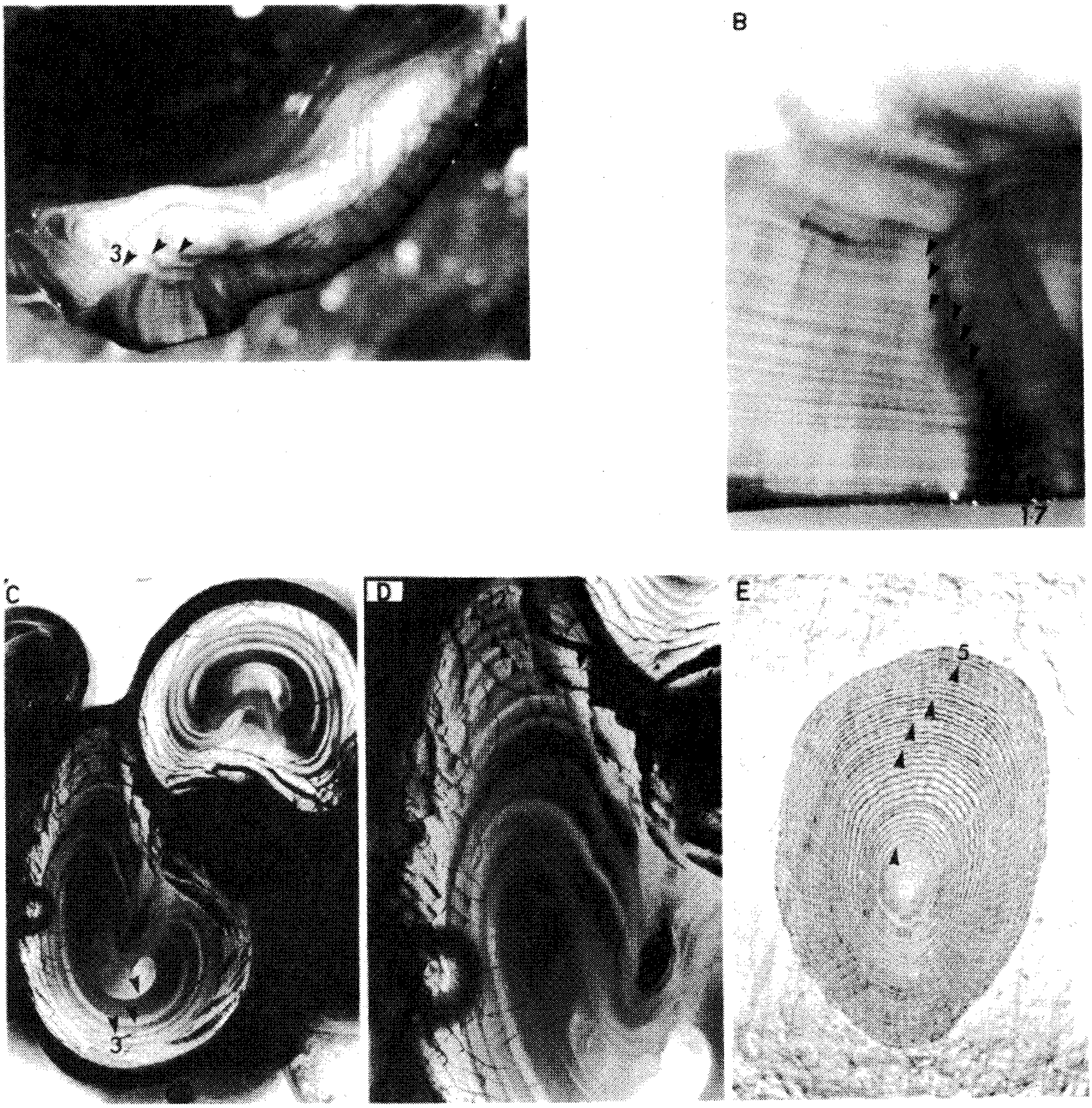

Fig. 2. Structures used for age determination collected from a 50 cm walleye pollock captured in the international waters of the Bering Sea (Donut Hole). A and B: Burnt otolith section showing 17 annuli. C and D: Pectoral fin-ray section showing 12 annuli. E: Scale showing 5 annuli. The otolith surface age was 11+.

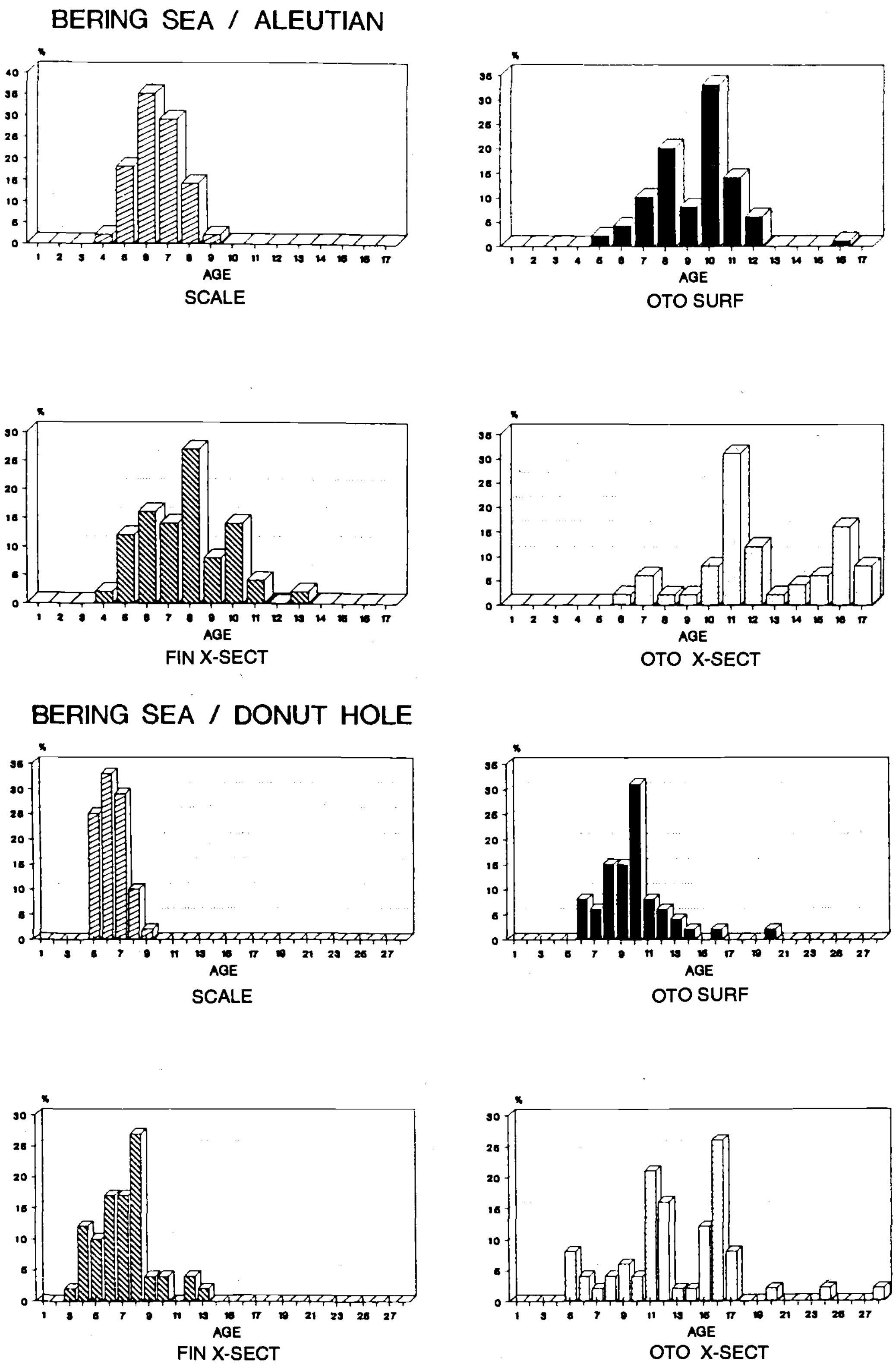

Fig. 3. Age compositions produced using the four ageing methods for the Bering Sea (Aleutian) area and the Bering Sea (Donut Hole) stocks.

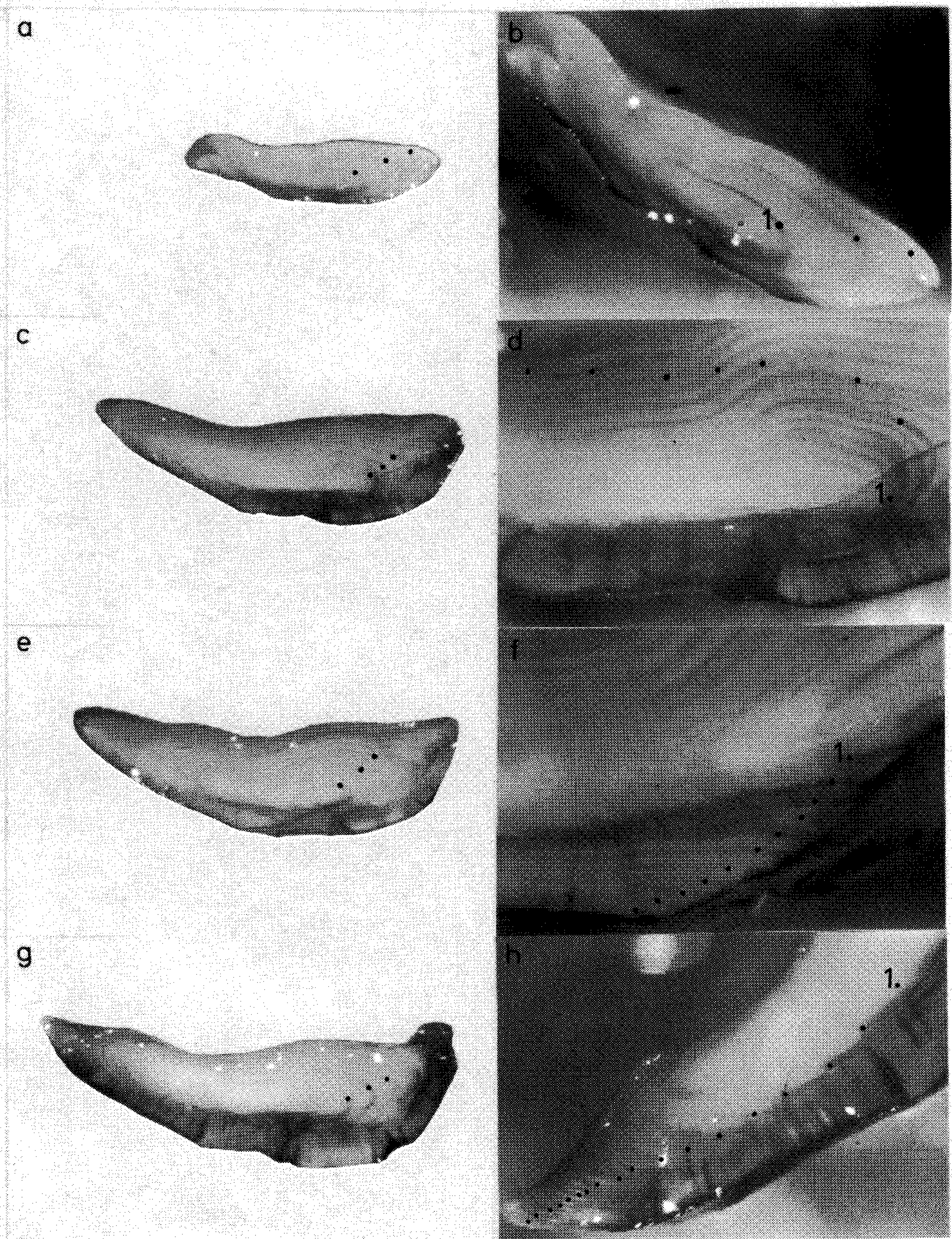

Fig. 4. Otolith burnt sections for walleye captured in the Sea of Okhotsk in July 1990. A and B: A 30 cm male showing 3 annuli, otolith surface age was also 3+. C and D: A 46 cm female showing 8 annuli, otolith surface age was 6+. E and F: A 53 cm male showing 11 annuli, otolith surface age as >3+ (difficult to interpret). G and H: A 57 cm female showing 18 annuli, otolith surface age was >5+ (difficult to interpret).

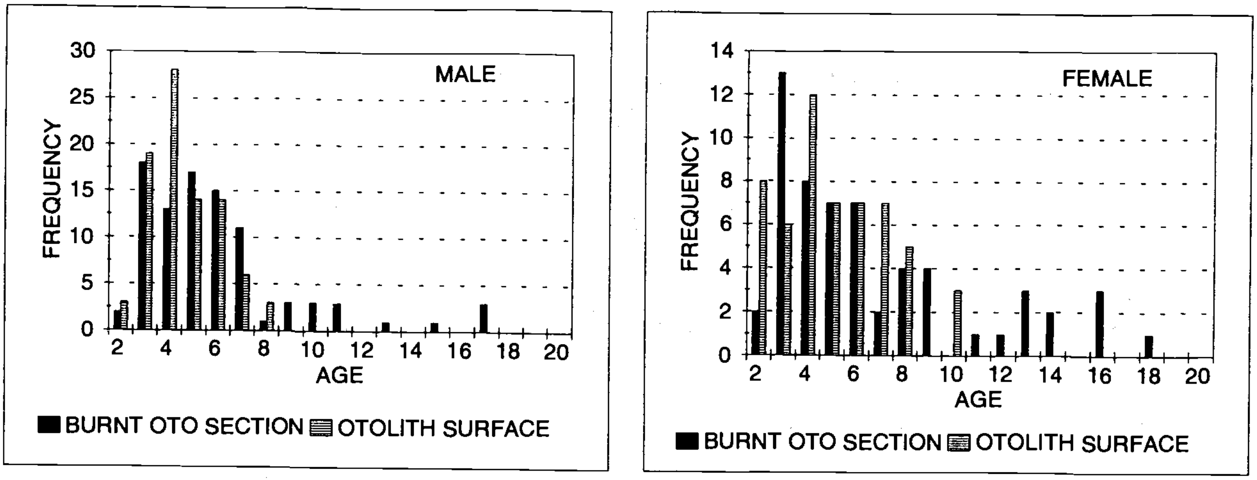

Fig. 5. Age compositions produced for Sea of Okhotsk walleye pollock using the burnt otolith section method and otolith surface method.

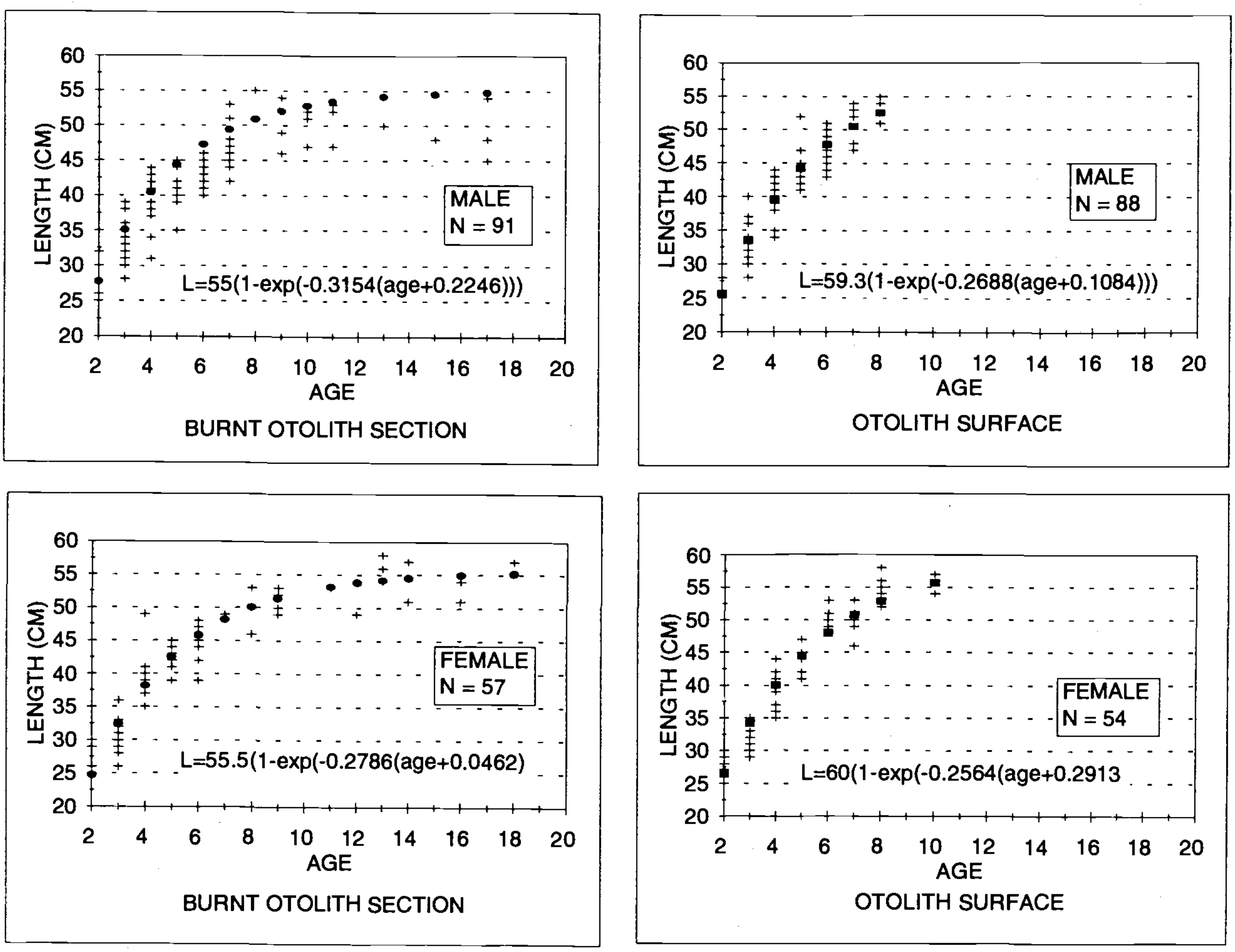

Fig. 6. Growth curves for male (upper panel) and female (lower panel) walleye pollock from the Sea of Okhotsk produced using the burnt otolith section method and the otolith surface method.

Migration of Greenland Turbot (*Reinhardtius hippoglossoides*) in the Okhotsk Sea

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The Sea of Okhotsk Greenland turbot annual catch has been 15-19 thousand tons since 1976. The ecology of the species is not well understood, particular, the distribution of larvae and young up to three years old and during the pelagic phase. This information would be useful to better manage the fishery. This paper presents an analysis of ichthyoplankton survey data from surveys in 1984-1987, pelagical surveys 1985-1993 and botton surveys 1963-1993.

The analysis showed that Greenland turbot with mature gonads (stages IV-V, V, V-VI) occurred along the continental slope of western Kamchatka, northern Okhotsk Sea and northeastern Sakhalin. The most intensive spawning occurred in TINRO basin, where catches were 10-25 per hour trawled but some catches exceeded 50 (Fig. 1A). The Lebed trough and Tinro basin are import for commercial fishing which was confirmed by data collected by scientific observers on fishing vessels in October-November, 1985. Almost all spawning was concentrated in these two areas (Fig. 1B). The northeast Sakhalin slope is of secondary importance, where some catches reached 25 per hour trawled but the majority of catches did not exceed 10. In other areas, spawning individuals were rare from 1 to 10 per hour.

Larvae of Greenland turbot from 17 to 24.2 mm were caught in the epipelagic zone. The larvae were distributed over the north of the Sea of Okhotsk and some specimens were collected near the Kuril Islands (Fig. 2). High concentrations were found in the TINRO basin and near the northeastern Sakhalin coast.

Twelve to 15 cm fingerlings were caught while trawling from 0-60 m above the 60 to 190 m depth. There was a significant difference in the distribution of larvae and fingerlings. Fingerlings were found in Terpeniya Bay, Shelikhov Bay and adjacent waters as well as the nearshore of southwest Kamchatka (Fig. 3). The highest catches of 7-8 cm (100 or more) specimens were in Shelikhov Bay and adjacent shelf waters of northwest Kamchatka. In waters adjacent to southeast Sakhalin, fingerlings were rare, less than 10 per trawl.

The distribution of larvae and fingerlings was related to the main currents of the Sea of Okhotsk. Larvae from TINRO basin were carried by the current along the continental slope of northwest Kamchatka (the north branch of the West Kamchatka current) to Shelikhov Bay (Markina and Chernyavskyi, 1984). The origin of the Sakhalin fingerlings was probably from mixed eggs and larvae carried by the middle current from the northern part of the Sea of Okhotsk to northeast Sakhalin where they were picked up by the East Sakhalin current to join with local larvae in the South Bay of Islands.

All areas in the Sea of Okhotsk, where larvae and fingerlings were found, were regions of high biological productivity(Chernyavskyi et al., 1981; Markina and Chernyavskyi 1984; Shuntov et. al 1993). Some drift to other areas also occurred as catches of larvae and fingerlings were obtained near Kuril and Shantar Islands.

Greenland turbot yearlings were from 14-23 cm. At one year old they usually settled to the bottom in the Bering Sea and on the shelf of East Kamchatka. In the Sea of Okhotsk, good catches of 18-20 cm Turbot were caught in a pelagic trawl at depths of from 64 to 210 m at the same location as fingerling. Yearlings occurred in the pelagic zone of Shelikhov Bay where catches reach 25-50 per hour trawled but were less than 25 near southeast Sakhalin (Fig. 4). Older specimens moved in an anticlockwise direction in Shelikhov Bay and there was an appearance of some yearlings in Tauiskiy Bay and adjacent waters.

Not more than 5 per hour trawled of 1+ individuals occurred along the shelf of the north part of the Sea of Okhotsk and they were distributed over a broader area compared to the fingerlings. They also occurred along the shelf of Tauiskiy and adjacent waters on shelf and upper continental slope of TINRO basin and the northwest shore of Kamchatka.

In contrast to the northern areas, the number of fingerlings in the pelagic zone near Sakhalin decreased significantly and the majority of 1+ settled to the bottom of Terpeniya Bay and adjacent areas of the East Sakhalin shelf.

In general, the eggs and larvae drifted in the West Kamchatka Current toward Shelikhov Bay. Probably the concentration of young fish near southern Sakhalin had the same origin. Eggs and the larvae also drifted to the northeast Sakhalin coast in the Middle Current, and local larvae were carried by the East Sakhalin Current into Southern Bay of Islands where they eventually settled to the bottom.

Kelp, coral and balanus prevent bottom trawl surveys in Shelikhov Bay. Nevertheless, judging from the stable and dense concentrations of larvae and juveniles up to age 2 in the northeast area and in pelagic zone of Shelikhov Bay it can be theorized that part of the Okhotsk Greenland turbot settle in this Bay. The northeast area was favourable for development of the young because there are numerous gyres and upwellings and it is a zone of high biological productivity during the larval drift period along the northwest Kamchatka shore. A vast gyre in Shelikov Bay prevent juveniles from being carried to less productive areas before they settle to the bottom. The northern shelf within the Sea of Okhotsk provides good condition for a gradual transition of Greenland turbot from shallow to the deep depth as they grow older.

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FIGURES

Fig. 1. Distribution of catches of spawning Greenland turbot on the continental slope of the Okhotsk Sea.

A - data of surveys 1977-1987 years,

B - commercial catches in October 1985. Boundaries of the fisheries area are shown by dotted line. See figure 3 for the explanations.

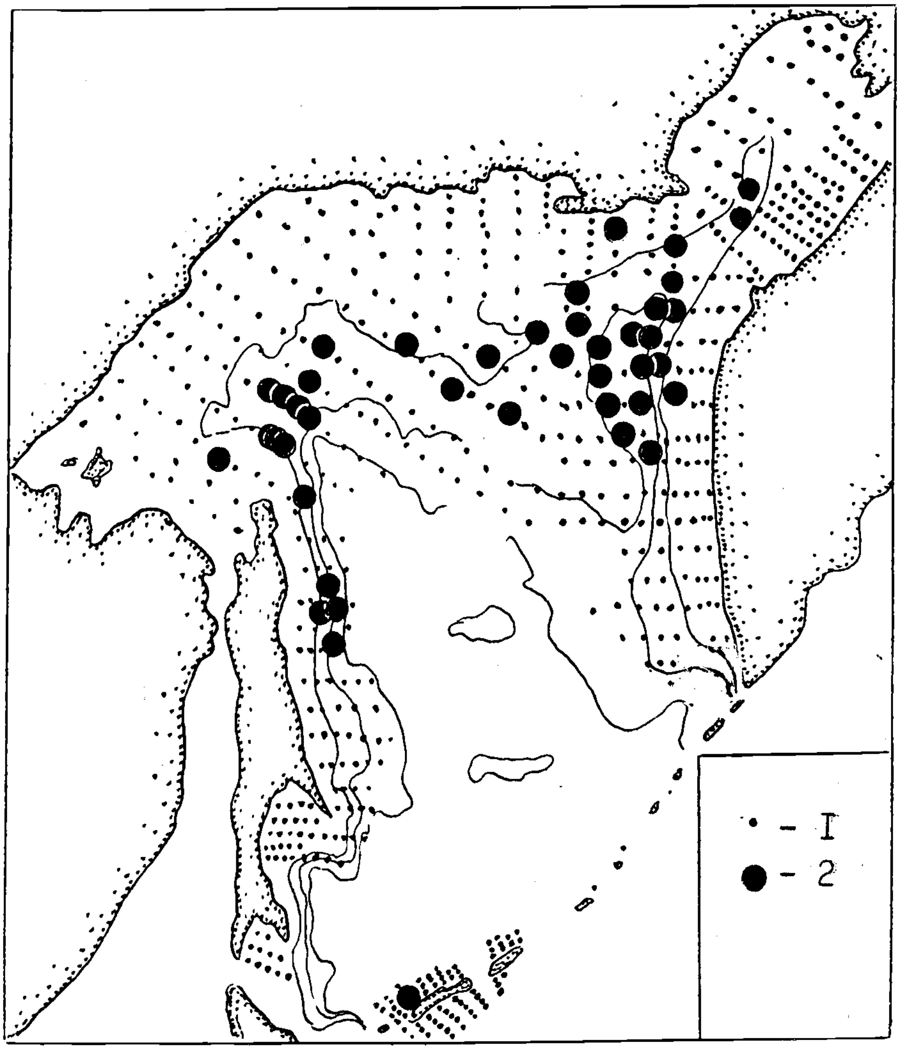

Fig. 2. Ichtyoplankton surveys in Okhotsk Sea 0-200 m in 1984-1988 (1 - stations) and catches of the Greenland turbot larvae (2). All catches from 1 to 5 specimens.

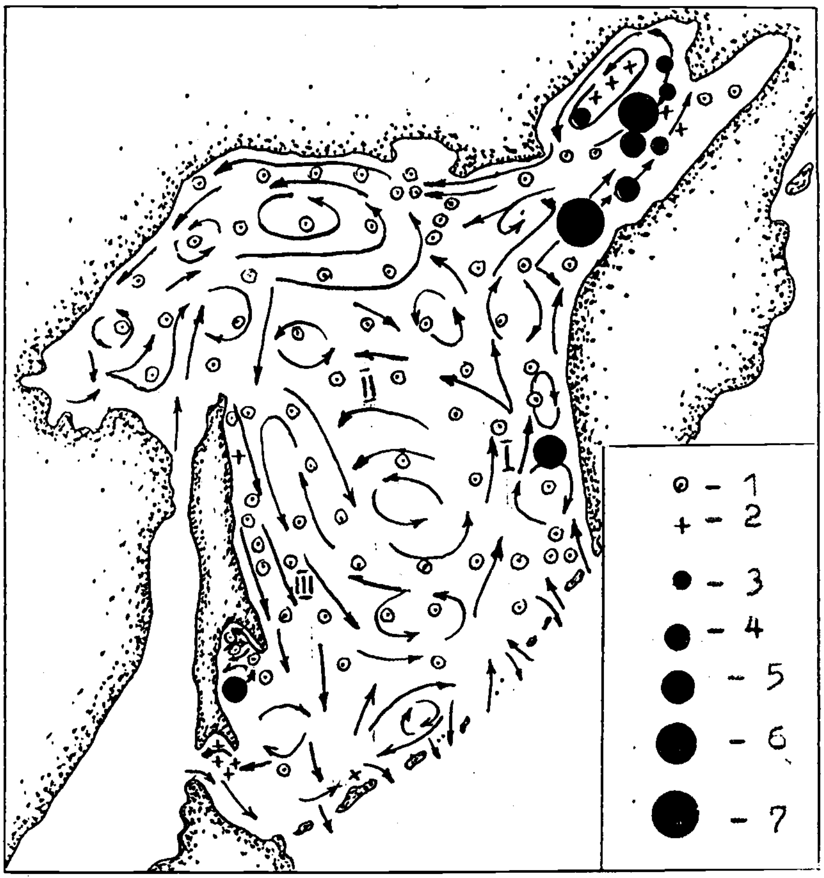

Fig. 3. Distribution of the Greenland turbot at age 0+ from the pelagic catches in the Okhotsk Sea in 1985-1992.

1 - no catch;
2 - 1-5;
3 - 6-10;
4 - 11-25;
5 - 26-50;
6 - 51-100;
7 - more than 100 specimens per hour trawling.

Arrow mark the main currents: I - Western Kamtchatka, II - Middle, III - Eastern Sakhalin.

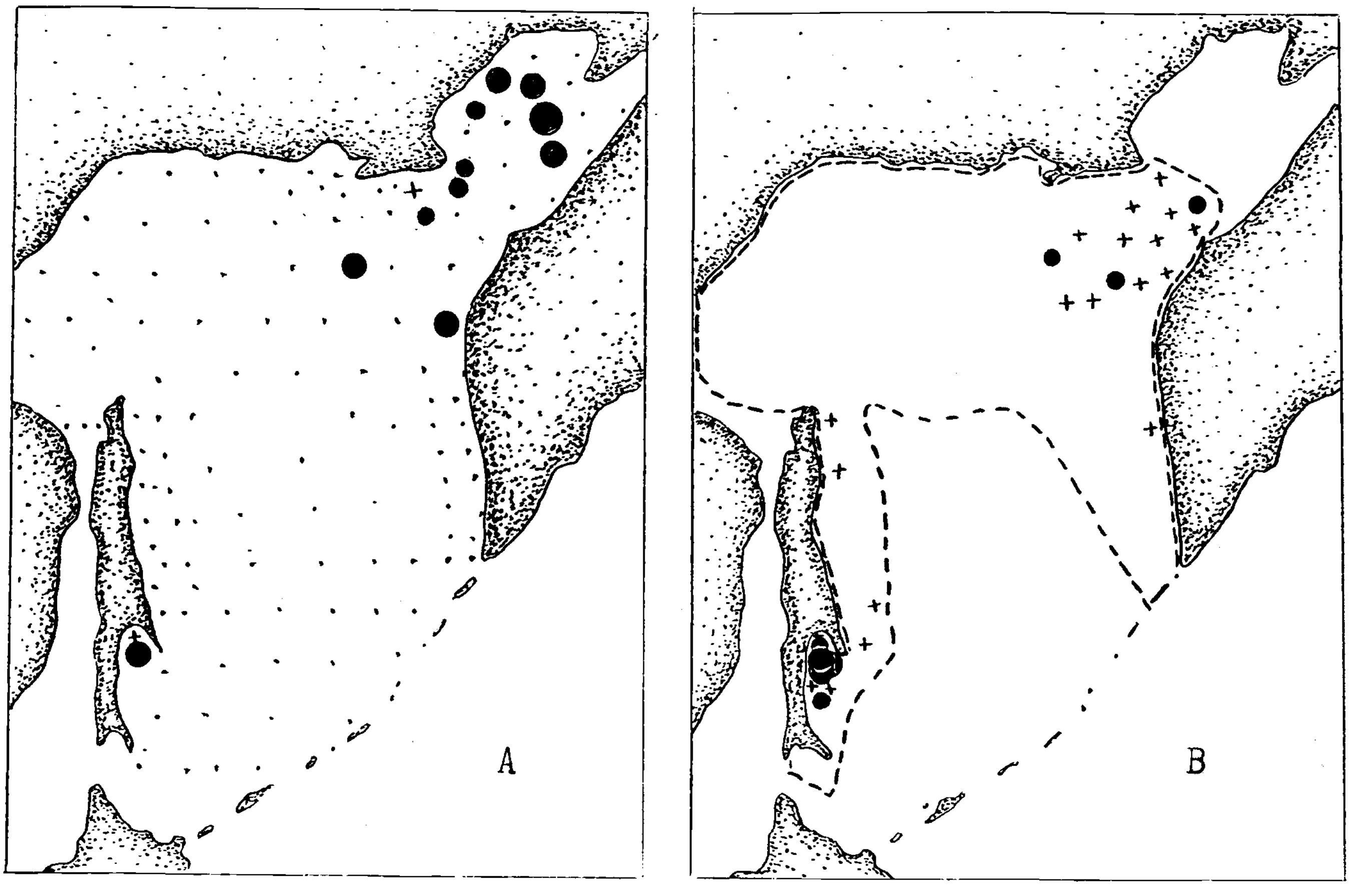

Fig. 4. Distribution of catches of the Greenland turbot at age 1+ in the Okhotsk Sea, judjing pelagic in 1985-1993 (A) and bottom in 1963-1993 (B) trawlings. Boundaries of the investigated area are shown by dotted line. See Fig. 3 for the explanations.

Fisheries Impact on the Sakhalin-Hokkaido Herring Population

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For several decades the Sakhalin-Hokkaido herring *Clupea Pallasi* has attracted attention of fishery scientists because of the commercial exploitation potential from the population where annual cumulative catch reached a high of 1 mln t., a greater annual yield than any other Far-East population. At the same time, other regional populations such as Sakhalin-Hokkaido declined. Birman (1973) indicated that an increase in the Sakhalin-Hokkaido herring abundance should have been expected in the 1970s but actually only the 1973 yearclass was good. Sokolovsky (1985) predicted stock increases during the 1980s but only the 1983 yearclass was good although it proved to be lower than the 1973 yearclass. Therefore in the 1970-80s the abundance of the Sakhalin-Hokkaido herring population remained at extremely low levels. Conservation measures such as, stopping fishing for spawning and immature fish, introducing a commercial fish size limit and full closure of the fishery for a five-year period did not produce an increase in the stock. Thus, understanding the reasons causing the declines in abundance and ways to stabilize and increase abundance of the herring would help manage the fishery. In this paper, the author attempts to propose possible solutions by establishing reasons for regulating the herring fishery.

Data on the annual Sakhalin-Hokkaido herring catches for a period 1921-1992 together with information on the age composition, yearclass strength and stock levels are analyzed. The long time series of data allows a review of abundance fluctuations which indicates three abundance related periods in the Sakhalin-Hokkaido population as follows:

1. Before 1950 during a period of the high abundance year-classes varies from 201.5 bln in 1939 to 1.8 bln in 1949 with average 28.3 bln.
2. 1951-1960 a sharp abundance decline occurs (transitional stage) from 5.4 bln in 1953 to 0.3 bln in 1960 with average of 1.9 bln fish.
3. 1961-1992 the population remains in a depressed state. Yearclass strength varies from 4.7 bln in 1973 to 0.05 bln in 1985 with average of 0.8 bln fish.

During 1949-1951, 1953-1956, 1958, 1961 several bln individuals were produced but lower abundances occur in 1965, 1970; 1972-1973 (Fig. 1). In the years that followed only the 1983 yearclass is high (2.85 bln). In the other years extremely low abundance levels (tens of millions individuals) are observed.

The stock level declines from the early 1950s to the present is from fishing and poor yearclass production (Fig. 1). It is interesting to note that the occurrence of a few good year-classes did not prevent the stock from continuing to decline. The stock has not shown any attempt to recover and has remained in a depressed state for a long time. For each of the three abundance-related periods, the Sakhalin-Hokkaido population, mean stock abundance and catches are calculated for several age groups as follows:

1. In the periods of high abundance, the exploitation rates of cohorts 3 to 9 years old constituted 5.35% for the age 3, 7.8% for the age 4, 9.6% for age 5, 10.9% for age 6, 11.2% for age 7, 16.2% for age 8 and 39.0% for age 9 (Fig. 2).
2. During the reduced abundance period, the exploitation rate of 3 years olds increases to 39.2%, for 4, 5, 6 and 7s; 35.5%, 26.8%; 16.3 and 22.4% respectively. The exploitation rate of 8 and 9 year olds decreases to 14.7 and 13.7% respectively. The fishery appears to be concentrating on fish 3-5 years old during maturation .
3. Exploitation rates during low stock abundance for 3 to 9 year olds is similar to that observed during the decline; 34.3% for age 3, 39.7% for age 4, 44.2% for age 5, 23.1% for age 6, 6.0% for age 7, 2.9% for age 8 and 0.9% for age 9.

During normal stock abundance levels, commercial catches are dominated by individuals of older age (that might have participated in spawning at least 4 times) groups, while in periods of abundance decline catches are dominated by immature and first maturing fish. While the stock was depressed, the 1973 and 1983 year-classes are relatively high and the 1974 and 1980 are at low levels. The first two year-classes are exploited at 75.7% for 1973 for the 3 year olds and 56% for 1983 (Fig. 3). Exploitation rate for 4, 5 and 6 year olds for both years are 51-52, 25-44.5, and 21.6-25.6% respectively. Catch during the low 1974 and 1980 stock abundance also tends to be concentrated on young immature fish before they are able to breed. The stock has been harvested by both Japan and Russia. During the last 16 years, the Russian catch varies between 0.7-4.3 th. t, while the Japanese catch varies from 1.4 to 72.4 th. t (Fig. 4). The average annual exploitation rate is 14.5 and 85.5 % respectively. The Russian fishery focuses on feeding concentrations and the Japanese on over wintering and pre-spawning fish. In the initial years of the fisheries, Japan caught much more than Russia, especially of high abundance year-classes (Probatov, 1954). For example, a total catch for the 1983 brood year constituted 614 mln individuals, with Japanese portion amounting to 92.2% or 559.8 individuals. The catch of the Japanese fleet in 1986 was 73% or 408.7 mln of younger than 3 years old (Fig. 5). In 1987 the Japanese fishermen took 83.7 mln individuals of the same yearclass. Therefore, about 88% of the total catch of the 1983 yearclass were taken by the Japanese fleet during maturation period, which greatly reduces the reproductive potential of the parent stock (Fig. 5).

The lack of spawners on the Sakhalin-Hokkaido grounds has been discussed (Kachina, 1974, 1981; Pushnikova, 1981, 1994) including meetings of different levels and meetings between Russian and Japan. Russian scientists proposed a closure of the fishery to allow the population to increase but the proposal was not accepted by representatives from Japan. The eggs surveys conducted in 1970, 1980 and 1990s, reveal that 90% (and in some years even more) of the traditional Sakhalin-Hokkaido population spawning grounds is not visited by spawners even though the substrate is ideal (good algae and eel grass). No herring eggs were found in traditional areas where major spawning usually occurs. Spawn was observed at smaller spawning sites that were difficult to find (Fridland, 1951).

Based on a study to determine an appropriate parent progeny ratio, it is estimated that an optimum parental stock abundance for the population should be 3 bln individuals (Pushnikova, 1994). The estimated spawning stock strength from 1968 to 1976 varies between 0.04 and 0.35 bln fish about 15 times lower than the optimum level for the stock. If the current fishing strategy is continued on these stocks, the abundance will likely continue to drop. This is supported by the abundance decline, poor yearclass strength and no spawning on traditional spawning grounds and extremely low spawner abundance. To prevent this continuing decline the parent stocks should be stabilized and provide for favorable conditions to allow the stock to increase, thus, a closure of the fishery for both Russia and Japan should occur.

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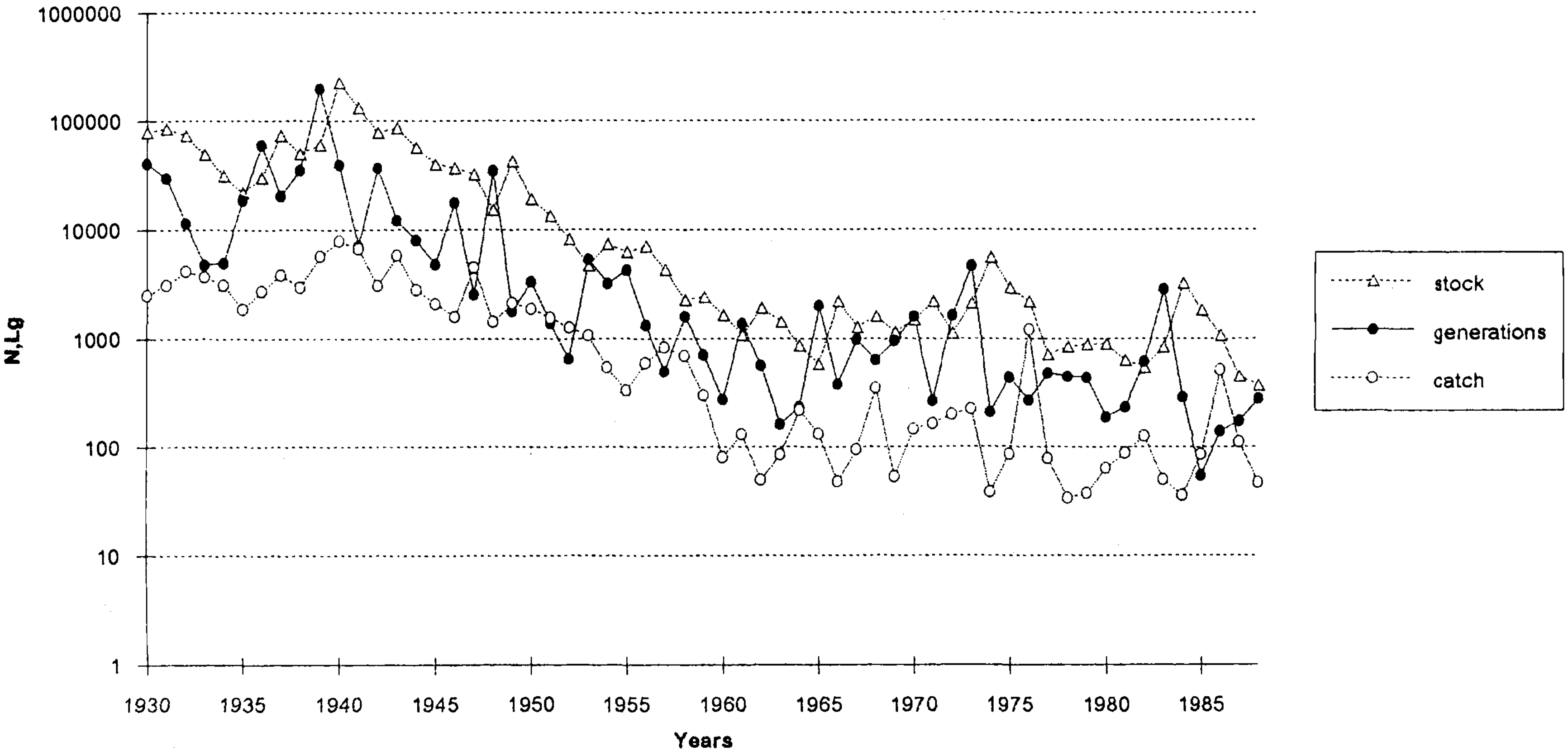

Fig. 1. Stock, generations and catch values (N) of the Sakhalin-Hokkaido herring in 1930-1990.

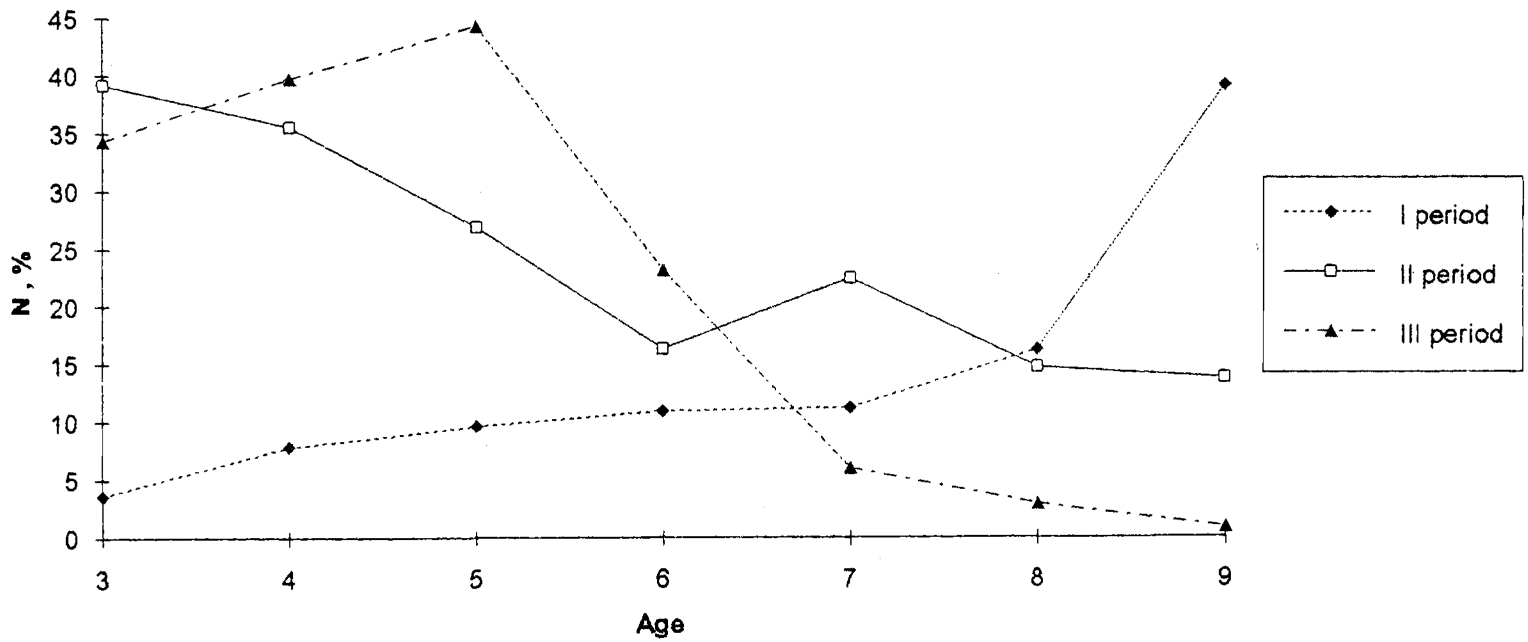

Fig. 2. Age composition of the Sakhalin-Hokkaido herring population in catches for three periods.

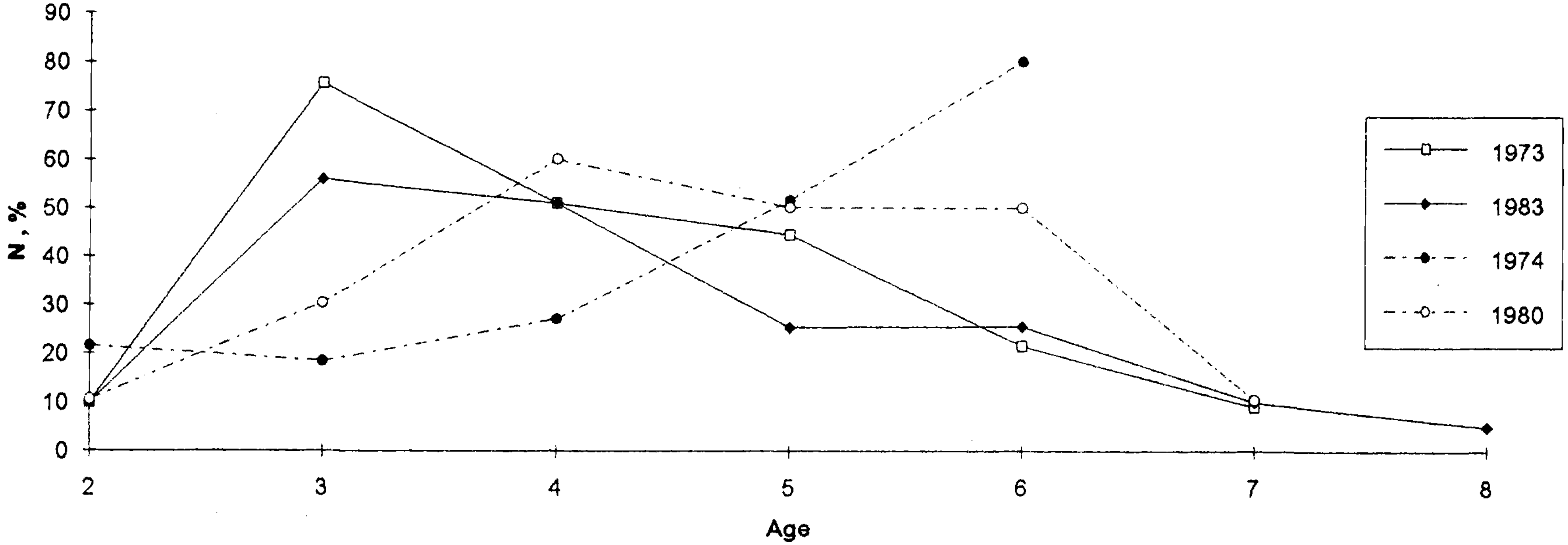

Fig. 3. Catch dynamics of Sakhalin-Hokkaido herring for 1973, 1983, 1974, 1980 generations.

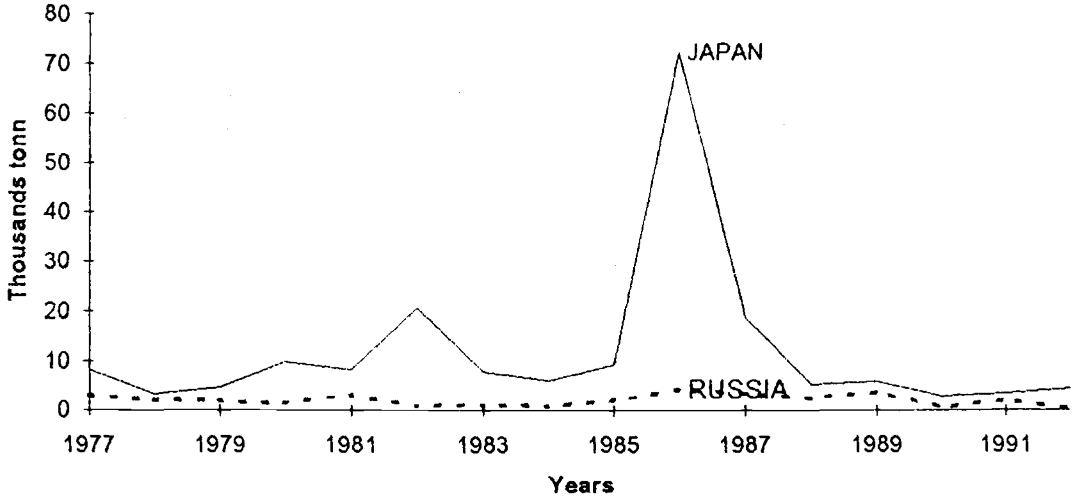

Fig. 4. Sakhalin-Hokkaido herring catch by Russia and Japan in 1977-1992.

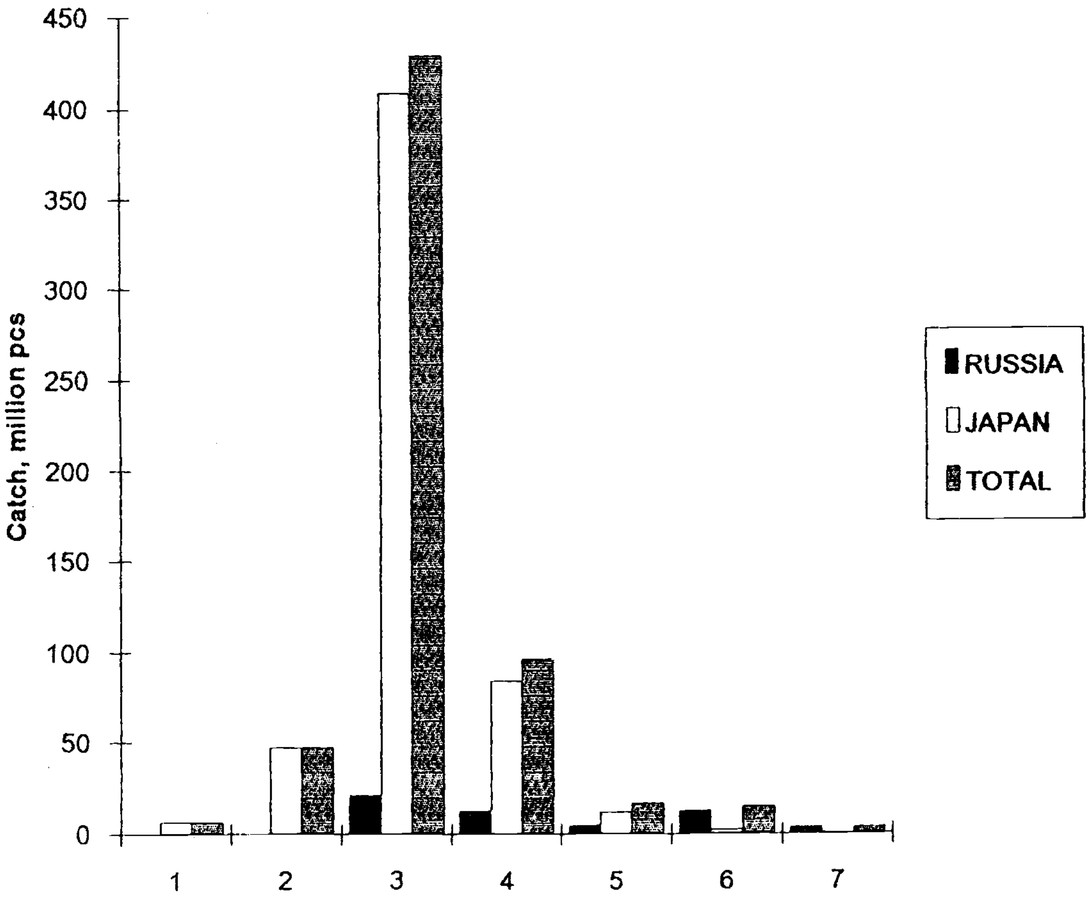

Fig. 5. 1983 generation catch.

Is Pollock Overfished?

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Is pollock overfished?, is a question often asked by fisheries and conservation groups. The primary motivation has been the growth in the harvest by U.S. vessels, and the entry of large amounts of pollock on the international market from the Far East. The appearance of Russian pollock in the international market along with large catches from international waters in the Bering and Okhotsk Seas has increased concern over the long term health of the pollock resources. Conservationist point to pollock fisheries as a possible cause of declines in the abundance of sea lions and sea bird populations for which pollock is an important food. The recent history of exploitation and stock declines and collapses in North Atlantic cod populations has also caused conservation groups to question the management and condition of pollock in the North Pacific.

Catch relative to exploitable biomass has been relatively low for the major North Pacific pollock stocks. Comparing the level of exploitation of eastern Bering Sea pollock to the major cod stocks of the North Atlantic for the period 1964-1990, it can be seen that the level of exploitation was about 20% for pollock, while Atlantic cod stocks were fished at a much higher level (Fig. 1). The northeast Arctic cod of the Barents Sea was closed to fishing in the early 1990s and recovered due to the fortuitous occurrence of a very strong year-class. The Northern cod of eastern Canada collapsed recently following an extended period of over harvest and has caused economic hardship to the Newfoundland fishing community. The North Sea cod is likely the next stock to collapse, since the fishery now operates on age 2 fish, of which about 75% are harvested. Iceland is attempting to reduce cod harvest this year and has made sharp reductions in cod quotas hoping that controls will prevent a stock collapse similar to Canada and Norway.

Why compare walleye pollock to Atlantic cod? Primarily, because they are ecological equivalents, being the dominant gadid species and having similar behaviors. Fig. 1 clearly shows that, in gadids, that exploitation in excess of 50% is not sustainable. The question is what is the safe level of fishing for pollock and other members of the cod family.

The abundance of pollock is controlled by recruitment variation. In the eastern Bering Sea the largest year-class (18 billion fish at age 3) was 11 times greater than the weakest year-class, 1.6 billion at age 3. Eastern Bering Sea recruitment is best fitted to a Ricker spawner-recruit function, which is logical for pollock because cannibalism by adult pollock is a major factor influencing recruitment (Fig. 2). Temperature is also important, and warm years usually produce strong year-classes and cold years, weak ones. Variation in recruitment produces variation in stock biomass which can be quite strong in pollock as shown in Fig. 3 for the eastern Bering Sea and other stocks. What is interesting is the similarities between the Okhotsk Sea and eastern Bering Sea. In both the 1978 year-class was strong and more recently the 1989. The apparent similarity of biomass trends between the two areas suggests the influence of broad scale climatic factors. Perhaps further study of this phenomenon will produce some insight in underlying causes of recruitment variation. Since 1977, pollock harvest in the eastern Bering Sea has been kept to under 1.5 million t including discarded catch. Can this harvest be sustained?

To examine the question, I have been modeling the population dynamics of the stock along with different fishing patterns. The primary variable is recruitment. I incorporated recruitment in the model as a Ricker model with log normal error to reflect the natural variation observed in the history of the stock. One result of the model with fishing at the $F_{0.1}$ level, which is the F that results in a yield per recruit that is 10% that obtained from the first increment of fishing effort, shows the recruitment trend is similar to the trend observed (Fig. 4). The important point is that fishing at the $F_{0.1}$ level produces catches on average that are greater than recent year averages, and the biomass does not fall below 4 million t--the lowest level observed in the stock (Fig. 4 lower panel). Fishing at $F_{0.1}$ equals an F of 0.31, an exploitation of around 20%. The maximum level of harvest is at $F=0.43$ which 28% exploitation. Fishing at levels beyond a 28% exploitation rate results in overfishing and reduced long-term yield.

The long-term yield from the fishery is greater than currently taken and the biomass is near the long-term average. My conclusion is that eastern Bering Sea pollock is not overfished and catches near the current level can be sustained without any problem. Model results indicate that any exploitation below 28% does not impact the productivity of the pollock resource. Similar results have been obtained for Northeast Arctic cod, which suggests a 30% exploitation rate may be a maximal exploitation rate for gadids. The best exploitation policy for eastern Bering Sea pollock may be to fix catch in the range 1.3-1.5 million t for economic reasons, and not allow the fishery to grow beyond this level, thus avoiding having to reduce quotas at times of stock decreases, which given the recent crises in the Atlantic cod stocks, are apparently difficult to do.

FIGURES

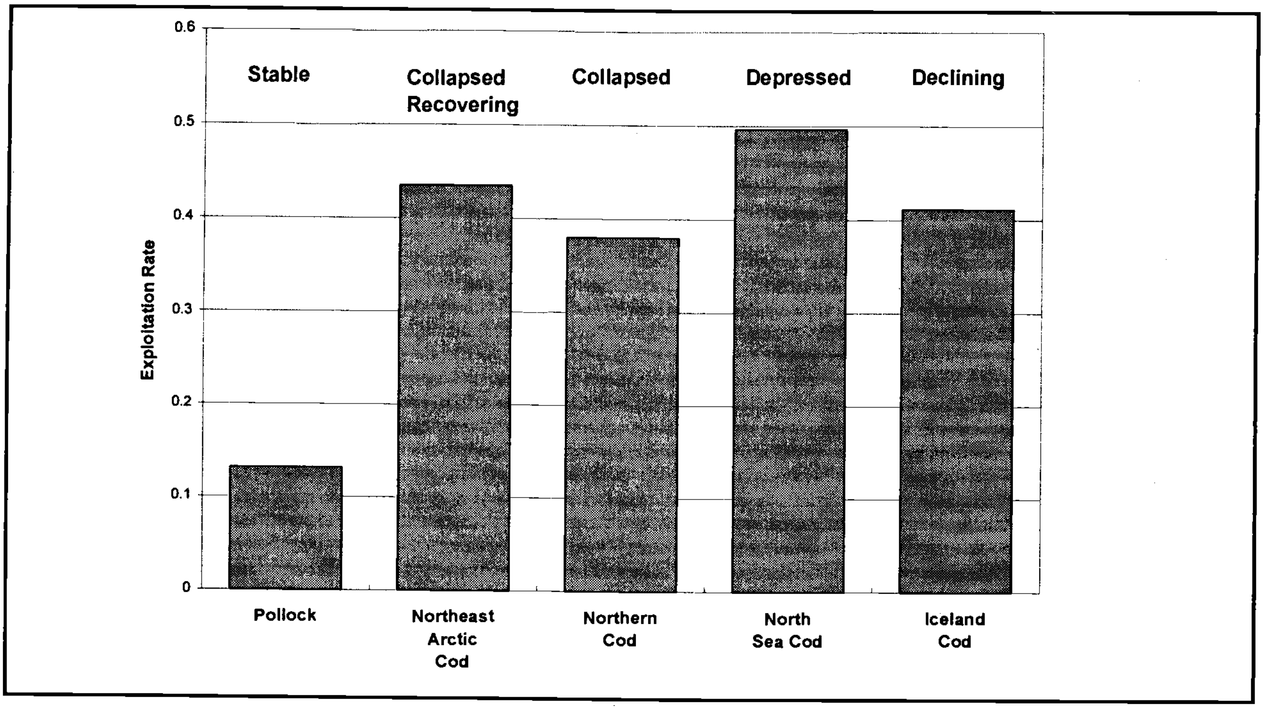

Fig. 1. Comparison of exploitation rates on eastern Bering Sea walleye pollock to exploitation rates on the major Atlantic cod stocks, 1964-1992.

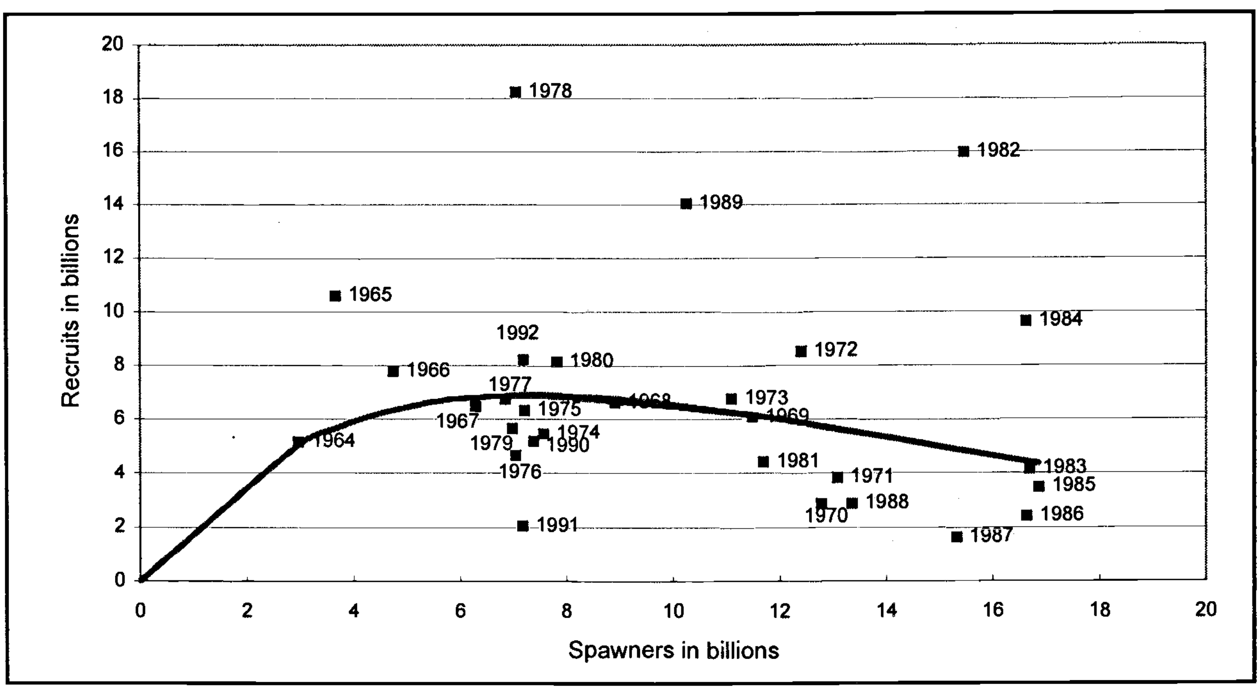

Fig. 2. Spawner-recruit relationship for eastern Bering Sea walleye pollock, 1964-1992 year-classes.

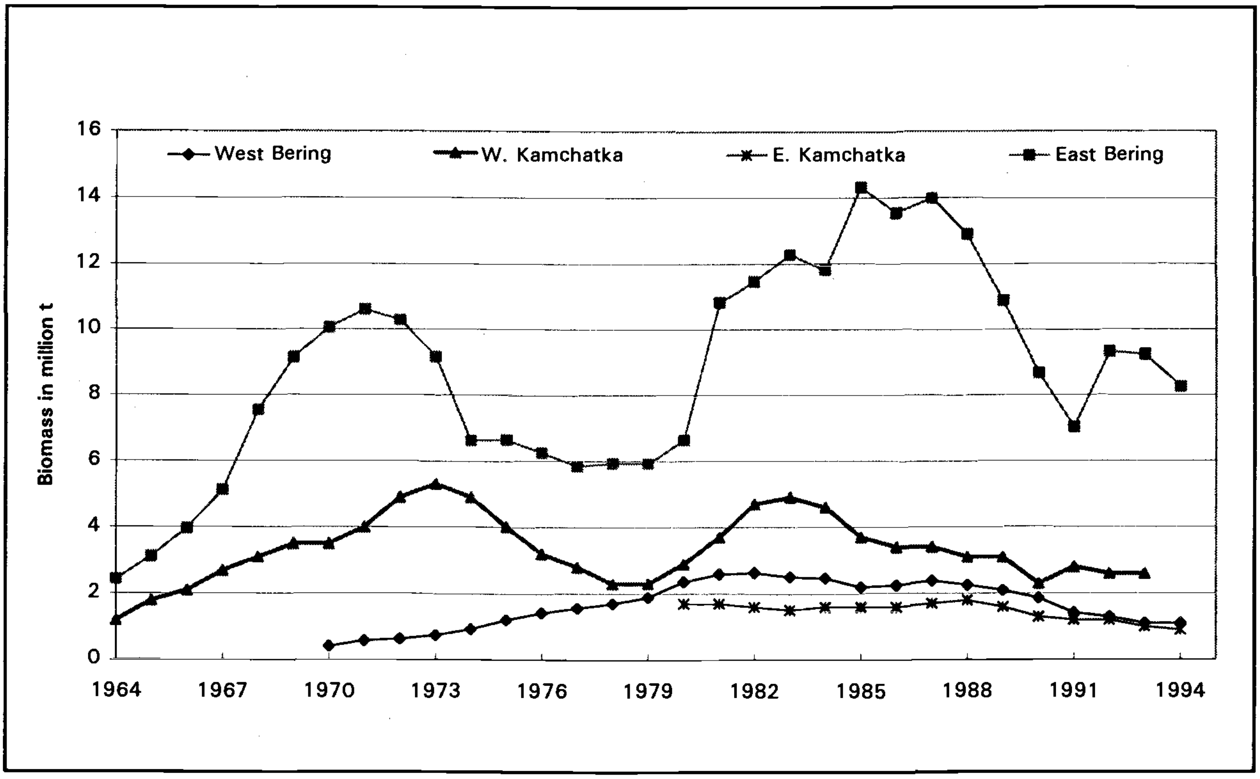

Fig. 3. Biomass trend of major walleye pollock stocks, 1964-1994.

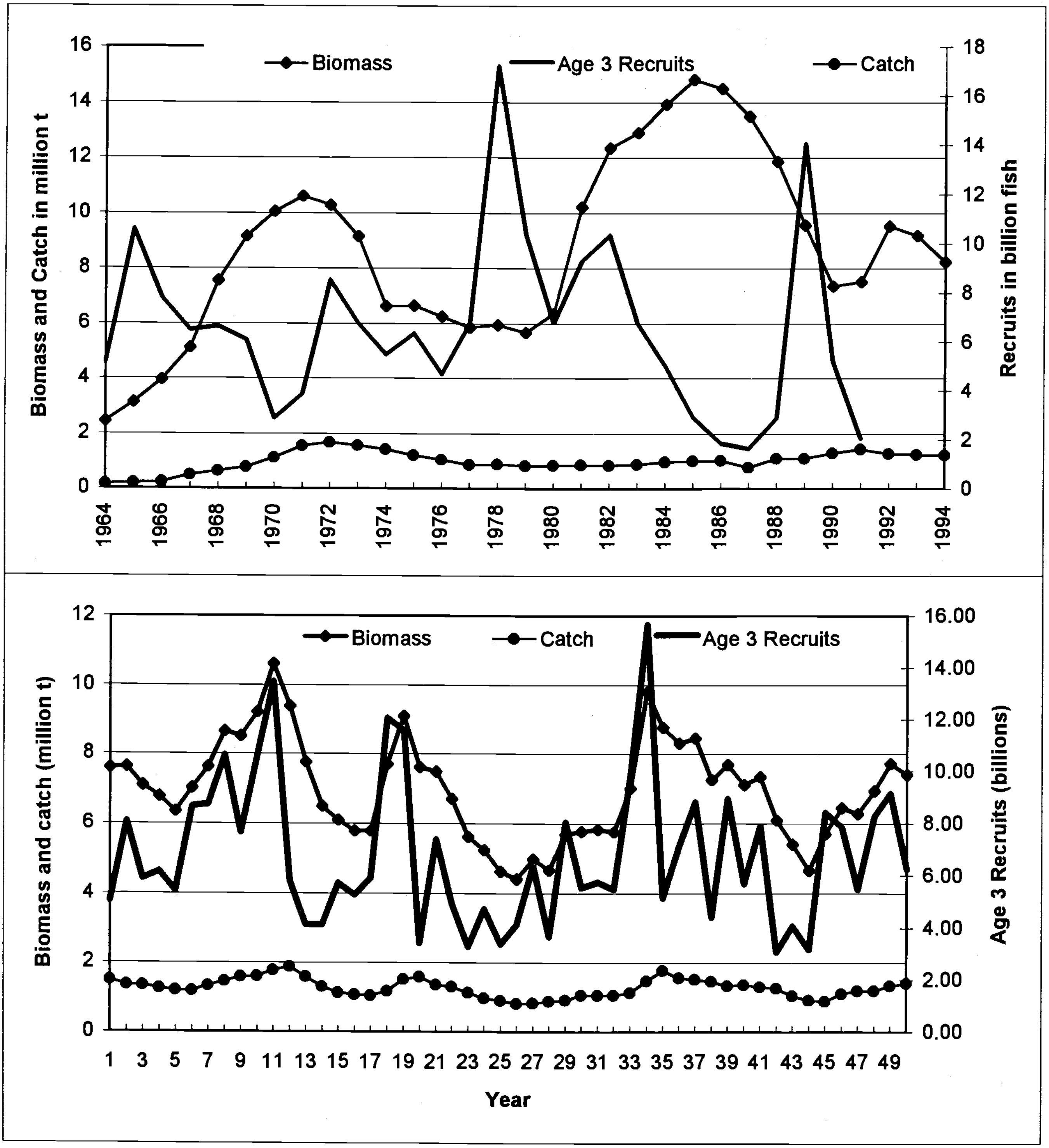

Fig. 4. Top panel: catch, biomass, and recruitment trend observed for eastern Bering Sea walleye pollock, 1964-1994. Bottom panel: a 50-year simulation of eastern Bering Sea walleye pollock catch, biomass and recruitment based on F=0.31 and a Ricker recruitment function incorporating log normal error.

Epipelagic Far Eastern Sardine of the Okhotsk Sea

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The far eastern sardine was one of the most abundant species in northwest Pacific in the 1970-1980 period. The distribution and migration patterns changed from earlier times (Kenya, 1981).

The maximum abundance of sardine during the feeding period (summer-autumn) migrates into the south part of the Okhotsk Sea from the Pacific following the warm waters from the Japan Sea and Soya Current. During the high sardine abundance levels, the Russian fishing fleet concentrated their effort on catching the species. Landings first occurred in 1977, however, the most successful fisheries were after 1984. The fishery usually occurs from June to October as was observed in 1988 when a maximum catch of 241,300 ton occurred (Fig. 1).

There are two main regions where sardines are caught in the Okhotsk Sea, near the Okhotsk Sea coast of the Kuril Islands and in the southern Okhotsk Sea near Sakhalin (Fig. 1). The sardine distribution in these two regions are usually distinct but in October 1985 they were continuous (Fig. 1.ii). Catches in the Okhotsk Sea are thought to have come from two different populations. A Pacific population that came through Kuril Straits to feed adjacent to the Kuril Islands, and a population from the Japan Sea entering into the Okhotsk Sea through Laperuza Strait, near Sakhalin. Sardines which fed near Sakhalin are from the Japan Sea population (Shvidkiy and Levada, 1987). Surveys indicate that the catch near the Kuril Islands was fish from the Pacific population near Sakhalin, a significant part of catch was from the Japan Sea population. The annual biomass was calculated for Sardines distributed near to Hokkaido, southern Kuril Islands (Pacific part) and in the Okhotsk Sea. Based on these estimates we assume that, in the summer-autumn period, up to 25% of the Pacific population migrates into the Okhotsk Sea.

The biomass of the Pacific sardine population during maximum abundance is estimated to be about 30 million tons which is comparable to the biomass of walleye pollock in the Northwest Pacific.

The sardine biomass in the Okhotsk Sea is calculated based on data that include the month, catch, catch per boat day and catch per effort (on one seine net haul). The analysis is standardized based on methods used by the Laboratory of Fish Resources from Kuroshio (Abakumov, 1993). The sardine biomass is estimated from 1985 to 1991. There is insufficient data for the earlier period since 1977. Biomass in the area of the fishery increases from 320 thousand tons to 1,200 thousand tons (Fig. 2). The total biomass is 3-4 millions tons as the fishery covered only small part of the distribution (Fig. 3). These data appear to indicate that sardine is the dominate species in the southern part of the Okhotsk Sea.

The total size of the sardine population has an influence on the epipelagic ecosystem of the Okhotsk Sea. It is one of the rare species that feeds on phytoplankton in this area (Kun, 1975). Sardine consume some zooplankton but the greatest portion of their diet consists of phytoplankton (Table 1). An estimate the quantity of food consumed by the sardine from data from the middle 1980's is used as an estimate of the biomass from the earlier period is poor. The food eaten during the day changes from 4 to 6% in the Japanese Sea, southern Kuril Islands and Hokkaido regions. Unfortunately, data on the ration of the sardine from the Okhotsk Sea is not available. The necessary food required during maximum abundance of the sardine is estimated to be about 8 million tons (Fig. 2). If the real biomass of the sardine is three times higher the volume of food consumed, it would be 16-24 million tons.

The efficiency of food utilization by sardines from the southern part of the Okhotsk Sea is evaluated by Dulepova (1991) who found that the sardine has a significant influence on abundance and biomass of phyto- and zooplankton.

The existence of competition for food between sardine and other species is evaluated. For example, the food similarity between sardine and walleye pollock is from 20 to 30% overlap in various regions. Highest overlap is in the southern Kuril Islands (juvenile walleye pollock and adult sardine). It should be noted that there is an independent population of the walleye pollock in the southern part of the Okhotsk Sea called the Sakhalin-Hokkaido population. Most years competition for food resources between sardine and walleye pollock is relatively small except during the high abundance of the sardine in a middle of the 1980's. It should also be noted that the catch of walleye pollock in this region has decreased in comparison with the 1970's.

The increase of the populations of sardine in the 1980's in comparison with the end of 1970's is more than 500-1,000 times. At the same time the vital space of the walleye pollock in the southern part of the Okhotsk Sea is reduced.

CONCLUSION

During high abundance, the far eastern sardine population expands into the coldwater ecosystem of the Okhotsk Sea. At the same time, the increase in abundance creates an intensive fishery which is comparable to the dominant species of the coldwater complex (for example, walleye pollock). The influence of the sardine on the ecosystem of the Okhotsk Sea is found to be as follows:

1. the sardine consumes a great amount of zoo and phytoplankton which impacts on their abundance;
2. the sardine competes for food resources with other fish in the summer-autumn period;
3. the sardine serves as food for predatory fish, bird and marine mammals;
4. the abundance of the sardine is so great that it occupies a large part of the southern Okhotsk Sea;
5. other subtropical fishes (saury, anchovy, the common mackerel) also influence the ecosystem of the Okhotsk Sea in summer-autumn.

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TABLES AND FIGURES

Table 1. Seasonal changes of food of the sardine (June - September).

Species	Months			
	VI	VII	VIII	IX
Calanus plumchrus	12.1	1.0	---	---
Calanus cristatus	1.2	---	---	---
Metridia lucens	8.7	1.6	2.5	---
Oithona varia	0.2	0.3	1.1	---
Paracalanus parvus	---	---	3.7	0.7
Parathemisto japonicus	2.1	2.5	1.7	---
Euphausiacea varia	---	0.8	9.6	---
Centropages nemurrica	---	---	---	1.5
Oikopleura diocca	---	---	---	0.6
Chaetognatha	---	---	---	0.4
Phytoplancton + Tintinnidae	73.9	91.3	74.8	90.7
Other	1.4	2.5	6.6	6.1

Table 2. The food of various fish species in the summer of 1985 (by Lapshina, 1990).

	Capelin	Walleye pollock	Greenling	Pacific herring	Sardine	Pink salmon
Capelin	---	17.0	9.4	18.1	13.4	1.9
Walleye pollock	17.0	---	31.7	26.1	22.9	5.1
Greenling	9.4	31.7	---	34.9	3.5	14.1
Pacific herring	18.1	26.1	34.9	---	17.1	6.7
Sardine	13.4	22.9	3.5	17.1	---	32.9
Pink salmon	1.9	5.1	14.1	6.7	32.9	---

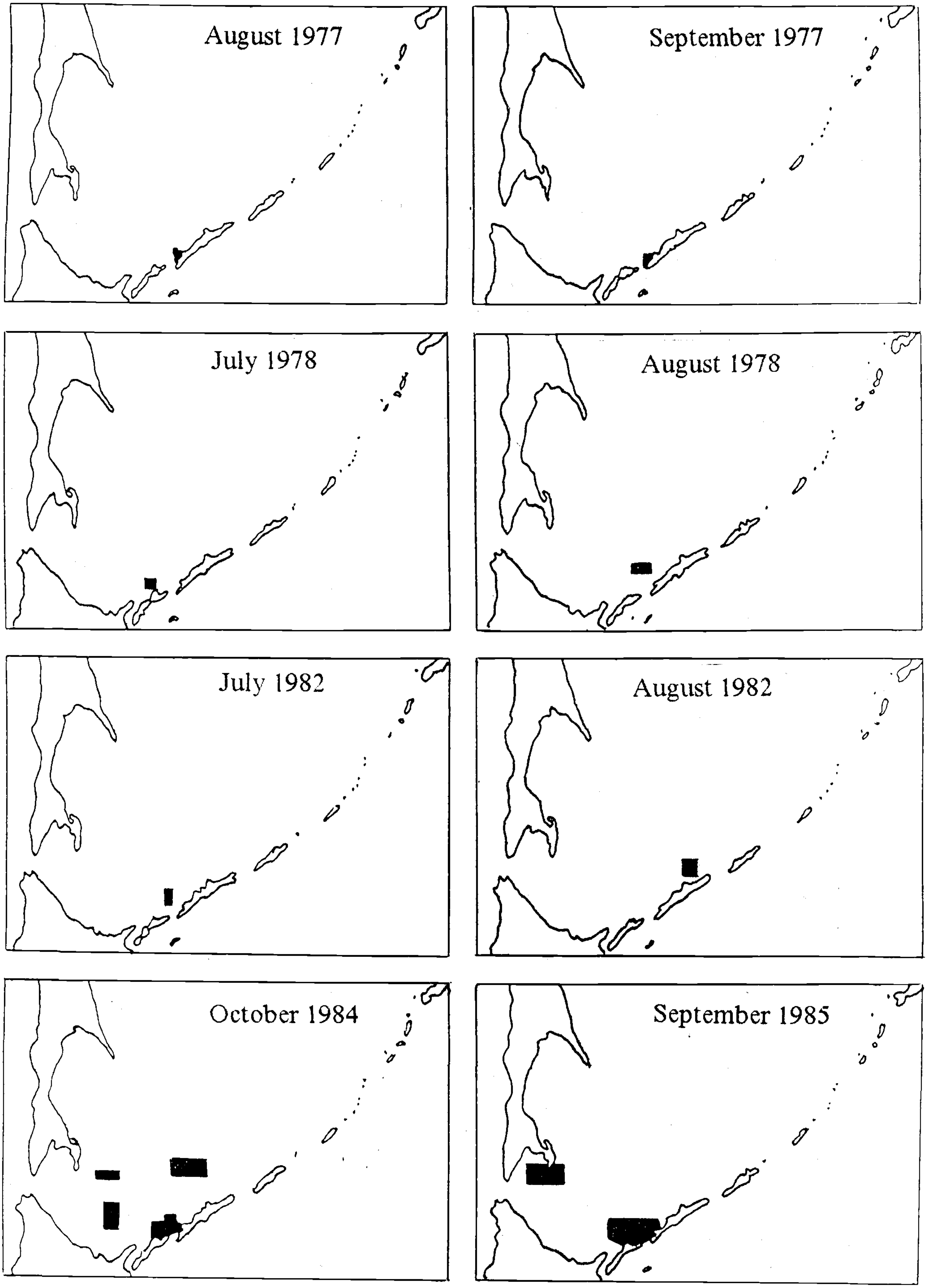

Fig. 1 (i). Fishing grounds of the sardine in the Okhotsk Sea.

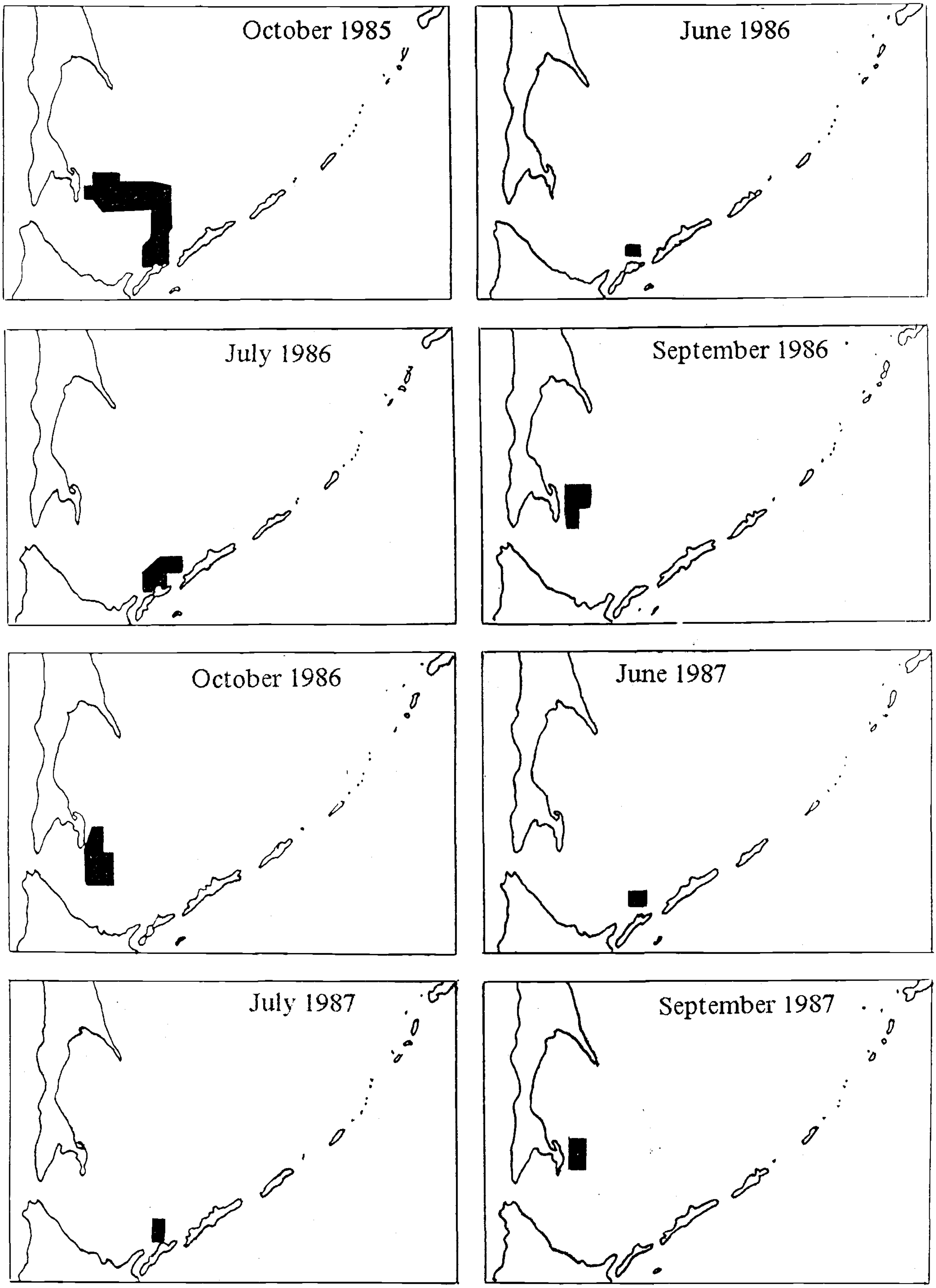
October 1985
June 1986
July 1986
September 1986
October 1986
June 1987
July 1987
September 1987

Fig. 1 (ii).

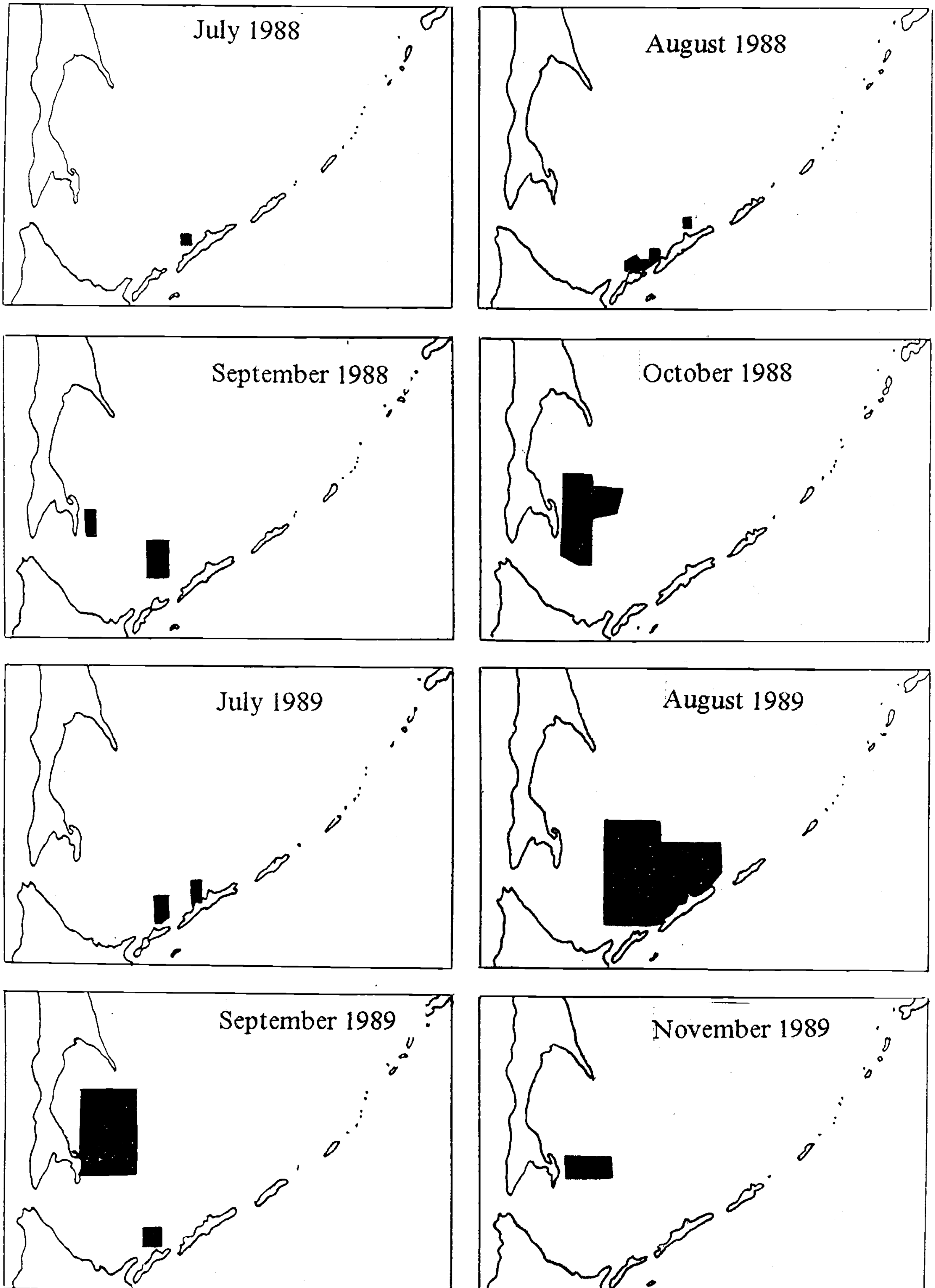
July 1988
August 1988
September 1988
October 1988
July 1989
August 1989
September 1989
November 1989

Fig. 1 (iii).

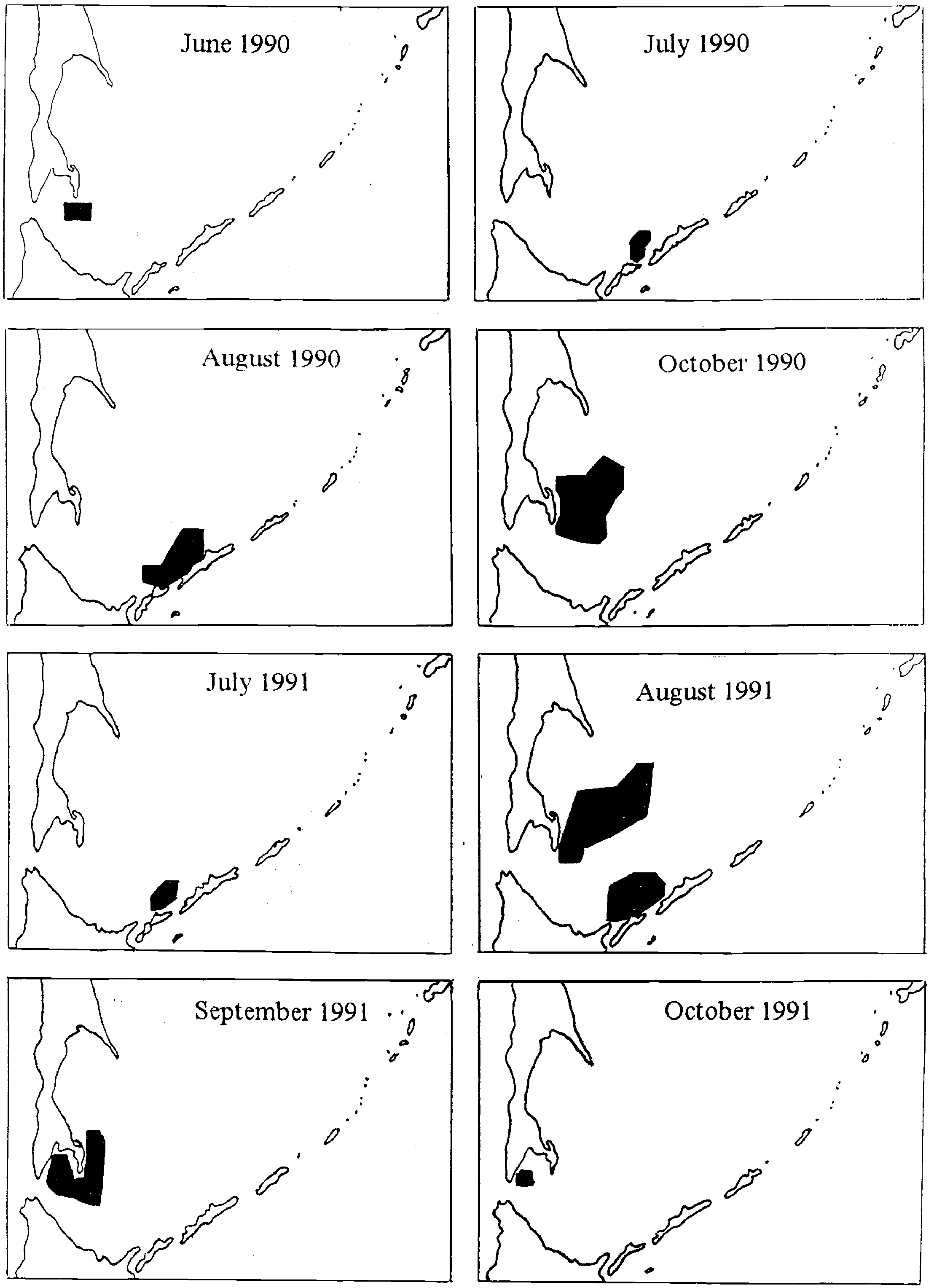
June 1990
July 1990
August 1990
October 1990
July 1991
August 1991
September 1991
October 1991

Fig. 1 (iv).

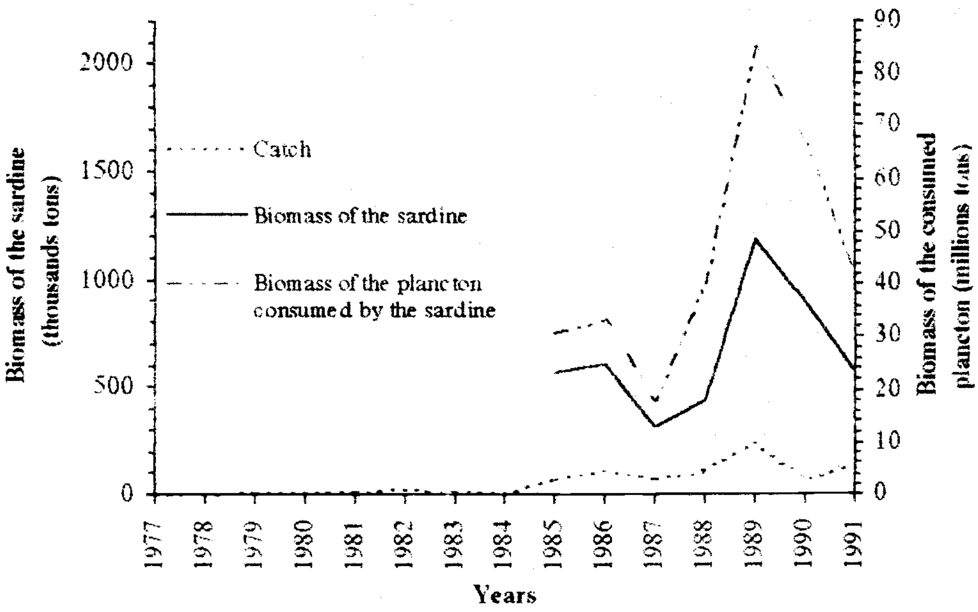

Fig. 2. Catch and biomass of the sardine in the Okhotsk Sea and biomass of the plancton consumed by the sardine.

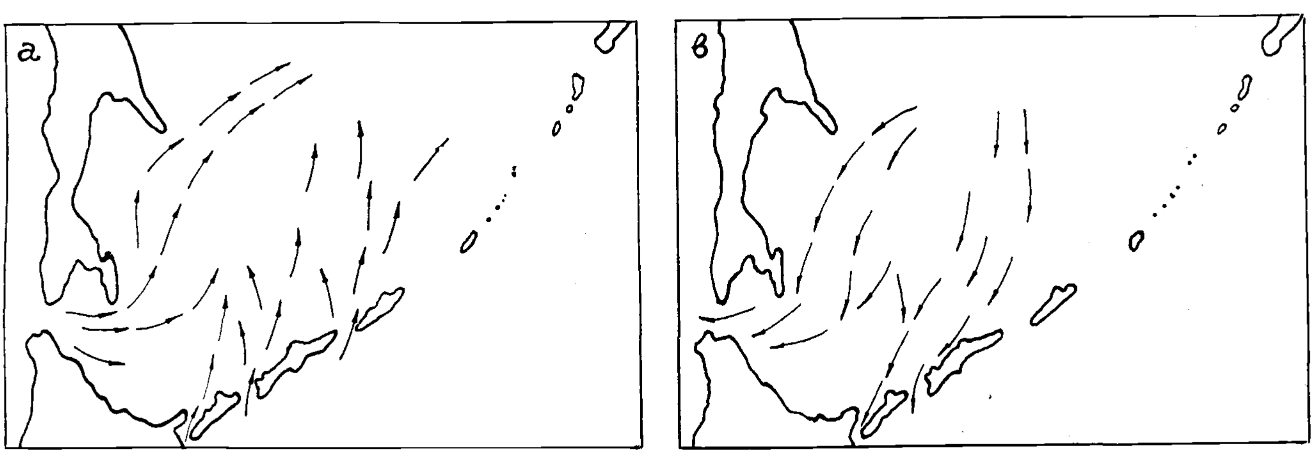

Fig. 3. Migration routes of the sardine in the Okhotsk Sea.
a - northward migration; b - southward migration.

A Preliminary Report on Stock Status and Productive Capacity of Horsehair Crab *Erimacrus Isenbeckii* (Brandt) in the South Kuril Strait

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Developing a new stock exploitation plan for a horsehair crab fishery in the South Kuril Strait is difficult without having knowledge about the abundance and productive capacity including measurements of the population structure, growth rates and longevity.

In this paper analysis of data by crab groups to present some productive characteristics of horsehair crab stock state using catch effort and size structure is attempted.

THE MATERIAL AND METHODS

Samples were collected using a standard truncated cone shape trap, with bottom ring diameter of 103 cm, upper ring diameter of 54 cm, height of 50 cm and mesh size of 60 mm, set in the central part of the strait between Kunashir and Shikotan Islands at depths of 52-78 m. Fresh-frozen pollock was used as bait in traps that were fished for one to two days. Vernier calipers (precision of ±0.1 mm) were used to measure the largest width (W) and length (l) of the carpace. Stock age structure is determined by the size of animals using probability paper (Harding, 1949) and known size-age from North Hokkaido horsehair crab (Abe, 1977, 1982, 1984 - cit. by Abe, 1992). Histograms indicate that the size step is 1 mm. Group growth is calculated using Bertalanffy equations because of the good correspondence between the modal values of W at age of t years.

Samples were collected from July-September. Ten samples of individuals of different sexes were collected before and after molting. Samples NN 1, 5, 8, 10 were gathered in 1991, NN 2, 3, 4, 6, 7, 9 in 1994. The number of crabs caught in the samples were 3060, 3063, 888, 1169, 3012, 1148, 1265, 903, 1781 and 652, respectively.

RESULTS AND DISCUSSION

In July, 85-87% of the individuals had soft or semi-hard carpace due to molting and by the end of September 30% had a hard carpace. Most of the catches (82-92%) consist of males with carapace width of 35-122 mm and 50-70% were commercial size ($W > 80$ mm). The average weights of individuals was 490-520 g. Females size varied between 41-102 mm. Moulting is complete by the end of August when 50% of the individuals are fertilized and their reproductive orifice are sealed indicating the success of mating.

The average catch effort ($\bar{y}$) in all groups (commercial males, commercial males and females) increases up to the second week of August to 3.07 individuals, for large males at a depth of approximately 70 m, then decreases rapidly. Values $\bar{y}$ of commercial groups are 1.49, 1.36, 0.8 and 1.08 individuals in 1991, 1992, 1993 and 1994, respectively indicating a stock decrease during the period. Unfortunately, this conclusion cannot be confirmed because correct official statistics are not available. At the same time, a horsehair crab stock decrease was observed in the neighboring area along the north coastal of Hokkaido, where catches dropped from the beginning of the 60s to 2-3 thousands tons (Abe, 1992).

Bearing in mind postmoulting growth of body size, the estimate of the modal values ***W*** for individuals of each sex and physiological state were the same in different samples so they are combined to calculate the corresponding average values (Table 1). The horsehair crab reproduction period is lengthy (Abe,1992), and settling was found to be polymodal (Fig.1) which makes comparison of the age modes difficult. Thus, Abe's size-age method is used: males and females up to the second year moult grow similar; at the sixth instar (one year) the average carapace length is 20.4 mm; at the ninth instar (two years) 46.4 mm; male growth increases reaching 59.1, 73.3, 88.2, 103.5, 117.5 mm, at age 3, 4, 5-6, 7-8, 9-10 years at instars NN 10-14; female growth is 55.9, 65.8, 74.1 mm at age 3-5, 6-8, 9-11, 12-14 years at instars NN 10-13, respectively. We calculate the theoretical relationship to determine lengths in widths:

for males:

if l < 75 mm, $W = 0.93l$,
if l > 75 mm, $W = 0.886l + 3.465$ (original data),

for females: $W = 0.95l - 0.1$ (Kawakami, 1934 - cit. by Abe,1992).

It appears, that male carapace widths are 19, 43.1, 55, 68.4, 81.6, 95.1, 107.6 mm at age 1, 2, 3, 4, 5-6, 7-8, 9-10 years, and female are 19.3, 44, 51.6, 62.4, 70.3, 79.7 mm at age 1, 2, 3-5, 6-8, 9-11, 12-14 years, respectively. The following measure of average values of modes: 54.5, 68.8, 81.4, 95.2, 107.4 mm and 51.7, 63.4, 70.2, 81.2 closely correspond to the theoretical figures (Table 1). On the bases of these modes the curves of linear growth were constructed (Fig. 2). Up to the age of 3 years females grow very fast and then by about 50 mm width their growth rate slows significantly, which corresponds to the beginning of first maturity (Abe, 1992).

The equations of horsehair crab linear growth are as follows:

$$W_t = 135 \cdot \left(1 - e^{-0.1823t}\right) \quad \text{for males,}$$

$$W_t = 112.23 - 60.5 \cdot e^{-0.2087(\tau - 1.333)} \quad \text{for females aged 4 or more years,}$$

where:

W_t - carapace width at age t (years);
135, 112.23 - definitive width sizes (W_∞), mm;
0.1823 year^{-1} and 0.2087 year^{-3} - constants of growth;
τ - conventional age equal to $t/3$;
1.333 - conventional zero age for t_0 = 4 years;
60.5 = W_∞ - W_o , where W_o =51.7 mm.

The following theoretical values correspond to given equations: for males at age 1, 2, 3 ... 9 years, sizes are 22.5, 41.2, 56.9, 69.9, 80.7, 89.8 (conventionally), 97.3, 103.6 (conventionally), 108.8 mm; for females at age 4, 7, 10, 13, 16 years, 51.7, 63.1, 72.3, 79.9, 86 mm respectively.

Approximation correctness is estimated in the Fig. 2 from calculated sizes. Thus, the biggest horsehair crab male found is 152 mm length and for females 117 mm (Abe, 1992) which corresponds to approximately 138 and 111 mm width.

The average maximal theoretical crab age ($W_{max} = 0.95 W_{\infty}$), was 16.4 year for males and about 37 years (!) for females. Such great longevity is theoretically due to the low rates of female growth. The real figures are likely lower due of strong fishing press.

The characteristics of growth for horsehair crab in the South Kuril Strait is identical to the populations off the coast of North Hokkaido; growth rates of mature females are very low which theoretically indicates greater longevity; for the last 4 years the catches decreases for the level of effort observed which could indicate that the stocks are over harvested.

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Table 1. The modal carapace widths (mm) of horsehair crabs from different samples.

N	Males before moulting					Males after moulting				Females before moulting			Females after moulting
N	Samples` numbers					Samples` numbers				Samples` numbers			Samples` numbers
	1	2	3	4	m̅	5	6	7	m̅	8	9	m̅	10
1			48.3 (1.1)*		≈48.3						47.8 (3.1)	≈47.8	
2			54.5 (2.5)		≈54.5						51.7 (0.7)	≈51.7	
3	60.7 (1.1)		60.5 (1.8)		60.6	63 (1.3)			≈63	57 (1.1)	56.5 (3)	56.7	57.6 (0.6)
4	65(0.8)		65.2 (2.4)		65.4					60 (1.0)	60.3 (1.5)	60.1	61.3 (1.6)
5	68.5(1.1)	68.5 (3.0)	70 (1.4)	68.2 (1.6)	68.8	67.9 (1.6)	68.2 (1.3)		68	63.3 (1.3)	63.5 (1.0)	63.4	64 (1.2)
6	72.2-76.5 (1.9-2.2)	73.8 (2.3)	74.2 (1.7)	74.1 (2.7)	74.1	72.2-76.5 (1.3-1.7)	72.5-76.9 (1.6-2)		74.5	66.6 (1.6)	66 (1.0)	66.3	67.5 (1.2)
7		79 (2.2)	79.3 (2.80)	77.8 (1.7)	78.7	80 (0.7)	80.3 (0.7)		80.1	70 (1.7)	70.5 (1.8)	70.2	70.2 (0.9)
8	81.3(1.2)		81.9 (1.1)	81.2 (1.4)	81.4	83 (1.2)	82.8 (1.5)	82.5 (1.6)	82.8	71.9 (1.3)		71.9	72.8 (1.1)
9	84.7(1.4)	84(1.8)	85.5 (1.2)	85 (1.4)	84.8	85.8 (1.3)	86 (1.6)	87.5 (1.9)	86.4	75 (0.9)	73.7 (1.0)	74.3	75.8 (0.9)
10	88.4(1.3)	87.9(1.5)	88.6 (1.1)	88.5 (1.6)	88.3	89.5 (1.3)	89.5 (1.2)	91.2 (1.4)	90	77.9 (1.0)	76.7 (0.4)	77.3	78.3 (1.0)
11	91.5(1.2)	91.4(2.1)	91.4 (0.9)	91 (1.0)	91.3	92.5 (1.3)	93.2 (1.5)	94.7 (1.3)	93.4	81.3 (0.7)	81 (1.0)	81.2	81.8 (0.8)
12	95.4(1.7)	95.5(1.0)	94-96 (0.5-0.7)	95 (1.4)	95.2	95.7 (1.4)	95.8 (1.3)	97.3 (0.9)	96.3	83 (0.6)		83	84.4 (0.6)
13	99.3(2.0)	99(1.25)	98 (0.8)	99 (2.0)	98.8	99.3 (1.1)	100 (1.0)	100.5 (2.0)	99.9	85.7 (0.5)			87.3 (1.1)
14	103.5(1.5)	103(1.2)	100.5 (0.7)	102.3 (0.9)	102.3	102.5 (1.1)		≈102.5					
15	106.2-108.6 (0.8-1.3)				≈107.4	105.4-108.7 (1.0-1.2)		≈107					

*- The standard deviations (δ) are given in the brackets.

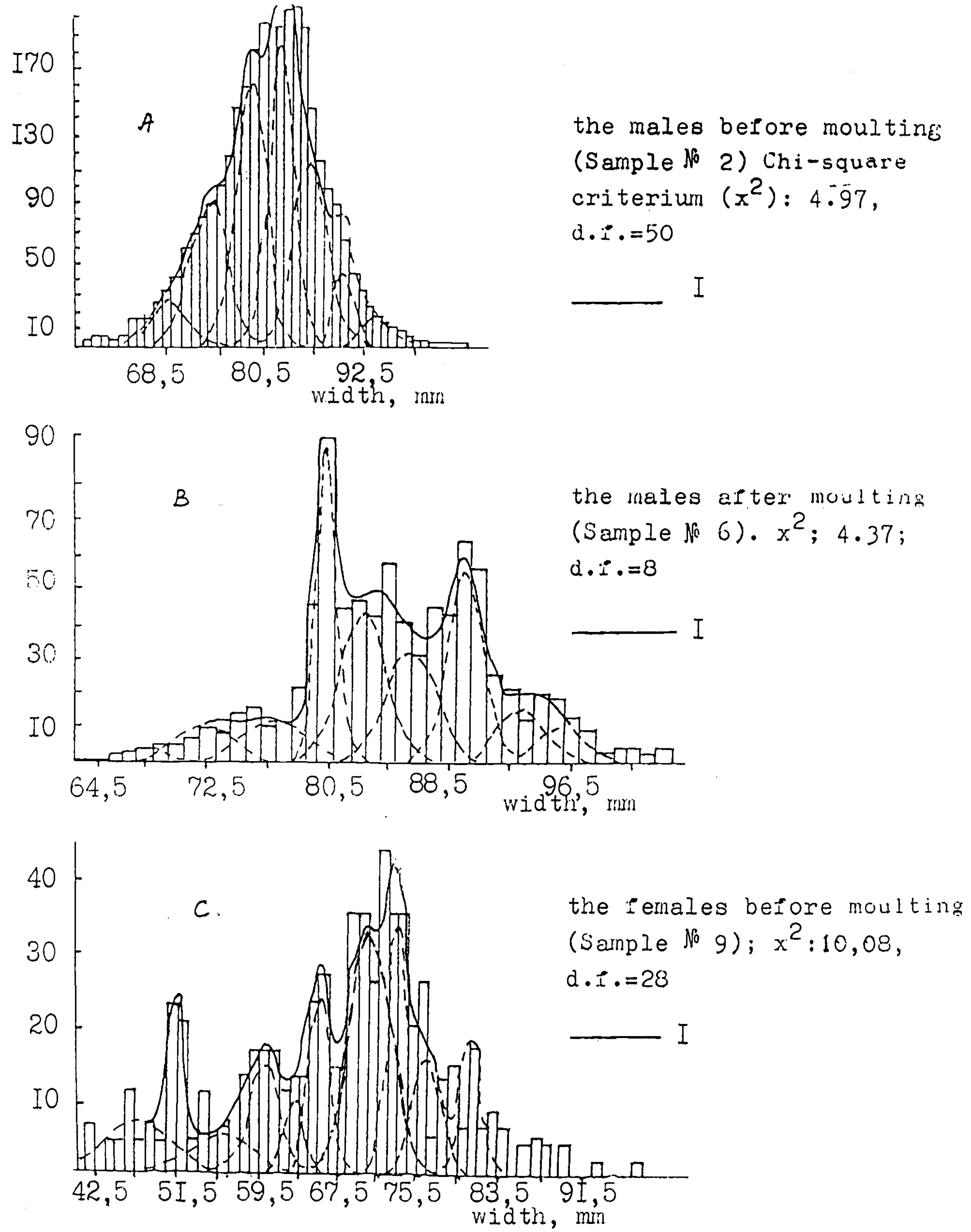

Fig. 1. Some examples of size-age structures of horsehair crab population in the South-Kuril Strait, July-September, 1994. Caraspace widths (mm) and frequencies (exempl.) are laid out on absciss and ordinate axes accordingly. I - lines, summing the normal distribution curves.

A - the males before moulting (Sample No. 2); chi-square criterium (χ^2):4.97; d.f. = 50

B - the males after moulting (Sample No. 6); χ^2:4.37; d.f. = 8

C - the females before moulting (Sample No. 9); χ^2:10.08; d.f. = 28

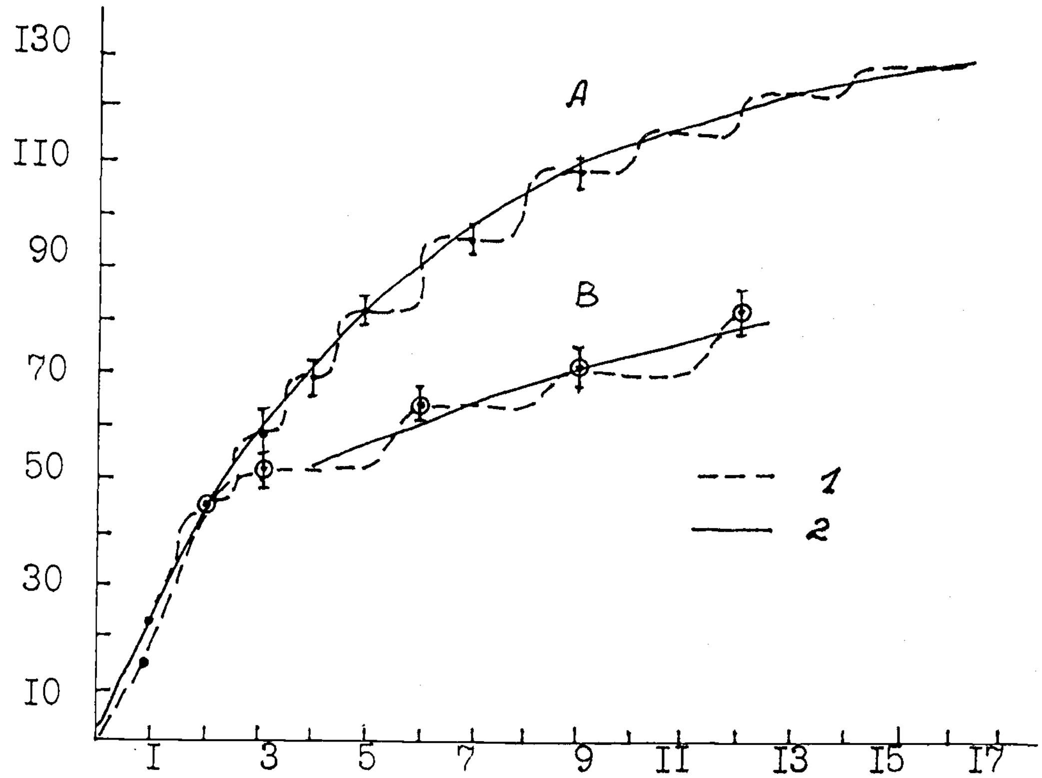

Fig. 2. The group linear growth of horsehair crabs (by Abe, 1992 with alterations).
A - the males
B - the females
1 - the real growth curves
2 - an approximation by growth equations.
Ages (years) and carapace widths (mm) are depicted on absciss and ordinate axes accordingly.

Mezoplankton Distribution in the West Japan Sea

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Species composition and biomass distribution of mezoplankton in the western Japan Sea from 0-100 m are evaluated from data obtained from two surveys during April-May in 1989 and 1990. Samples were collected using a Jady plankton net (mouth square 0.1 sq. m., mesh size 0.168 mm, rising velocity 0.5 m/s). Phytoplankton biomass is estimated from the net samples. Zooplankton is divided into three size fractions and fishing efficiency is used to calculate their biomass ("Recommendations", 1984; Volkov, 1986). The distribution of plankton is considered in four specific water mass regions which had been defined by temperature salinity analysis:

I. - Primorye Current zone,
II. - subarctic zone,
III.- Polar front between region II and IV zone(Fig. 1),
IV.- subtropic zone.

A phytoplankton "bloom" of 50 to 500 mg/cub.m occurred in April from southwest to northeast. The species of genera *Coscinodiscus, Chaetoceros, Thallasiosira, Ceratium* are dominant. The "bloom" ended in late May when the biomass decreases to 50 mg/cub.m. Patches of high phytoplankton biomass (200-500 mg/cub.m) occur in the Primorye Current zone and in an area known for it's high productivity (Kun, 1984; Markina and Cherniavsky, 1985) (Fig. 2). In spring plankton accumulates in the upper 0-100 m layer (Zenkevich, 1963; Vinogradov, 1968). Zooplankton in Japan Sea is characterized by the highest biomass in spring (Kun, 1975; Markina and Cherniavsky, 1985; Volkov, Chuchukalo 1986; Lapshina et.al., 1990). The mean total biomass of zooplankton is about 1,000 mg/cub.m in April-May of both years. The total stock of plankton in the upper 100-m layer is estimated as 120 t/sq. km in 1989 and 140 t/sq. km in 1990. The ratio between size fractions in 1989-1990 is equal though the total biomass in 1990 is higher. The high numbers of the small zooplankton fraction (1.5 mm organisms were 100-360 mg/cub.m or almost 40% of total biomass) testifies to the reproductive success. The middle fraction biomass is formed by large numbers (Figs. 3 and 4).

A boreal complex was found to be present in the mezoplankton. This complex is composed of *Parasagitta elegans*, *Neocalanus plumchrus*, *Neocalanus cristatus*, *Eucalanus bungii*, *Metridia pacifica*, *Oithona similis*, *Oncaea borealis*, *Pseudocalanus minutus*, *Thysanoessa longipes*, *Euphausia pacifica* and others. Some are homogeneously distributed, while others are concentrated creating a large biomass in certain regions (Figs. 5 and 6). *Copepoda* dominated in all the sampled areas. *N. plumchrus and M. pacifica* constitute the maximal biomass but *O. similis* and *P. minutus* are the most numerous. All stages of maturity of these animals are present but the young are the most abundant.

The biomass of certain groups of zooplankton dominate in each of the four regions: *Copepoda* are the most abundant (84%) in the subarctic zone; followed by *Amphipoda* and *Chaetognatha* (each about 20%) in region II; *Euphausiacea (Thysanoessa longipes)* and *Chaetognatha* dominate in the Polar front, and they are observed to be the most significant species because of the faunae mixture; *Chaetognatha* and *Euphausia pacifica* dominate in the subtropic zone. The ratio of the main groups of zooplankton and size at maturity correspond to the rate of plankton community succession in a particular water mass.

The day night cycle led to a change in the ratio of size fractions and the abundance of some groups (Table 1). There are such active migrants such as *Euphausia, Amphipoda* and *Chaetognatha.*

Diurnal migration coefficients are 3.0-10.0. They are specifically for *Copepoda*: *Metridia pacifica* 3.0 (adults) and 1.5 (copepodites III-IV); *N. cristatus* 5.0, *Pareuchaeta japonica* 6.0, *Gaidius variabilis* 8.0. Small *Copepoda, O. similis, P. minutus, O. borealis* concentrations did not change considerably throughout the maturity stages during the day/night cycle.

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TABLES AND FIGURES

Table 1. Distribution of zooplankton in different regions in the Japan Sea.

Date	Reg.	Daily Time	SF	MF	LF	Total	Main groups of plankton				
							Cope-poda	Amphi-poda	Eupha-usiida	Chae-togn.	Et. all
1989	I	D	357/45	61/ 7	380/48	798	664/83	78/10	4/ +	28/ 4	24/ 3
	I	N	359/45	151/19	281/36	791	662/84	34/ 4	8/ 1	47/ 6	40/ 5
	II	D	375/46	63/ 8	371/46	809	516/64	141/17	68/ 8	59/ 7	25/ 4
	II	N	140/21	37/ 5	492/74	669	275/41	174/26	78/12	137/20	5/ 1
	III	D	199/42	35/ 7	241/51	470	263/56	48/10	22/ 5	22 / 5	115/24
	III	N	120/34	37/11	191/55	348	191/55	95/27	9/ 3	22/ 6	31/ 9
	IV	D	100/45	15/ 7	107/48	222	122/55	14/ 6	7/ 3	10/ 6	69/31
	IV	N	179/36	47/ 9	272/55	498	270/54	98/20	112/22	4/ 1	14/ 3
1990	II	D	255/48	55/10	227/42	535	356/67	7/ 1	59/11	98/18	15/ 3
	II	N	362/27	61/ 5	896/68	1319	561/43	143/11	123/ 9	452/34	40/ 3
	III	D	181/46	50/13	160/41	391	258/66	13/ 3	19/ 5	88/23	13/ 3
	III	N	114/10	74/ 6	977/84	1165	337/29	194/17	318/27	315/27	1/ +
	IV	D	280/53	75/14	171/33	526	382/73	10/ 2	16/ 3	107/20	11/ 2
	IV	N	230/20	150/13	754/67	1134	567/50	158/14	142/13	247/22	20/11

Note: all entries in the table mg/m^3 / % of total biomass.
I - Primorye current ;
II - subarctic waters;
III - frontal zone;
IV - subtropic waters.

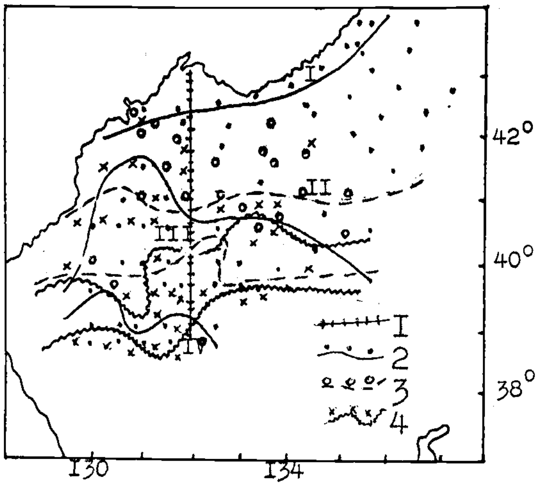

Fig. 1. Region of surveys

1. standard section
2. survey of 1989
3. first survey of 1990
4. second survey of 1990

I. zone of Primorye current
II. subarctic waters
III. frontal zone
IV. subtropic waters

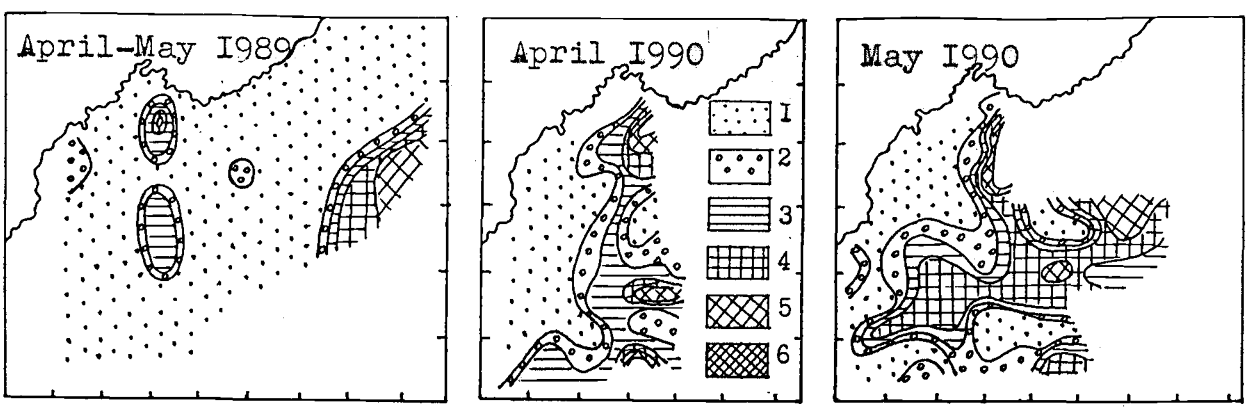

Fig. 2. Distribution of net phytoplankton biomass (mg/m^3)

1. less than 50
2. 50-100
3. 100-200
4. 200-500
5. 500-1,000
6. more than 1,000

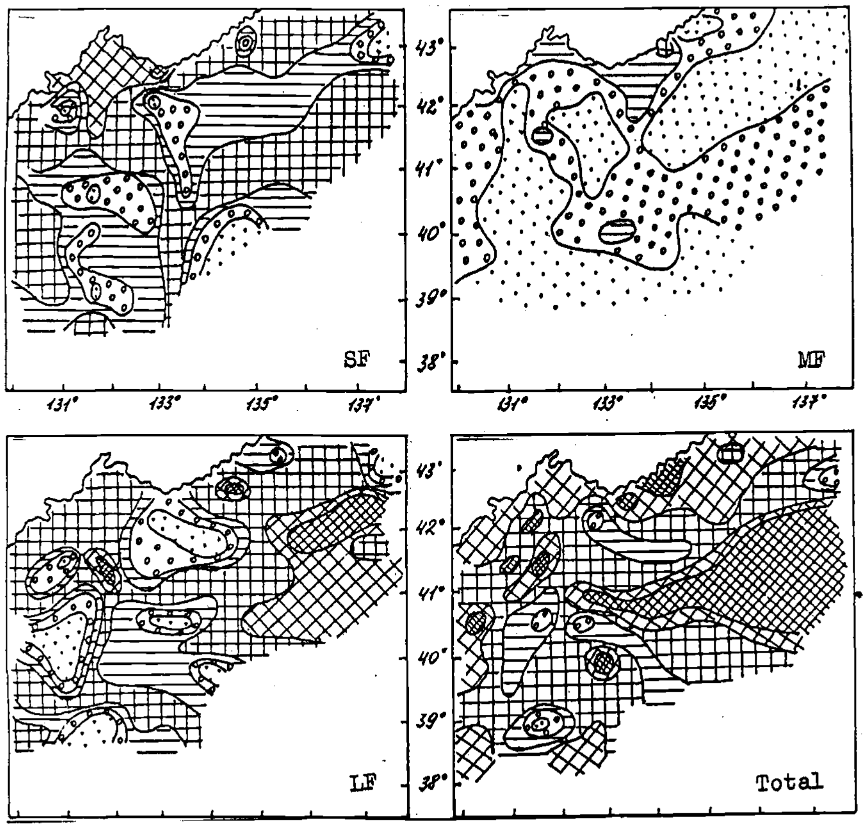

Fig. 3. Distribution of zooplankton biomass by three size fractions in 1989.

SF - small fraction (less than 1.5) MF - middle fraction (1.5-3.5)
LF - large fraction (more than 3.5 mm)

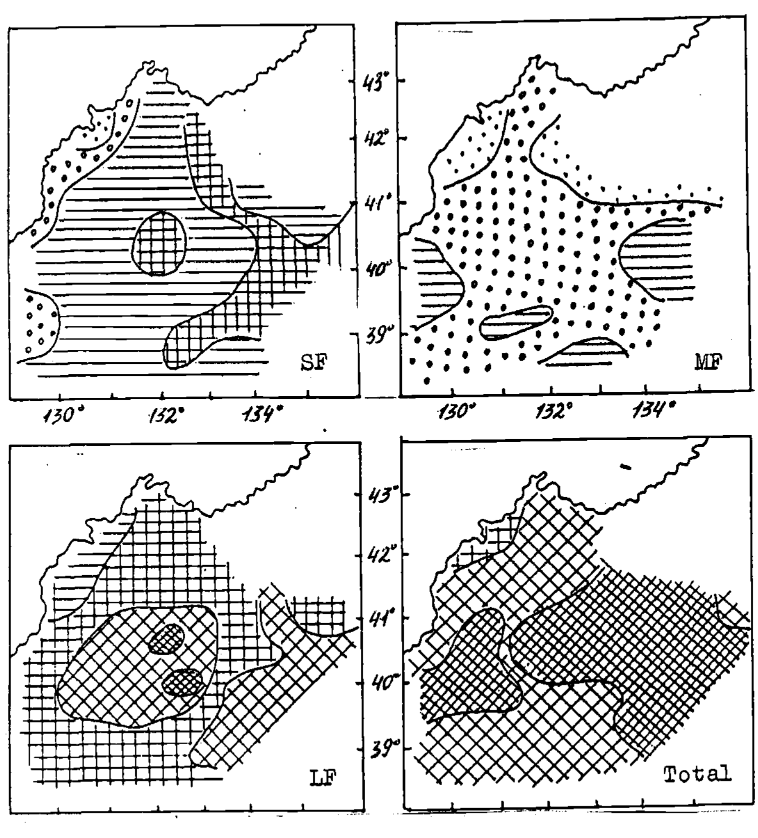

Fig. 4. Distribution of zooplankton biomass by three size fractions in 1990.

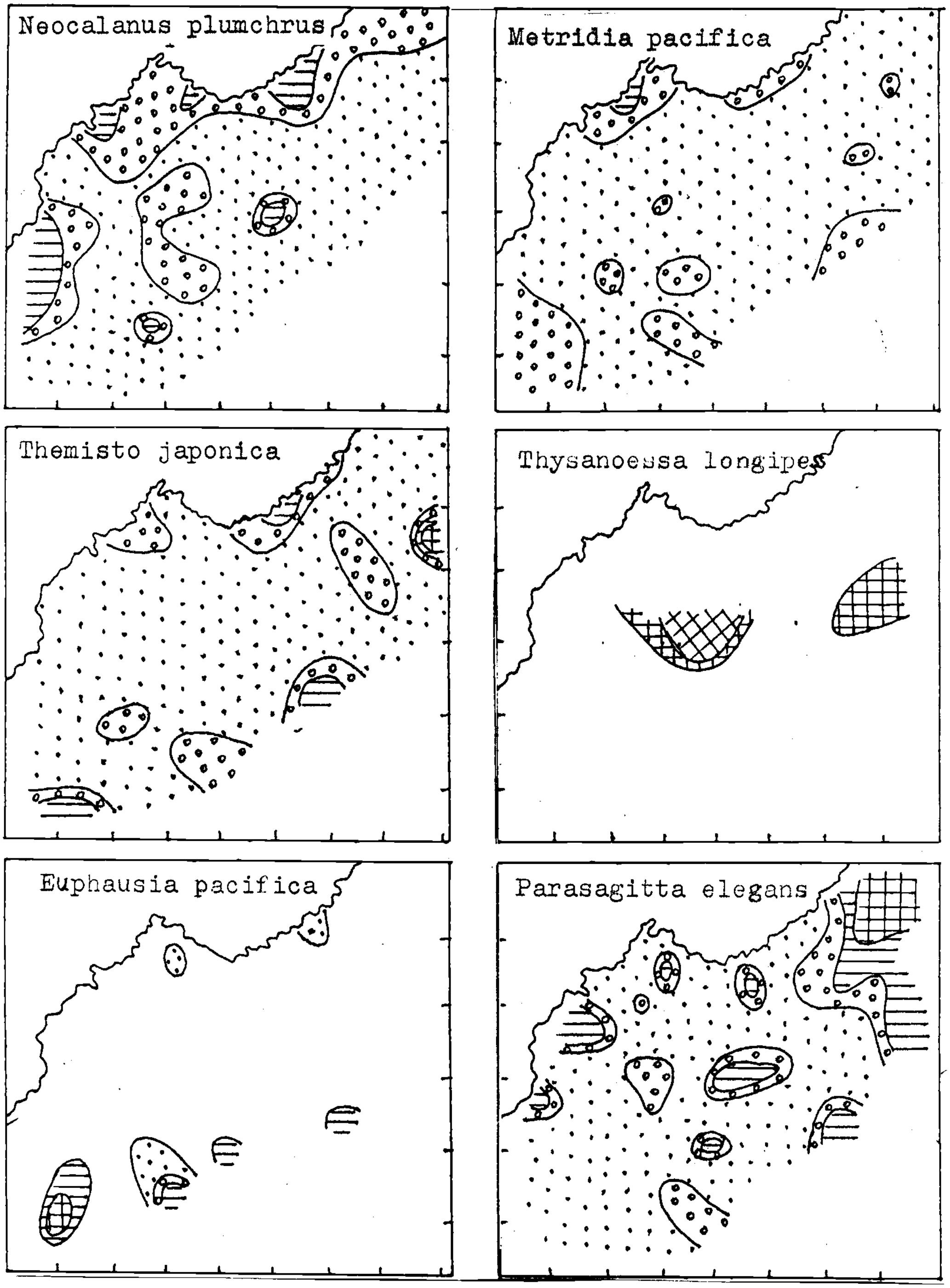

Fig. 5. Distribution of dominated species of zooplankton (mg/m^3) in 1989.

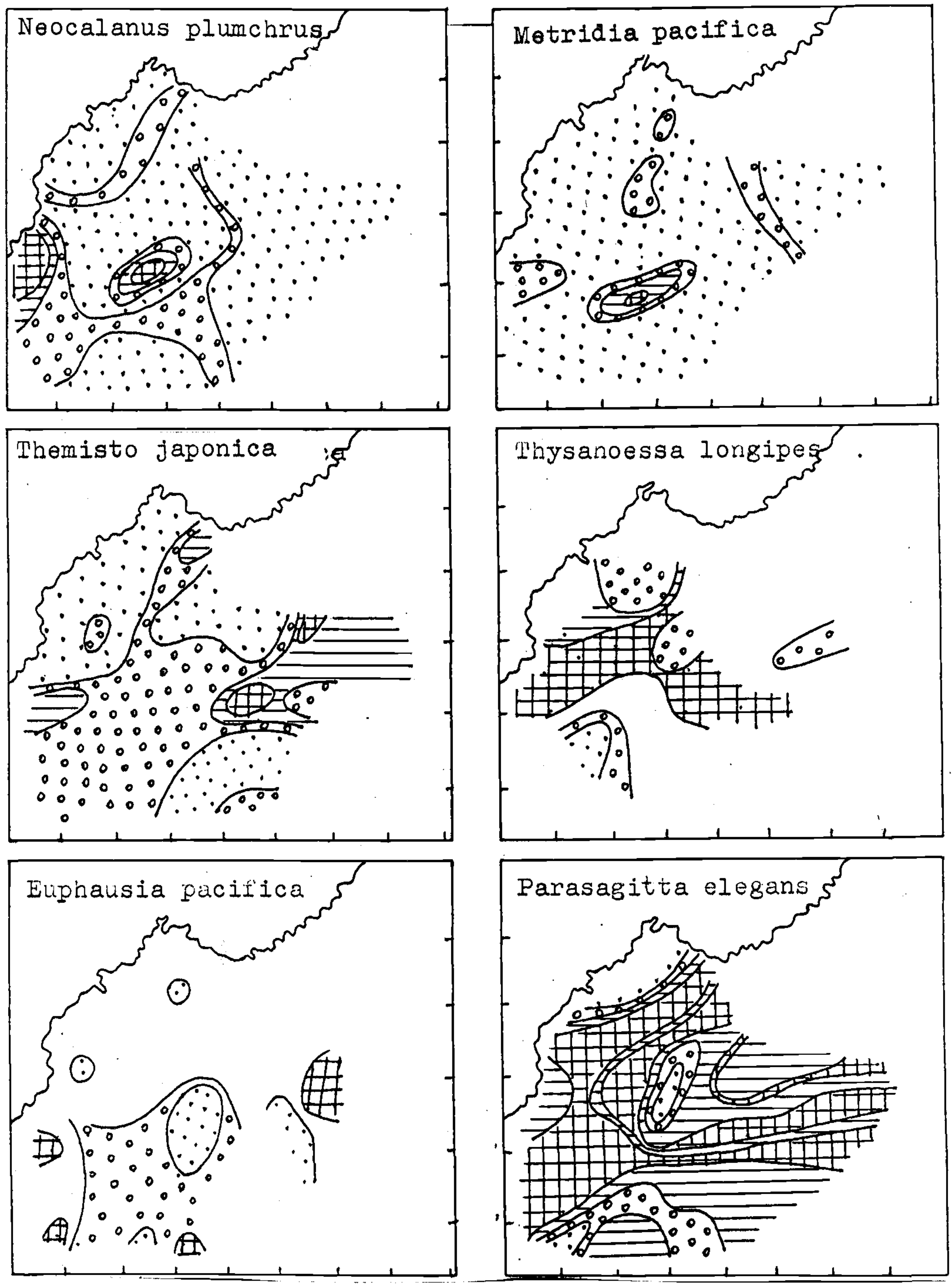

Fig. 6. Distribution of dominated species of zooplankton (mg/m^3) in 1990.

Application of Pink and Chum Salmon Genetic Baseline to Fishery Management

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The salmon form aggregations composed of numerous stocks during their marine portion of life. Identification of these stocks in mixtures has been a great problem in salmon management for fisheries agencies. The absence of the information on the stock composition results in either overharvest or over escapement.

One of the most informative methods for investigating stock structure is the electrophoretic analysis of protein variation. The method and its application began with developmental work by Utter and his associates at the National Marine Fisheries Service in the 1970's. This method has been used by several fisheries agencies in North America since the early 1980's and past results show that genetic stock identification (GSI) is a practical fisheries management tool (Grant et al., 1980; Milner et al., 1985; Utter et al., 1987; Shaklee et al., 1990; Wilmot et al., 1992).

Unfortunately, to date GSI analysis was almost never used for management purposes in Russia. Recently, the genetic baselines were constructed for Asian pink and chum salmon. These baselines cover main spawning regions of pink and chum in Asia ranging from Hokkaido to Anadyr river. Two goals of this work were:

1. to evaluate the accuracy and precision of stock composition estimates using computer simulations of baselines,
2. to estimate the stock-group contributions of the mixed fishery samples from the Sea of Okhotsk and the North Pacific Ocean via maximum likelihood method.

MATERIAL AND METHOD

Chum and even year pink salmon baselines (Auke Bay Laboratory NMFS) were used for computer simulations. Chum salmon baseline includes allozyme data for 30 loci and 33 stocks; even year pink salmon baseline - 24 loci and 21 stocks (Fig. 1 and Table 1). We attemped to obtain 100 adults whenever possible from each stock. Six hundred and twenty six pinks were collected in the Sea of Okhotsk and the North Pacific Ocean in 1994 during June-August by scientific vessels (Fig. 1).

Four tissues (muscle, liver, heart and eye) were taken from each fish for protein electrophoresis. Protein electrophoresis was conducted as described by Aebersold et al. (1987). Specific enzymes were stained according to Harris and Hopkinson (1976) and Aebersold et al. (1987).

Estimation of the mixture composition and a simulation of possible mixture scenarious for a given baselines were performed using the SPAM program (Gates, 1995).

RESULTS AND DISCUSSION

Simulated mixtures were used to evaluate the accuracy (bias) and precision (standard deviation) of the stock composition estimates. These hypothetical mixtures were generated using the baseline allele frequencies assuming Hardy-Weinberg equilibrium. First, we used a simulated mixture of 100% of the group and these simulations showed at least 87% accuracy for chum salmon and 83% for pink salmon (Tables 2 and 3). We also used mixtures where the contributions of each baselines stock-group to the simulated fishery mixture represented the stock compositions of likely mixed-stock fisheries. These simulations were performed to explore the effects of sample size on the accuracy and precision of the maximum likelihood estimates too. Our simulations revealed that chum and even year pink baselines can provide a reasonable estimates of regional contributions. The increase in sample size reduced the bias and standard deviations of the estimates (Tables 4 and 5).

Maximum likelihood were calculated for the samples collected from the Sea of Okhotsk and the North Pacific Ocean. The West Kamchatka region was the predominant group in all the estimates; its contribution ranged from 46% in the south part of the Sea of Okhotsk to 93% by the North Kuril Islands (Fig. 1 and Table 6).

The alaskan component was also fairly consistent in the Sea of Okhotsk near West Kamchatka ranging from 13% in the end of July up to 28% in the begining of August. These data contradict with tagging information (Takagi et al., 1981) and are needed to verify, but simulation showed that alaskan pinks can be identified with high accuracy and precision (Tables 2-5).

Computer simulations and mixed fishery analyses show the potentiality to use chum and pink salmon baselines for both management and studies of the marine migration. Our permanent challenge is to improve baselines, incorporating a new important stocks.

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Table 1. Enzyme names, enzyme commision (EC) numbers and locus abbreviations for chum and pink salmon.

Enzyme name	EC No abbrev.	Locus	Chum	Pink
N-Acetil-b-glucosaminidase	3.2.1.30	bGLUA	+	-
Aconitate hydratase	4.2.1.3	sAH	+	-
		mAH-3,4	+	-
		mAH-3	-	+
		mAH-4	-	+
Adenosine deaminase	3.5.4.4	ADA-2	-	+
Alanine aminotransferase	2.6.1.2	ALAT	+	+
Aspartate aminotransferase	2.6.1.1	sAAT-1, 2	+	+
		sAAT-3	+	+
		mAAT-1	+	+
		mAAT-2	+	-
Creatine kinase	2.7.3.2	CKA-2	+	+
Dipeptidase	3.4.*.*	PEP-A	+	-
Esterase D	3.1.*.*	ESTD	+	-
Formaldehyde dehydrogenase	1.2.1.1	FDHG	-	+
Fumarate hydratase	4.2.1.2	FH	+	+
bGalactosidase	3.2.1.23	bGALA	+	-
Glucose-6-phospate isomerase	5.3.1.9	GPA-A	+	+
Glycerol-3-phosphate	1.1.1.8	G3PDH-1	-	+
dehydrogenase		G3PDH-2	+	-
Isocitrate dehydrogenase	1.1.1.42	sIDHP-2	+	-
		mIDHP-1	+	-
Lactate dehydrogenase	1.1.1.27	LDHA-1	+	+
		LDHB-1	-	+
		LDHB-2	+	+
Malate dehydrogenase	1.1.1.37	sMDHA-1,2	+	+
		sMDHB-1,2	+	+
Malic enzyme	1.1.1.40	sMEP-1	+	+
		mMEP-2	+	-
Mannose-6-phosphate isomerase	5.3.1.8	MPI	+	+
Phosphoglucomutase	5.4.2.2	PGM-1	+	-
		PGM-2	+	+
Phosphogluconate dehydrogenase	1.1.1.44	PGDH	+	+
Proline dipeptidase	3.4.13.9	PEPD-2	-	+
Triose-phosphate isomerase	5.3.1.1	TPI-3	+	-
		TPI-4	+	+
Tripeptidase	3.4.11.4	PEPB-1	+	+

Table 2. Simulation. Estimated contributions of chum salmon where each region comprises 100% of the mixture.

Region	Japan	Primorye	Sakhalin	Magadan	West Kamchatka	East Kamchatka
Japan	.9850	.0287	.0251	.0070	.0078	.0097
Primorye	.0013	.9482	.0098	.0017	.0004	.0012
Sakhalin	.0013	.0170	.9537	.0003	.0001	.0003
Magadan	.0010	.0002	.0005	.8761	.0255	.0225
West Kamchatka	.0044	.0008	.0033	.0630	.8808	.0900
East Kamchatka	.0041	.0008	.0039	.0408	.0821	.8716

Table 3. Simulation. Estimated contributions of pink salmon where each region comprises 100% of the mixture.

Region	Japan	Kuril Islands	Sakhalin	West Kamchatka	East Kamchatka	Alaska
Japan	.8317	.0648	.0522	.0153	.0017	.0056
Kuril Islands	.0279	.8338	.0023	.0042	.0015	.0041
Sakhalin	.1125	.0797	.9028	.0308	.0529	.0086
West Kamchatka	.0145	.0116	.0260	.8710	.0545	.0205
East Kamchatka	.0039	.0019	.0059	.0462	.8659	.0020
Alaska	.0085	.0081	.0102	.0310	.0226	.9583

Simulated sample size: 150. Number of resamplings: 100. Estimates not summing to 1.0000 are caused by randomly generated genotypes that cannot be explained by a randomly generated baseline.

Table 4. Simulation. Expected and estimated contributions of chum salmon for different sample sizes.

Region	Expected	Estimated N=150	Estimated N=50	Estimated N=25
Japan	.7000	.7064 (.0433)	.6866 (.0788)	.6552 (.1261)
Primorye	.0100	.0166 (.0173)	.0156 (.0250)	.0250 (.0430)
Sakhalin	.0800	.0753 (.0297)	.0705 (.0558)	.0687 (.0703)
Magadan	.0300	.0276 (.0285)	.0278 (.0379)	.0330 (.0553)
West Kamchatka	.0900	.0886 (.0404)	.0970 (.0669)	.1049 (.0815)
East Kamchatka	.0900	.0816 (.0395)	.0980 (.0650)	.1092 (.0987)

Table 5. Simulation. Expected and estimated contributions of pink salmon for different sample sizes.

Region	Expected	Estimated N=150	Estimated N=50	Estimated N=25
Japan	.0500	.0797 (.0697)	.0947 (.1003)	.0913 (.1191)
Kuril Islands	.1000	.0835 (.0679)	.0614 (.0720)	.0553 (.0972)
Sakhalin	.2500	.2400 (.1225)	.2381 (.1504)	.2865 (.1805)
West Kamchatka	.3000	.2892 (.0827)	.3054 (.1399)	.2594 (.1599)
East Kamchatka	.1000	.0953 (.0702)	.0873 (.0874)	.1043 (.1284)
Alaska	.2000	.2115 (.0673)	.2122 (.1043)	.2008 (.1311)

One standard deviation is in parenthesis. Number of resamplings: 100. Estimates not summing to 1.0000 are caused by randomly generated genotypes that cannot be explained by a randomly generated baseline.

Table 6. Mixed fishery analysis. Estimated contributions of pink salmon to the Sea of Okhotsk and the North Pacific Ocean test fishery in 1994.

Area	Japan	Kuril Islands	Sakhalin	West Kamch.	East Kamch.	Alaska
A	.0910 (.0879)	.0000 (.0000)	.4199 (.1645)	.4561 (.1548)	.0000 (.0000)	.0000 (.0000)
B1	.0001 (.0000)	.0000 (.0000)	.0000 (.0000)	.7874 (.0564)	.0649 (.0453)	.1263 (.0362)
B2	.0001 (.0000)	.0002 (.0000)	.0000 (.0000)	.6370 (.1363)	.0633 (.0952)	.2784 (.0902)
C	.0004 (.0001)	.0001 (.0001)	.0001 (.0000)	.9256 (.0619)	.0000 (.0000)	.0566 (.0619)

One standard deviation is in parenthesis.

Area A: Date of sampling - August 10. N = 92. Trawls 20 and 21 are summed.

Area B1: Date of sampling - July 17 - 27. N = 329. Trawls 27, 28, 36, 37, 43, 45, 51 and 55 are summed.

Area B2: Date of sampling - August 3-5. N = 143. Trawls 70, 73, 74 and 76 are summed.

Area C: Date of sampling - July 28-31. N=116. Trawls 59, 64 and 65 are summed.

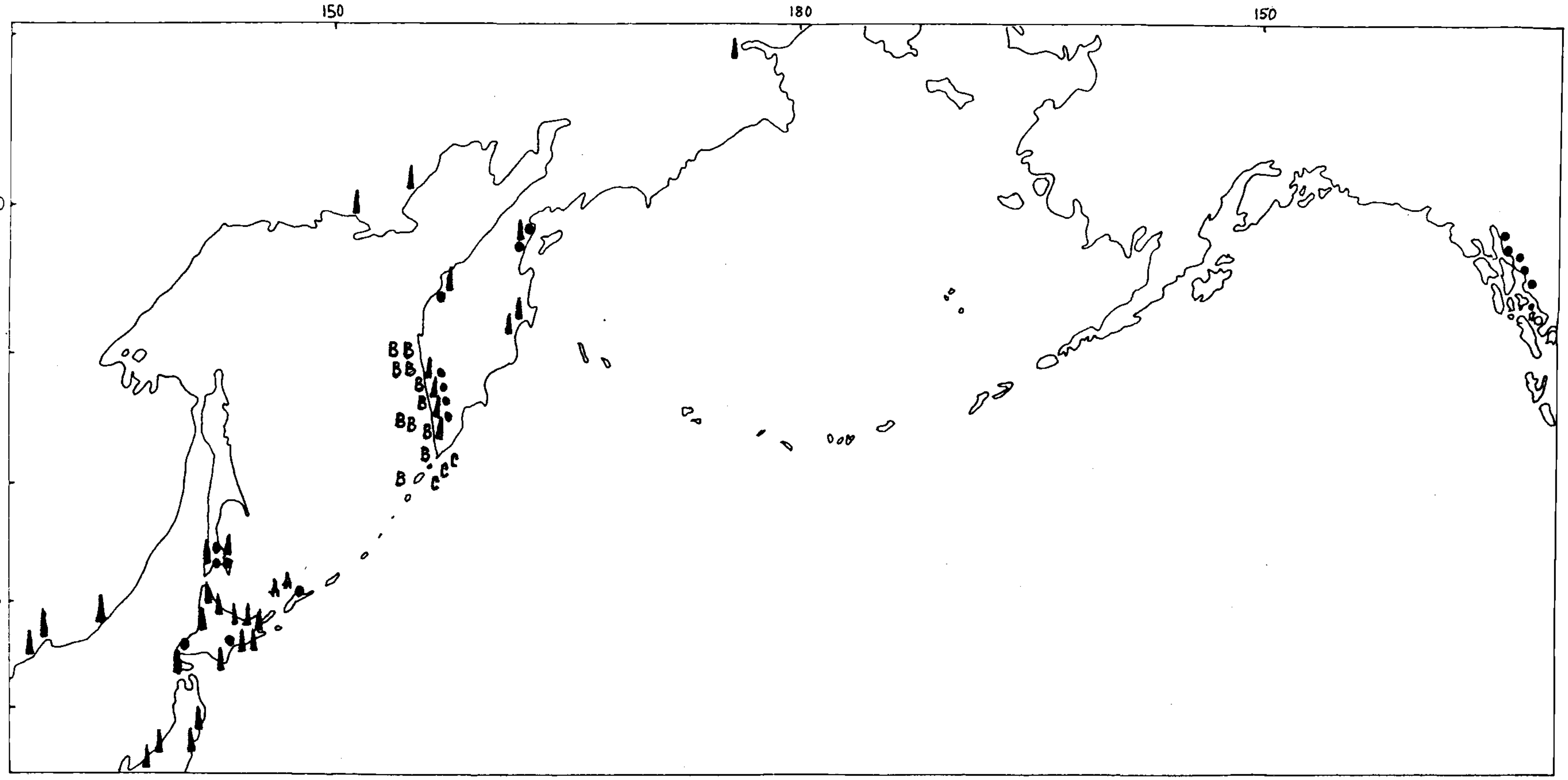

Fig. 1. Sampling sites for chum and pink salmon. Triangles show chum salmon baseline sites, circles show pink salmon baseline sites. Letters correspond to mixed fishery collection sites listed in Table 6. Japanese data were taken from Winans et al., 1994.

Strategy for Culture, Breeding and Numerous Dynamics of Sakhalin Salmon Populations

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ABSTRACT

The marine littoral zone and the influence of hatchery produced salmon fry on the biocenose structure in South Sakhalin were studied. The littoral area is highly productive and had a complex community structure. The release of hatchery salmon fry influences a number of the components of littoral biocenose, particularly, the *Harpacticoida* which are the preferred food items of salmon fry upon entering the sea. In shallow waters, the competition for food by chum and pink salmon fry causes a deterioration of the habitat conditions for other species of fish, namely, pond smelt (*Hypomesus olidus*), Pacific sand lance (*Ammodytes personatus*) and the fry of plaice and Far-Eastern navaga etc. Salmon fry are also feed for carnivorous fishes such as kunscha (*Salvelinus leucomaenis*), rainbow Asiatic smelt and sculpins (Cottidae) etc and they compete for food with wild salmon fry which lead to increased mortality of the naturally bred fry.

INTRODUCTION

For ten years, the Chairman of Water Ecology and Sea Culture of Far-Eastern State University studied the conditions of salmon fry in regions influenced by hatchery production in the southwestern and eastern Sakhalin waters. There is an enormous shallows which is separated from the open sea by a stone ridge along the southwestern coast of Sakhalin. The warming and active aeration of waters in the area creates an intensive growth of aquatic vegetation producing favorable conditions for the reproduction of small invertebrates. Historically, a number of fish species inhabit the shallows and more recently young hatchery salmon have been introduced to feed as they move into the sea. The Department of Aquatic Ecology and Aquaculture has carried out research on wild communities and the impact of hatchery produced salmon on the coastal areas (Andreyeva et al., 1994).

MATERIALS AND METHODS

The investigations were carried out in different areas of southern Sakhalin from 1985 to 1991. Samples of plankton, benthos, epiphyton, and fish were collected during May-July, during 3-5 day periods. At the same time, 2 hr. diurnal observations were carried out in laboratory conditions. The temperature, salinity, oxygen content, water level, direction and strength of wind were measured.

RESULTS AND DISCUSSION

The salmon young feed on small invertebrates dwelling, in the water layers, on the vegetation and on the bottom surface layer. The community composition can be classified as plankton, benthos, and epiphyton as well as intermediate forms (planktobenthos). The most abundant groups in the study area are *Harpacticoida* and *Amphipoda*.

The data indicate that seasonal and interannual abundance changes occur for most animal groups but especially for *Harpacticoida* which are about 80-90% of the total biomass of plankton, epiphyton and meiobenthos. A maximum biomass of *Harpacticoida* (760 sp.m^{-3}) occurs in mid-May which then decreases and is replaced by other species (Fig. 1). Abundant spring species are also replaced by less abundant summer forms due to warm water formation (Fig. 2). Undoubtedly, the abundance of *Harpacticoida* depends on the amount eaten by the salmon young which are in high abundance at the end of May.

The plankton abundance (*Pseudocalanus minutus,Acartia clausi, Centropages abdominales, Oithona similis*, some larvae of *Polyhaeta*) is maximum during the flood tide except for *Eurytemora thompsoni* which increases during the falling tide. Daily rhythms were observed for other animals such as *Amphipoda, Harpacticoida, Isopoda, Ostracoda, Mysidacea*, however, the increased abundance in the water usually occurs during the night (Fig. 3). Diurnal fluctuations of abundance of these groups can be explained by changes in their activity during the day. According to some authors, the numbers and biomass of animals living in the bottom surface layer and on the vegetation increases in the water column at night (D'Amours, 1988; Walters, 1988). During this study, diurnal migrations vary among the different species but the number and biomass of *Harpacticoida* increases during the day. Animals with a pronounced daily migration into the water column are found to be more vulnerable to feeding young salmon and other fish. Young salmon mainly feed on *Harpacticoida, Amphipoda* and less often of *Polychaeta* and *Insecta* larvae. Daily changes in feeding intensity and food composition is typical for salmon young.

The food of the salmon young in the coastal marine areas consists of 14 groups of organisms, usually the size preference was a length of 0.5-2.5 mm. The food spectrum depends on the habitat type. In bays *Amphipoda* and *Harpacticoida* are 34.6 and 36.6% of the diet and in lagoons it is mainly *Polychaeta, Harpacticoida*, and *Amphipoda* to lesser extent. The food composition changes in May to large species of *Harpacticoida, Harpacticus uniremus* and species of *Thalestris* and *Dactylopodia*, whose size are 0.8 - 1.5 mm. In June smaller species are eaten such as *Tusbe* and *Scutellidium* which are 0.4-0.7 mm. The salmon young consume the maximum food at 1,200 in May and 1,400 in June. During the daily cycle *Harpacticoida* is the dominant species in May, *Amphipoda* and *Insecta* in June. The abundance of salmon fry had an influence on the abundance of the main components of the littoral biocenose, particularly, *Harpacticoida* due to heavy predation when leaving the river for the sea.

The salmon young near southwestern Sakhalin feed from the beginning of May to end of July. They are competitors with other of coastal fishes: silver smelt, sand lance, burnstickle as well as the young of Pacific navaga, flounders and other fish. Salmon fry are also food for carnivorous fishes of biocenose: kundscha (*Salvelinus leucomaenis*), rainbow Asiatic smelt, sculpins (*Cottidae*) etc. The salmon fry produced by hatcheries are competitors for food used by wild salmon fry which could lead to an increase in mortality of naturally spawned salmon fry (in rivers).

During feeding in the coastal marine areas (a month and a half on average), the young salmon consume up to 135 tons of food organisms daily which is estimated to be 30 mg day-1 per individual and approximately 80-100 million individuals aree released from the hatcheries of southwestern Sakhalin. The impact of hatchery salmon production changes food organism abundance and species, such as for Harpacticoida, Amphipoda, Polychaeta and others, during there migration to the sea. Food availability for a number of fish (smelt, flounder, sand lance, navaga and others) is also effected by the large hatchery production. From studies of the daily ration of fry and estimates of the optimal production of fry in this region about 3.5-11.5 million of fry would be optimum for the available littoral area of Kalinin.

The analysis of data show that the total production of Sakhalin hatcheries did not contribute to the low survival of fry and low recurrence of salmons. Rather the practice of releasing 20-30 million fry at one time from hatcheries impacts on survival. A better policy would be to release 2-4 million from the end of April to first part of May, 6-9 million from the middle of May and then reduce the output throughout June until the total production has been released. Additionally, it would be good practice organize the release by spreading it along the Sakhalin seashore.

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FIGURES

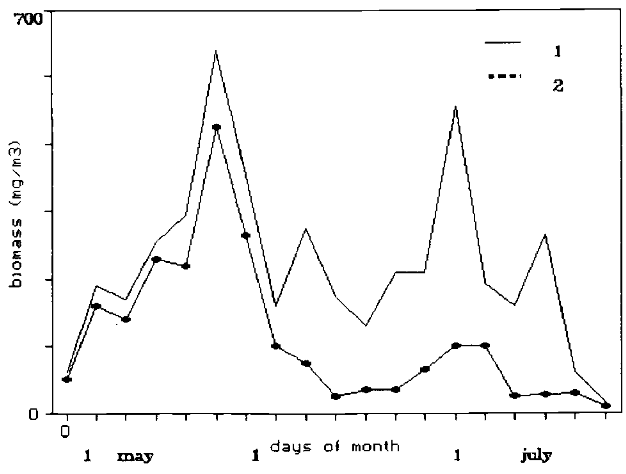

Fig. 1. Seasonal dynamics of biomass of plankton.
1 - total biomass 2 - biomass of Harpacticoida

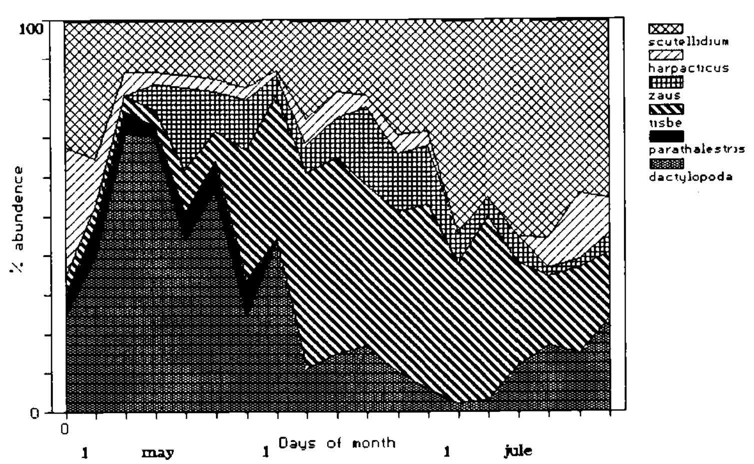

Fig. 2. Seasonal exchange of species composition of Harpacticoida in plankton.

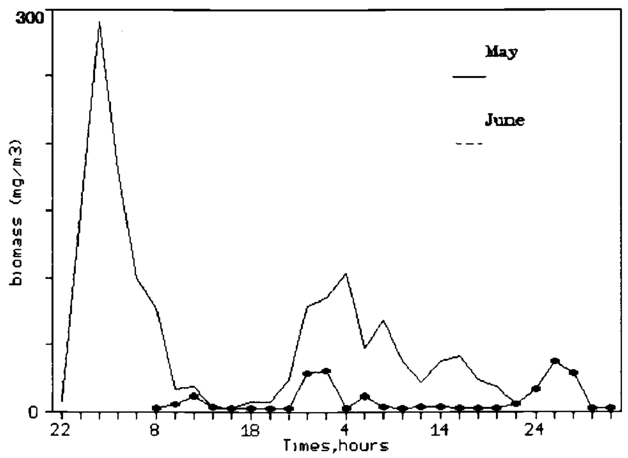

Fig. 3. Daily dynamics of abundance of Harpacticoida.

Primary Production in Sakhalin Shelf Waters

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INTRODUCTION

The distribution and productivity of phytoplankton on the Sakhalin shelf varies in space and time depending on different physical forcing. The dominant physical effects on phytoplankton processes in this region are the strong seasonal changes in intensity of incoming solar radiation, wind direction and nutrients in the water.

This work examines primary production on petroleum deposits on the continental Sakhalin shelf at Chayvo, Arkutun-Dagi, Piltun and Sakhalin Bay. Development in these areas has started and the measurement of primary production can be used as an indication of the effects of chronic petroleum pollution and navigation on bioproductivity.

Productivity data were primarily collected from 27 stations located between 52° and 54° N and 142° and 144°E in depths not exceeding 90 m relative to the shelf waters.

METHODS

With some modifications, the primary production is measured according to Steeman Nielsen (1952). Photosynthesis is calculated by the incorporation of C^{14} in particles collected on 0.4 mkm Synpor filters. All samples are processed in 0.1 NHCl and analyzed with the help of the Delta-100 liquid scintillation counter. The fixing of carbon during the dark is determined in each experiment. The water is selected from different layers and incubated on the deck with neutral density filters to simulate the *in situ* radiation field. The fractional exposition of the same water samples are used to determine the daily production. In a special experiment C^{14} incorporation is very low at night compared to the usual radioactive background.

The curve of daily production of 1 m^3 of water is plotted on data of fractional expositions (by calculation of under peak square) to determine the daily production in the water column under 1 m^2. The coefficients for each daylight period are calculated to permit exposition at any time.

The Phytoplankton Primary Production on Petroleum Deposits of Continental Sakhalin Shelf

Two major natural parameters regulating the phytoplankton quantity and production in the ocean are light and nutrients, particularly, nitrogen. In the investigated region seasonal changes of solar radiation on the sea surface and nitrate concentrations are significant. The Sakhalin Bay nitrate concentration is very low, average 6 mM despite the Amur river discharge, much lower than in the open Okhotsk sea 15 mM, and Piltun deposit 18 mM (Tech. Report, 1992). The primary production is 0.33 gC/m^2 day, 0.8 gC/m^2 day and 2.4 gC/m^2 day respectively. The nitrate concentration is taken into account from the lower level of the photosynthesis zone to a depth not exceeding 50 m, since in the upper layers the concentrations are grazed and it would underestimate the initial conditions. In

August 1992 on the Piltun deposit the average value of primary production reaches 2.4 gC/m^2 day (maximum 5.56 gC/m^2 day), and in August 1993 it did not exceed 0.53 gC/m^2 day (Tech. Report, 1993). The comparison of primary production and nitrate concentration on stations with close coordinates indicate that nitrate contents are some times higher (Table 1). The 1994 primary production at the end of October during a shorter daylight period is compared to the longer daylight period of August 1993. The values of primary production varies from site to site: Chayvo the average primary production is 0.4 gC/m^2 day (maximum 0.65 gC/m^2 day); Arkutun-Dagi 1.24 gC/m^2 day (maximum 2.84 gC/m^2 day); Piltun 0.68 gC/m^2 day (maximum 1.4 gC/m^2 day) and in Sakhalin Bay 0.42 gC/m^2 day (maximum 1.21 gC/m^2day) (Fig. 1). The length of daylight is the major regulating parameter in the rate of phytoplankton production which explains the lower rate of photosynthesis on the Piltun stations, for example, 0.68 gC/m^2 day in October 1994 and 3.11 gC/m^2 day August 1992. Additionally, the role of the nutrient flux in the Okhotsk Sea euphotic zone should be taken into account as is shown in the nitrate example.

It is difficult to separate the different influences of these processes in determining primary production because they are closely related. Some regeneration of nitrogen in the eutrophic waters is caused by zooplankton and microzooplankton metabolism. The greatest phytoplankton biomass and rate of primary production is from the nitrate flux from upwelling (Eppley and Peterson, 1979; Dortch and Postel, 1989). While photosynthetic radiation defines the rate of primary production *in situ*, the rate of dissolved nitrogen production is responsible for high primary production in the upwelling zone. As a rule, a combination of the solar radiation and nitrate flux provides higher levels of primary production in summer.

The arrangement of the deposits and the distribution of primary production is shown in Fig. 1. The lowest primary production is observed on Chayvo, the highest on Arcutun-Dagi, and on other two sites the values are similar and intermediate. The change of the primary production on Chayvo is possibly connected to sampling conditions (the stormy weather causes the top and bottom water layers to mix in the shallow depths) as is evident from the vertical distribution of primary production in different layers. The maximum primary production which usually occurs near surface or just below does not occur at nearly all the stations. A similar distribution is observed on the very shallow Sakhalin Bay (maximal depth 22 m) deposit. The value of primary production is reasonably high 1.21 gC/m^2 day. The deposit is near the Amur river influence and the water structure is characterized by the upper quasi-homogenous layer to 10-15 m. It is reflected in the homogeneous vertical primary production structure. The lowest daily production, which did not exceed 0.2 gC/m^2 day, is observed in strong current. Thus the non-uniformity in primary production (from 1.21 to 0.15 gC/m^2 day) is connected to the hydrodynamic processes in this region.

At deep-water sites, there is a more ordered vertical distribution of primary production (Piltun deposit, maximum depth 63 m, and Arcutun-Dagi maximum depth 90 m). At the Arcutun-Dagi site, the photosynthetic zone ceases at 90 m while in summer months of 1993 it is 40 m (Tech. Report, 1993) and 60 m in 1979 (Eppley and Peterson, 1979).

Within the limits of each site, the variability of primary production is (particularly at Arcutun-Dagi deposit) from 2.84 gC/m^2 day to 0.09 gC/m^2 day. Such a mosaic, within the limits of the small area, testifies to the complexity of the photosynthesis process. The high primary production of waters at the study site indicates the possible problems that could occur from future industrial development. Primary production is sensitive to pollution, as is found for the toxic compounds of drilling muds which suppress photosynthesis (Tech. Report, 1993). As phytoplankton is the primary unit in the trophic food web, it is not hard determine possible consequence to the system of a toxic event. Therefore, primary production measurement can be used as main indicator of environmental conditions and to select harmless drilling mud.

The relationship between primary production in the water column and surface phytoplankton pigment biomass was investigated for the purpose of the determining the opportunities of using pigment concentration for predicting primary production (Eppley et al., 1985; Perry, 1986). It is shown that the biomass variability defines many, but far from all factors of primary production. Thus, the primary production method of research on photosynthesis gives the best representation of bioproductivity of the ocean. The method permits the simulation of any conditions *in situ*. In particular, the influence of various additives on primary production can be produced for guidance in areas where industrial development is planned.

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TABLES AND FIGURES

Table 1. The comparison of nitratcontents and primary production (PP) on stations of Piltun deposit in August 1992 and 1993.

Year	NO_3 mM	PP gC/m^2 day
1992, 7, August	14.18	1.17
1993, 14, August	8.43	0.53
1992, 7, August	19.03	2.33
1993, 14, August	5.01	0.15

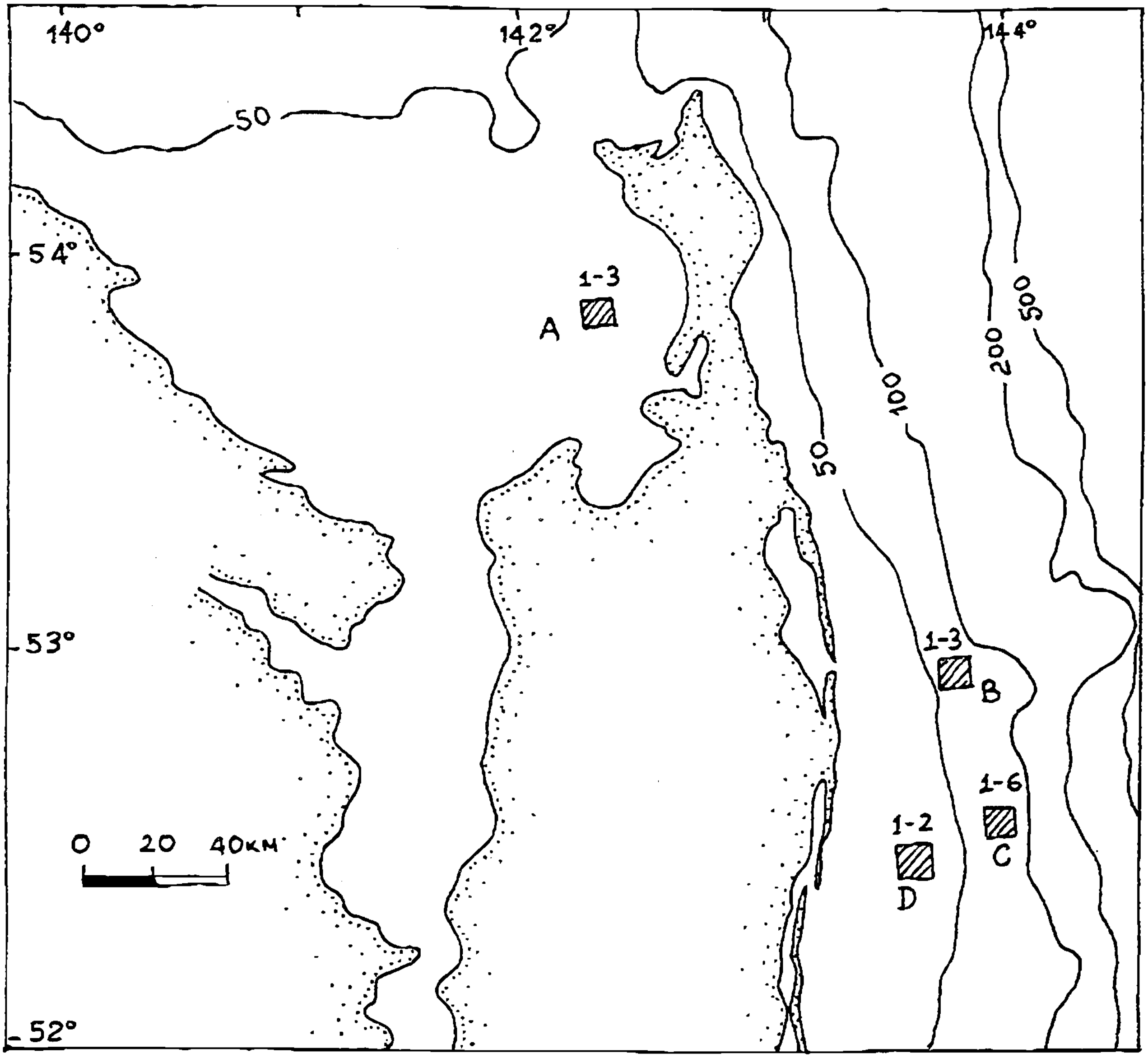

Fig.1. Map of Primary Production in Sakhalin Shelf Waters.
A - Sakhalin Bay, B - Piltun, C - Arcutun-Dagi, D - Chaivo.
The numbers indicate ranges in measured rates of PP, gC/m^2 : day: 1 - 0.500; 2 - 0.501-1.000; 3 - 1.001-1.500; 4 - 1.501-2.000; 5 - 2.001-2.500; 6 - 2.501-3.000.

Some Reasons for Resource Reduction of *Laminaria Japonica* (Primorye Region)

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At the present time, the resources of *Laminaria japonica* are significantly reduced in three regions of the Primorye (north, middle and south). Surveys from recent years show that in a large area there are no commercial fids or they are in a depressed state. This lead to a 1991 closure of harvesting of *Laminaria japonica* to allow the stocks to rebuild. To determine the possible causes of the problem, analysis of growth, biological characteristics, climate and oceanographical condition were studied.

All three regions occur in the Prymorsky cold current. In the north the conditions are the most favorable for *Laminaria japonica* (many biogenes and low water temperature). In the South Primory region conditions are less favorable as there are less biogens and the temperature is higher (Fig. 1).

North Primorye the plants grow to a larger size and mass and the volume of sporogenesis tissue is greater than in the South Primorye. For example, in North Primorye one plant weighed 1,000 g and the coefficient of sporogenesis tissue K was 0.7 on a thallus. In the south region plants of *Laminaria japonica* weigh 600 g and the K was 0.5. In the middle region the weight is 800 g and K is 0.6 (Fig. 2). These proportions remained relatively stable in the three regions except for one year in the last 7-8 years when a weakening of the Prymorsky cold current resulted in less growth. For example, in 1981, in the north one plant weighed 800 g and K was 0.6; in the middle one plant weighed 500 g and K was 0.3; in the south one plant weighed 300 g and K was 0.2.

During the reproductive cycle in the fall, after zoospores are released to settle and sprout the temperature is found to fluctuate from 3°C-14°C which causes the destruction of gametophytes (Fig. 3). Thus, in these years the reduction of sporogenesis tissue causes the death of zoospores that are already formed. In the north and middle regions, cold waters results in low growth of rhizoids and zoospores are unable to attach to the substrate (Fig. 3). All these facts influence the yield of future years.

Commercial harvesting of *Laminaria* in Russia is undertaken by divers who only remove the plant material leaving the rhizoids to grow another year. In the years of reduced productivitiy, commercial harvesting of *Laminaria* should be stopped. At least harvesting should be stopped in the north and middle regions when the cold current causes low productivity. Taking into consideration all these facts there is an opportunity to use a new method for forecasting *Laminaria* yield and developing better management strategies for harvesting the plant.

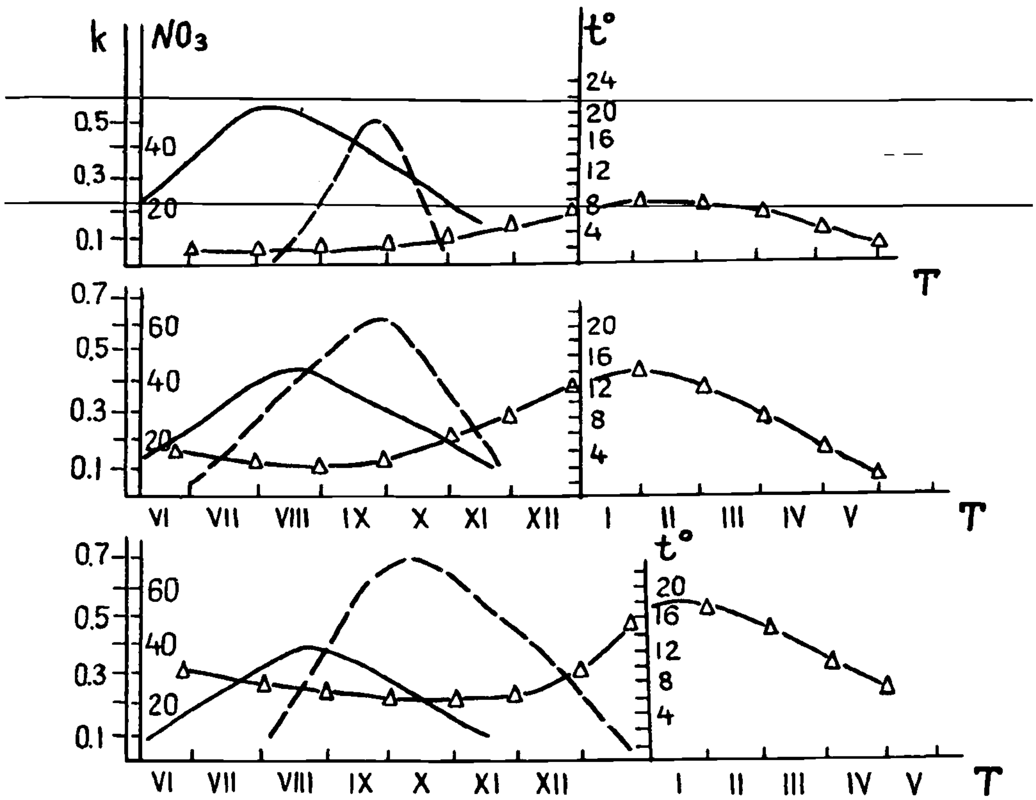

Fig. 1. Mean parameters from Middle Region.

— temperature (t°C)

- - - coefficient of covering of thallus by sporogenesis tissue (K)

-Δ- NO_3 (mkg/l)

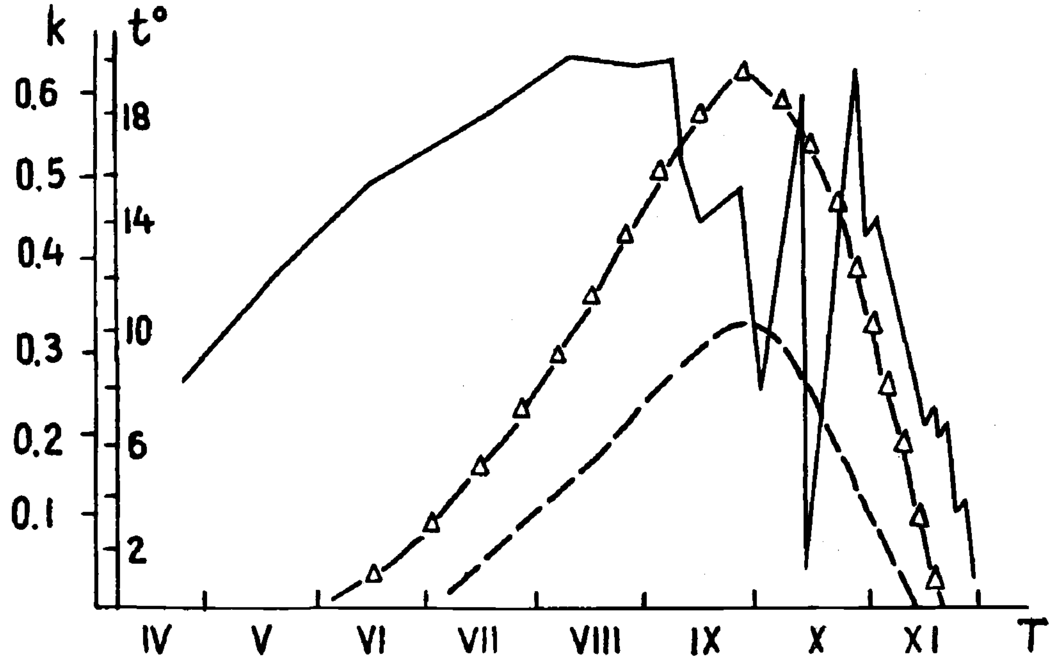

Fig. 2. Temperature of water and coefficient (K) of thallus covered by sporogenesis tissue in 1981 in Middle Primorye.

——	temperature of water (t°C)
- Δ -	coefficient of thallus covered by sporogenesis tissue over many years (K)
------	coefficient of thallus covered by sporogenesis tissue in 1981 (K)

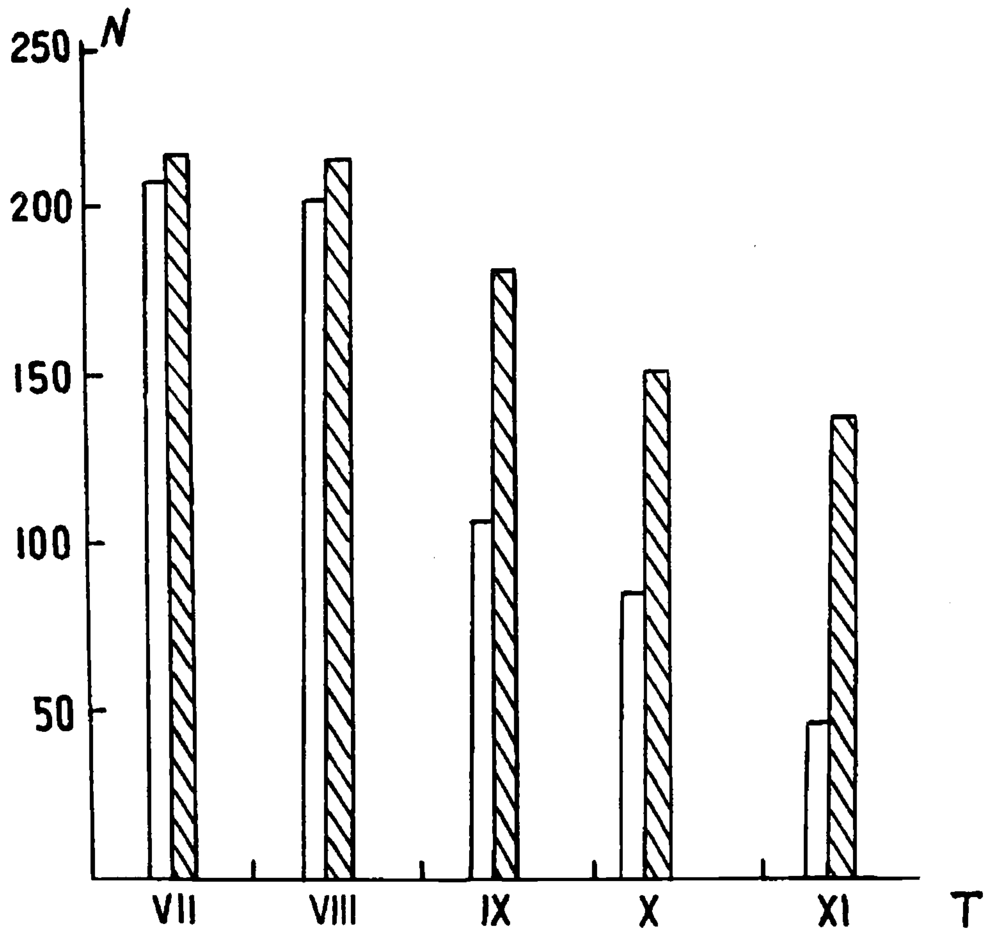

Fig. 3. Proportion between existing Laminaria plants and new rhizoides attaching to the substrate.

☐ plants
▨ rhizoides

Mercury in Bottom Sediments of the Northeastern Okhotsk Sea

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To delineate the problem of monitoring mercury in the marine environment, data is needed at the ecosystem level. For example, data from bottom sediments are of great importance because they serve to locate where the long-term storage of mercury occurs, which potentially can be reintroduced into the environment (Hiroshi et al., 1989). In bottom sediments, mercury is transformed by microbiological activity into a highly toxic methyl-mercuric form which can cause serious ecological disturbances when incorporated into biota and *vice versa* (Akagi et al., 1979). Reasonable mercury levels in the bottom sediments can serve as an indicator of both anthropogenic (waste drain waters, aerosols, toxic waste burials, etc.) and natural (the seepage from the interior along deep faults, ore oxidation zones, disseminated cinnabar deposits) sources in the ocean.

The quantitative estimation of the extent of bottom pollution by mercury was determined using the flame atomic absorption spectroscopy method (Hatch and Ott, 1968) from bottom sediment probe samples collected on the R/V "Acad. A.Nesmeyanov" (24^{th} Cruise) in 1993. The grain-size composition of bottom sediments was determined using the pipette method for estimation of the correlation between the mercury contents and the structural sedimentary types (Petelin, 1967). A map of the sediment type distribution has been plotted on the basis of grain-size analysis data (see Fig. 1). The most coarse-grained sediments (fine psammites) occur within the zone of intensive water-mass movements in the nearshore region off the west coast of Kamchatka near the Shelikhov Sound neck where the intra-structural hydrological front is characterized by high biological efficiency (Chernyavskiy, 1970). Aleurites and pelites are laid at greater depths where the dynamic activity causes the accumulation of finely dispersed sediments.

Bottom sediment mercury concentrations vary from 0.006 till 0.028 mcg/g of the dried mass. The lowest mercury content (0.006 mcg/g) is found in psammites that may be connected with their weak adsorption properties and with the intensive washout. At increasing depth, growth and particle size decreases and the mercury concentration increases up to 0.028 mcg/g due to the high metal adsorption capacity of the aleuritic fraction of bottom sediments (Duzzin et al., 1988).

When mercury concentrations in bottom sediments of our region are compared with the background values to determine a criterion for a quantitative pollution level estimation based on the relative mercury ground accumulation coefficient. For the Shelikhov Sound neck region, the coefficient varies from 2 to 4 units. The mercury content excess (relative to the background content) is a factor of 2-4 in the bottom sediments which was assigned to a category of sediments enriched with mercury. It should be noted that it was only this area where we observe elevated mercury concentrations in the near-bottom water layer. The high level is likely due to natural mercury fluid seepage from the deep earth crust. The mercury transfer is usually effected by alkaline sulfide solution or from organic compounds incorporated into the carbon bearing gases. The mercury transfer can also be in a vapour phase (Ozerova and Pikovskiy, 1982).

The tectonics data for the Okhotsk Sea region indicates that the Shelikhov Sound area is characterized by folded deformations in the earth crust. These deformations are caused by deep seated faults (Gnibidenko and Khvedchuk, 1982). Tectonic movements along the faults are caused by active processes within the earth crust and upper mantle and by mantle differentiation. As a whole, our data shows that the mercury content values for the bottom sediments (laid within the anomalous mercury concentration zone in the near-bottom layer) are not high enough to cause environmental contamination. It was assumed that the mercury entering into the near-bottom water layer is in a vapor form. As the result of the high water agitation observed, the mercury transfer processes is presumably dominated by the mercury settling to the bottom surface. Thus, the undesirable action of the toxicant to biota tends to be diminished.

The data suggested development of a monitoring system for mercury contamination in the marine environment and for setting estimation criteria in waters and bottom sediments.

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FIGURES

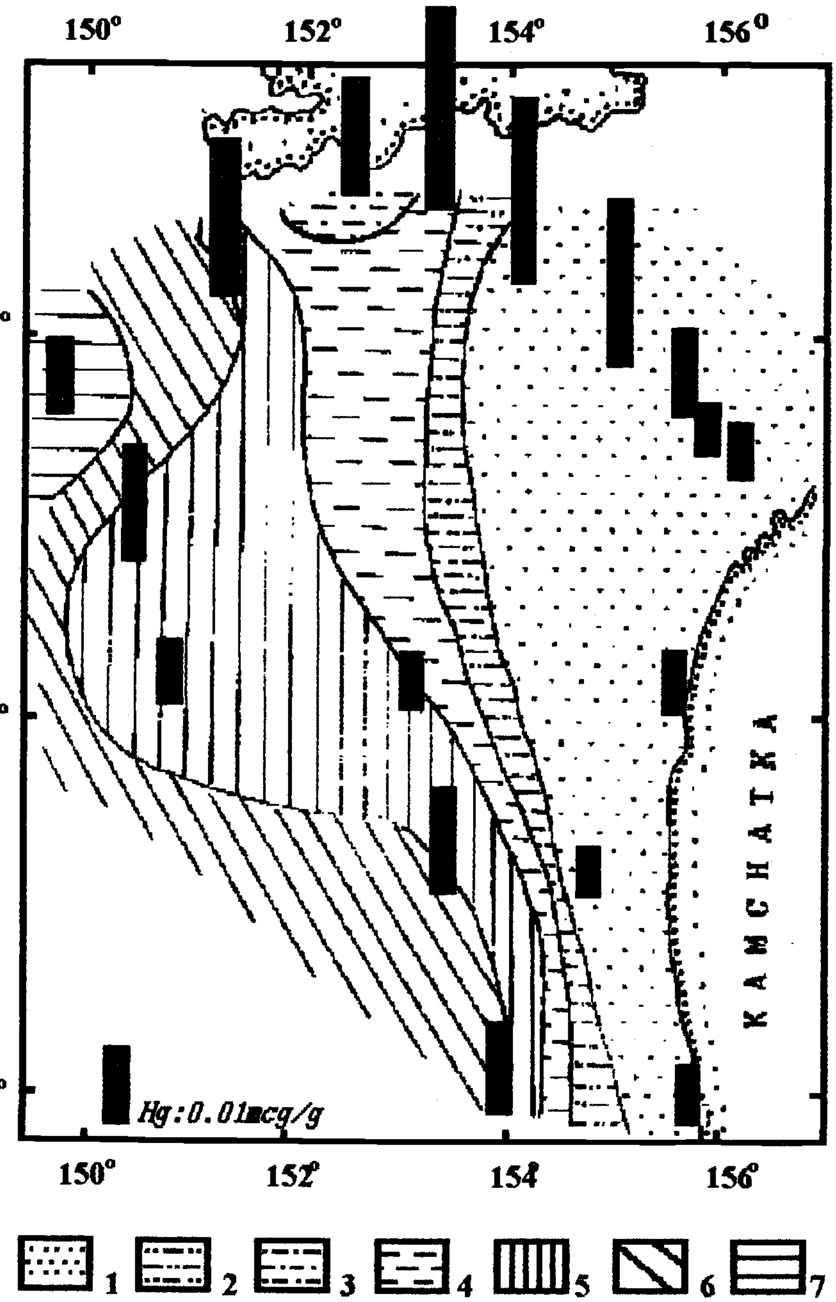

Fig. 1. Mercury distribution in bottom sediments of the North-Eastern part of the Okhotsk Sea:

1 - fine-grained psammites
2 - aleuritic psammites
3 - psammitic aleurites
4 - aleurites
5 - pelitic aleurites
6 - aleuritic pelites
7 - pelites

Lectins and Glycosidases from Marine Macro and Micro-organisms of Japan and Okhotsk Seas

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ABSTRACT

Carbohydrate binding proteins and carbohydrases are widely used in glycobiology and biotechnology. In our laboratory galactose specific lectins were isolated from marine invertebrates of the Japan Sea from the mussel *Crenomytilus grayanus* and the marine worm *Chaetopterus variopedatus*. The peculiar lectin obtained from hemolymph of crab *Erimacrus isenbecki* showed affinity to sialic acids and N-acetyl-aminosugars. The lectins were found to bind Ehrlich carcinoma cells and the humane and animal erythrocytes in various manners. The reaction of agglutination was inhibited by such glycoproteins as mucin, fetuin, alpha-1-acid glycoprotein. The mannose specific lectin isolated from the celomic fluid of the marine cucumber *Stichopus japonicus* was shown to interact with high mannose "hybrid type" glycoproteins.

To search for producers of beta-N-acetyl-D-glucosaminidase, chitinase and carrageenase, the screening was carried out using marine bacteria from the Kuril Islands. The low-molecular weight of kappa- and lambda-carrageenans with potential antiviral activity were obtained by fermentolysis of natural polysaccharides. In a preparative scale, Chitobiose and chitotetraose were isolated after chitin degradation with a crude enzyme from marine bacteria KMM B-07. These substances are useful intermediates in technology of biologically active substances.

INTRODUCTION

The screening of genetic sources as tools for marine carbohydrate biotechnology is a problem of modern oceanography. The lectins from plants are very well known (Kilpatrick, et al. 1991; Gabius and Gabius. 1993). Recently, researchers are being directed to marine organisms (Renwrantz, 1986; Pavlenko et. al., 1990; Hatakeyama et. al., 1993). Special attention is being directed to substances (oncoprecipitins) which may bind with human oncofetal antigens (Pavlenko et. al., 1990; Moroz et. al., 1993). The isolated lectins and oncoprecipitins will be useful for diagnosis and therapy of cancer.

RESULTS AND DISCUSSIONS

Carbohydrases are useful tools for bioglycans structure investigation and the preparation of various biologically active substances. A chitinase, N-acetyl-beta-D-glucosaminidase, kappa- and lambda-carrageenases were obtained from some marine microorganisms. The following lectins and carbohydrases were isolated from marine invertebrates and microorganisms of Japan and Okhotsk Seas.

Lectin of the mussel *Crenomytilus grayanus* (CGL)

CGL was isolated from the mussel body using extraction of the mussel homogenate with saline solution followed by centrifugation and fractionation of the mixture obtained by affinity chromatography on the hydrolyzed Sepharose 6B or on Lactosyl-Sepharose 4B to yield the purified lectin.

Using HPLC on TSK G2000SW column or gel filtration on Sephadex G-75 column, the average molar weight was determined to be 36 kDa. A desegregation of the lectin was observed in the presence of 2-mercaptoethanol. CGL treated with 2-mercaptoethanol was subjected to sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) to show a single band of 18 kDa. These data demonstrated that the mussel lectin appears to consist of two sub-units.

CGL was found to possess an agglutinating activity in relation to the human erythrocytes (ABO), sheep erythrocytes and Ehrlch's carcinoma cells. The highest agglutination titer was observed with the trypsinized human erythrocytes to reach up to maximum value for blood group B. A maintenance of agglutinability in the wide range of pH-values (2.5-10.0) indicated an occurrence of reversible alterations in the protein molecule. An inhibition of hemagglutination was achieved with galactose and derivatives of alpha-D-galactoside demonstrated alpha-D-galactose specificity of CGL. A peculiarity of the mussel lectin was thermo-stability of the molecule. CGL was found to maintain agglutination at an elevated temperature of up to 60C.

Lectin of the marine worm *Chaetopterus variopedatus* (CVL)

CVL was isolated from fresh marine worms *C. variopedatus* collected in the sublittoral zone of Bay of Peter the Great in the Japan Sea. Marine animals harvested were homogenized and subjected to extraction with a saline solution followed by precipitation with ammonium sulphate. The fraction obtained was shown to possess a hemagglutinating activity. Hemagglutination was inhibited with galactose and lactose. In this connection, a purification of CVL was achieved using affinity chromatography on lactosyl-Sepharose 4B followed by elution of the lectin with an aqueous solutions of galactose. The CVL obtained showed a single band on SDS-PAGE with a molar weight ca. 30 kDa. SDS-PAGE of CVL in the presence of 2-mercaptoethanol showed the same single band demonstrating the absence of disulfide bridges in the lectin. CVL was found to agglutinate all types of the human erythrocytes. The sheep and rabbit erythrocytes were also agglutinated with CVL. A treatment of erythrocytes with trypsin was shown to enhance hemagglutinating activity of CVL. In addition, a high titer of agglutination of the cells of Ehrlich's sarcoma was observed.

An alteration of pH-values of the buffer solutes demonstrated that specific activity of CVL was maintained in a range of pH 5-9. CVL showed a maximal activity at pH 8. An elevation of temperature of CVL solutes failed to substantially reduce specific activity up to 40C. A significant lost of activity occurred on heating at higher temperature. CVL was found to become inactive completely at 50C.

The minimal concentrations of various monosaccharides, oligosaccharides and glycoproteins require to completely inhibit agglutinating activity of CVL were determined. The galactose showed a maximal inhibitory activity among monosaccharides investigated. The inhibition of CVL with N-acetyl-D-galactosamine was substantially lower than that with galactose. The inhibitory activity of D-fucose and D-galacturonic acid reduced 3 and 4 fold respectively in comparison with that of D-galactose. This phenomenon indicated certain participation of the C5-C6 region of sugar in binding the lectin. An inhibitory ability of lactose was found to be equal to that of methyl beta-D-galactopyranoside. Lactose showed the most inhibition in comparison to raffinose and melibiose.

These data were possibly connected with an anomeric configuration of the galactose residue in the oligosaccharides as follows: beta-galactosyl residue involved in lactose while raffinose and melibiose contained alpha-galactosyl residues.

Mucin, fetuin and alpha-1-acid glycoprotein were found to be effective inhibitors of hemagglutination. It is noteworthy that desialylation of fetuin and alpha-1-acid glycoprotein was accompanied by a substantial increase of inhibitory activity while the desialylated mucin showed the same inhibition as the parent glycoprotein. As is known, the neuraminic acid residues occurred at C-6 of the subterminal galactose residue in mucin while C-3 atom was additionally involved in linkages with the neuraminic acid residues in both the other glycoproteins. This phenomenon demonstrated that the hydroxyl group at C-6 failed to influence binding the galactose residues of glycoproteins with CVL while hydroxyl group at C-3 appeared to be very significant for binding glycoproteins with the lectin. CVL was found to possess a substantial agglutinating activity in relation to the tumour cells due to oncofetal antigens involved in tumour cells which are known to contain regions which resemble those of mucin (Mikheyskaya et al, 1995).

The crab *Erimacrus isenbeckii* lectin (EIL)

A very interesting lectin was isolated from the hemolymph of crab *E.isenbeckii* (EIL) using affinity chromatography on bovine serum mucin-agarose column in the presence of Ca-ions. Elution of EIL was achieved with 0.5M GlcNAc in Tris-HCl buffer in the absence of Ca-ions. The EIL fraction was subjected to chromatography on a column with DEAE-Toyopearl 650M to obtain a purified lectin.

SDS-PAGE showed a single band of 70 kDa in the presence or absence of 2-mercaptoethanol thus indicating the occurrence of a single subunit. Homogenecity of EIL was confirmed by immunodiffusion against antiserum obtained by immunization of rabbits with a purified hemolymph of the crab. EIL was shown to represent glycoprotein which contained 2% sugars. An absence of amino acid residues contained S-atom was a peculiarity of the lectin.

EIL was found to agglutinate the human A, B, O erythrocytes. More high agglutinability was observed in relation to erythrocytes digested with trypsin. The sugar specificity of the lectin was elucidated using inhibition of EIL-hemagglutination with various sugars. The lectin agglutinability was inhibited with aminosugars (GlcNAc, GalNAc), with N-acetyl neuraminic acid (NANA) and glycoproteins which contain NANA residues (mucin, fetuin et. al.). In addition, uronic acids (GlcUA, GalUA) and KDO (2-keto-3-deoxy-octonic acid)-containing lipopolysaccharides were found to inhibit a hemagglutination of EIL.

Hemagglutinating activity of EIL was estimated to continue in the range of pH-values from 7 to 10. Activity was half a maximum at pH 6. EIL was shown to afford a precipitate at pH-values less than 4. EIL showed thermostability at the interval of temperature from 4 up to 40C. Its agglutinability was completely maintained at 37C for 30 min. Half an activity was observed at 50C. Activity was shown to disappear completely at 60C for 10 min. EIL was shown to represent Ca dependent protein similar to lectins from other species of crabs. The agglutination activity of EIL was completely lost after dialysis with a buffer containing EDTA. An addition of Ca-ions led to restoration of hemagglutination of EIL.

The marine cucumber *Stichopus japonicus* lectin (SJL-M)

SLJ-M was found in celomic fluids of *S. japonicus* by affinity chromatography on mannan-Sepharose 4B. Lectin agglutinated human group 0 and rabbit erythrocytes. The hemagglutination was inhibited by yeast mannan from Saccharomyces cerevisiae and extra cellular mannan from Vibrio flavialis.

Two other lectins described early from cucumber's body have specificity to galactose (Hatakeyama et al, 1993). Such variability of the carbohydrate binding molecules to one organism is convincing that the Ocean might possibly be a good source of genetic information.

The mannose-binding proteins have various physiological activity and participate actively in the homeostasis and the defense of macroorganisms (Ohta et al, 1994; Nermes et al, 1995).

Carrageenases from marine microorganisms

The search for the enzymes which specifically degrade carrageenan (sulphatated galactan from red alga) is urgent because of its low molecular weight it is used in cosmetics and medicine. (Akagawa-Matsushita et al, 1992; Luk'yanov et al, 1995). The screening of carrageenases bacterial producers were carried out among epibiotic microorganisms of Rodophitae and microbes from various species of decomposed red algae as result of accessing 20 bacterial cultures capable of growing on solid kappa-carrageenan medium. Four strains had the highest enzyme production. The enzyme secretion was observed to be maximal in the period between 21 and 30 hours from start of bacterial growth in a 0.5% carrageenan medium.

Crude enzymes were obtained from the 25 h cultural medium of the most promising strains (KMM SW-4f, KMM 12-3, KMM 10-32). The enzymes purified by 40-70% (NH4)2SO4 precipitation with following gel chromatography had a specific activity of 10-20 units per mg protein which were determined by color reaction of reducing carbohydrates with 2, 3, 5-triphenyltetrasolium chloride with 0.25% carrageenans as substrate. The enzyme preparation was shown to be cryo-stable (after freezing-thawing it lost only 15% activity) and to have pH-optimum in the range of 5.5-7.0.

The isolated enzyme hydrolyzed kappa-carrageenan as it was shown by the decrease of polysaccharide solution viscosity and gel permeation chromatography. Low molecular weight carrageenan had molecular mass of 30-50 kDa.

Chitinase and beta-N-acetyl-D-glucosaminidase (NAGase) from bacteria

The complex of enzymes which hydrolyzes chitin (poly- beta-(1,4)-N-acetyl-D-glucosaminide) in living organisms consists of chitinase and (or) NAGase [ ]. The chitinase degrades polysaccharide to chitobiose, NAGase to N-acetyl-D-glucosamine. These compounds of polysaccharide fermentolysis are useful in biotechnology for synthesis of various biologically active substances. The high chitooligosaccharides are essentially interesting as substrates for lysozyme and syntons for preparation of glycolipids with immunostimulating activity.

The perspective bacterial strains (32) were found by the screening of more 200 chitinolytic strains from a Collection of Marine Microorganism (Pacific Institute of Bio-Organic Chemistry, FEB RAS, Vladivostok). Six of them had only chitinase activity. An enzymatic preparation was obtained from KMM B-07 culture by 40-70% (NH4)2SO4 precipitation. The chitobiose (37% from chitin), chitotetraose (8%) and chitohexaose (1.5%) were prepared by polysaccharide fermentolysis using this enzymatic preparation in a preparative scale.

Thus, it has been shown that the Ocean is a rich source of carbohydrate-binding and polysaccharide-hydrolyzing molecules as described above. The lectins isolated will be investigated for there diagnostic significance in use for oncological diseases.

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PCR-Fingerprinting of Mitochondrial Genome of Chum Salmon, *Oncorhynchus Keta*

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Among existing approaches, the analysis of mitochondrial DNA (mtDNA) polymorphism seems to be the most feasible for the genetic marking of populations and separate stocks of Pacific salmon. However, the restriction endonuclease analysis of whole mtDNA from chum salmon (*Oncorhynchus keta Walb.*) and coho salmon (*O. kisutch Malb.*) as well as of its fragments, amplified by polymerase chain reaction (PCR) demonstrates the low level of intraspecific variability in these species of salmon (Ginatulina et al., 1988; Cronin et al., 1993). The use of the expensive direct sequencing for the mass screening and identification of populations, stocks and individuals is cumbersome.

The DNA fingerprinting technique (Wright, 1993) seems to be more useful but not less informative, including the recent approaches for the analysis of mtDNA polymorphisms as based on the PCH with a single primer (SP) PCR (Derenko and Malyarchuk, 1994), and low-stringency (LS) SP-PCR (Pena et al., 1994). The LSSP-PCR of the human mtDNA results in the set of PCR-products, whose quantity and distribution pattern depends on the type, quantity and character of mutational events in the studied DNA segment (Pena et al., 1994).

In this paper we present the results of LSSP-PCR fingerprinting of mtDNA genome of chum salmon which enable genetic identification at an individual level. This level partly includes the family due to the matrilinear inheritance of mtDNA (Avise and Lanchman, 1983) and maternally akin individuals possess the identical mitochondrial genomes.

MATERIALS AND METHODS

Standard methods were used to isolate the mtDNA from salmon muscle. The fragments from the control region of mtDNA (about 1,300 bp long) are amplified with the primers L15926 and H651 using conditions described by Kocher et al. (1989). The PCR products are isolated from the gel of LNP agarose (BioRad) and reamplified, using some modifications in the process, with the L15926 primer under LSSP-PCR conditions as described by Pena et al. (1994). The reaction mixture contains Taq-buffer (according to Hertzberg et al., 1989), dNTPs, 15 ng of DNA template, 48 pN of primer and 2.5U of Taq DNA polymerase. DNA is amplified under 35 two-phase cycles (1 min at 93° and 1 min at 30°). LSSP-PCR products are fractionated in 5 % polyacrylamide gel and stained by silver (Brandt et al., 1992).

The fragments of 5-ended cytochrome b gene region 375 bp long are amplified with the B1 and B2 primers (Kocher et al., 1989). Restriction analysis of cytochrome b gene of chum salmon is performed using restriction endonucleases AluI, HaeIII, HinfI, MspI, and RsaI from MBI Fermentas, Lithuania. LSSP-PCR fingerprinting of products of the first PCR round is performed using the B1 primer. The PCR and analysis conditions are identical to those described above for the mtDNA control region.

The mathematical analysis of data include the construction of binary matrix where the columns correspond to the individuals and lines to the found segments with 1 and 0 elements according to the presence or absence of segmentation, respectively. Distinction coefficients (D) are calculated by dividing the number of segments which differ in the compared individuals by the sum of all segments found.

RESULTS AND DISCUSSION

The feasibility of a single primer PCR (LSSP-PCR technique) for the analysis of intraspecific variability of mtDNA control region was recently demonstrated for humans (Pena et al., 1994) and fur seal (author's unpublished data). This technique results in a set of fragments of mtDNA which is specific for species and individuals. The employment of the method described above for the analysis of mtDNA control region allows the identification of several samples of chum salmon and coho salmon. These results were unexpected since the non-coding regions of mtDNA in vertebrates possess a marked structural closeness, being significantly variable (Cantatore and Saccone, 1987).

The information about the variability of coding regions of a genome whose evolution more corresponds to a neutrally selective one is of consequence in the case of evolutionary and population genetic studies. In this case the character of accumulation of genome changes during molecular evolution looks to reflect the sequence of evolutionary changes in individuals, populations, species etc. The cytochrome b (cyt b) gene of mtDNA is among such regions whose polymorphisms are used in the phylogenetic studies in animals (Irwin et al., 1991). This protein (cyt b) has a rather conservative aminoacid sequence but the nucleotide sequence of the responsible gene possesses both intraspecific and higher range variations. The RFLP analysis reveals the mitochondrial genomes of such salmons as chum salmon and coho salmon have a somewhat low polymorphism thus making a genetic analysis difficult (Ginatulina et al., 1988; Cronin et al., 1993). Thus, we attempt to estimate the variability of evolutionary conservative cytb gene of chum salmon by means of PCR-fingerprinting.

We formerly demonstrate the low variability of cyt b gene of chum salmon by RFLP (Radchenko and Malyarchuk, 1995). One half of the sampled fish are characterized by 5A mitotype and the remainder by 5B mitotype. In this paper we use ILSSP-PCR fingerprinting to assess the variability of cytb gene in four chum salmon fish (sampled in Yana river, Magadan region). The RFLP shows these salmons to have 5A mitotype (samples Nl and N2) and 5B mitotype (N3 and N4). The LSSP-PCR spectra is characterized by a significant band variability. The number of bands sized (1,800 - 80 bp) per sample varies between 20 and 24. The individual differences in the number, position and intensive bands dominate in the LSSP-PCR spectra. The pair comparison of spectra show the variation in the number of common bands is 10 to 17. The samples Nl and N2 which had common 5A mitotype also shows the greatest similarity in LSSP-PCR spectra (D=0.652). However the samples N3 and N4 which also belong to a common mitotype 5B had fingerprints differing (D=0.74) from the pairs N2-N3 and Nl-N3 (D=0.733 and 0.724 respectively).

Our results point out the existence of a rather high level of diversity of cyt b gene in chum salmon which could not be proven by RFLP. LSSP-PCR-fingerprinting which has a higher resolving ability could, evidently, be recommended for studies in the micro-differentiation of populations as well as for separate stocks of salmon. This approach allows estimation of the real levels of genetic variability in populations and it is hoped to enable the elaboration of techniques for marking populations according to LSSP-PCB spectra and estimating the degree of kinship of populations.

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Chaos and Relaxation in Dynamics of the Pink Salmon (*Oncorhynchus Gorbuscha*) Returns for Two Regions

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INTRODUCTION

"... Simple non-linear systems do not necessarily possess the simple dynamics properties".
Robert May. 1991

At present, the ecology of Oncorhynchus gorbuscha has been well studied (Birman, 1985). Pink salmon live in the freshwater for a very short period and migrate great distances in the ocean. Pink salmon tagging indicate that the frequency and the range of deviation from native rivers when returning to spawn is inversely related (Maksimovich, 1991). It seems quite reasonable to propose, that migration fluctuations are produced by the environment and represent system noise in nature. Consequently, there is some probable pink salmons population structure fluctuation. The strays join existing stocks to form new stocks without contradiction of the concept of fluctuation (Glubokovsky and Jivotovsky, 1986) and local (Ivankov, 1993) stocks, compete with strays from other stocks. This would mean that there is a statistical relationship of returns to different spawning sites.

We emphasise that the length of life of pink salmon has been determined with enough precision. The pink salmon hatch and leave for the ocean to return to spawn and die. This results in a chain of generations that do not overlap in time, but with strict reciprocal correspondence. It may be said that nature displays a biological model of known mathematical formulation: discreet mapping of a segment of the real straight line onto itself (Haken, 1985; Shuster, 1988; Ahromeeva et al., 1992; Sharkovsky, 1964; May, 1976; Feigenbaum, 1979).

Correspondence of mapping as a model of a natural prototype in many respects will be determined by the mapping parameters. It is assumed, that the most generalised demographic parameters, that reflect the biological state of a population, are reproduction and carrying capacity (Odum, 1975).

Reproduction integrates such characteristics as mortality, fertility and sex in pink salmon. These characteristics depend on a great number of factors, where the change in the scale of the time period is much less than the length of the reproductive cycle. Examples of the main groups of such factors are: weather, sea and river waters state, currents, anthropogenous activity and predation. Eventually changes in combinations of these factors take place that are specific to a region. As a result, local spatial fluctuations of the habitat appear. As solitary fluctuations are weekly forecast, it is more advisable to regard them as stochastic noise. Noise is present in almost all natural processes (Haken, 1985; Shuster, 1988; Ahromeeva et al., 1992). The influence of fluctuations on discrete mapping is analysed in general (Haken, 1985; Shuster, 1988; Wull et al., 1984) and in a particular case of disturbance of reproduction by white noise (Rabinovitch and Thieberger, 1988).

The scale of carrying capacity change corresponds to the scale of climatic change. Climate as a global factor is displayed in a similar way for different stock reproduction. Birman (1985) and Chigirinsky (1993) advanced and substantiated the thesis of a correlative connection between long-term pink salmon abundance and global climate variations. The role of climatic epoches in marine ecosystems was analysed by V.P. Shuntov (1993).

Taking into account the existing problems of forecasting pink salmon spawning abundance, it is necessary to study, in general, the role and contribution of external factors in affecting returns.

RESEARCH METHODS

The influence of the environment on the abundance of pink salmon spawning returns is studied using a simple model based on '"logistic" mapping of real straight line segments (May, 1976) with perturbed parameters. Reproduction is subjected to accidental non-correlative fluctuations and the carrying capacity changed quasi-periodically following global climatic variations. The model used was:

$$(1) \qquad \mathbf{x_n = X_n / K_n, \delta \le x_n \le \Delta, n = 0,1,\ldots,N,}$$

$$(2) \qquad \mathbf{x_{n+1}} = \begin{cases} \mathbf{(K_n / K_{n+1})(r + \varepsilon_n)x_n(1 - x_n),} & \mathbf{if} \ \ \delta \le \mathbf{x_n} < 1, \\ \delta, & \mathbf{if} \ \ 1 \le \mathbf{x_n} \le \Delta, \end{cases}$$

$$(3) \qquad \mathbf{K_n = K + s_x \sum_{m=1}^{3} \sin(\pi n / T_m + \varphi_m),}$$

where controlling parameters r>0 and K>0 characterise pure reproduction and carrying capacity, respectively. X_n is a return number; x_n belongs to a segment of the real positive number [δ, Δ], where Δ is the greatest of numbers x_n, $\mathbf{n = \overline{0,N}}$; the n index of year return and discreteness of one iteration corresponds to a two years period. The quantity ε_n is white noise with parameters **0** and **σ;** s_x is the standard deviation of abundance during **N** years; $\mathbf{T_m}$ is a period and φ_m a phase of harmonic with index **m** in the trend of carrying capacity changes; π=**3.14...** . Periods, $\mathbf{T_m}$, m=1, 2, 3, are equal to 11, 22, and 45 years, respectively, and phases $\varphi_1=1.2\pi$, $\varphi_2=0.5\pi$ and $\varphi_3=\mathbf{1.6}\pi$ are selected so, that maximums will lie in the neighbourhood of 1989 (Shuntov, 1993). Shifts of the process with respect to adjacent generations is accomplished by changing the index **n** by half of the iteration step. A small parameter δ corresponds to the number of individuals, labile to the most unfavourable changes of the external environment. The equations (1) - (3) set a stochastic process, known as a Marcov chain (Rabinovitch and Thieberger, 1988).

The simulation process consists of setting an initial value of $\mathbf{x_0}$ from actual time series and reconstruction of the model time series according to $\mathbf{x_0}$ by the set parameters **r, K, σ,** δ of model (1) - (3). The model is tested on time series of pink salmon abundance returns of "even" and "odd" yearclasses (Birman, 1985) in two regions for the period 1970 - 1993. Location of regions with respect to each other is shown in the Fig. 1. For each model iteration the correlation coefficient **R** and standard deviation s relative to actual series are calculated. For every combination of parameters (**r, K, σ,** δ) 100 iterations took place, by which a frequency spectrum **f(R)** is produced. The position of the extreme right mode of spectrum serves as a criterion of model quality. That combination of parameters is considered to be the best, by which the quality criterion approaches the maximum value $\mathbf{R_{max}}$. The last iteration is calculated by the gradient descent method (Bundy, 1988).

Using mode values, cross tabulations of **R** and s, the discriminating signs for parameters formally stood out in the form of couples (**R**, s). All outputs received in the process of modelling are classified with the help of discriminate analysis. Properties of return dynamics are studied comparing probability appearance characteristics of corresponding class, number, size, distribution and fluctuation in the time period for each output. The known characteristics of discrete mapping with noise were used.

RESULTS AND DISCUSSION

Results of parameter identification are presented in Table 1. The sensitivity of quality criterion $\mathbf{R_{max}}$ to the estimates of parameters (for exception of rather arbitrary parameter δ) appear to be an order higher for even year generations.

The spectrum **f(R)** for optimum the combination of parameters by region and generations are shown in the Fig. 2. The quantity $\mathbf{R_{max}}$ corresponds to the position of the extreme right line of all spectrums. Otherwise, the most similar output appears to be the most probable. By the figure one can compare the output with the actual dynamics for every region.

We note, that optimum values of **r** and σ form couples equal for the generations of the same eveness independently of the region. In Fig. 3 theoretical distributions of r are shown for even and odd year generations, respectively. The upper 99% percentile in these generations is practically the same and equal to $\mathbf{r_{0.99}} = \mathbf{r_f} = 4.5$. Thus, every couple (**r**, σ) is determined by the equality $\mathbf{r} + 3\sigma = \mathbf{r_f}$.

Of 1,000 outputs modelled by optimum parameters, there are five classes with peculiar values of **R** and s for every region and generation. For example, in Fig. 4 the classes for odd-year generations of Region 1 are shown. Visually comparing the morphometry of typical points of the discriminating output allows the setting of each class of output to possess a specific stable fluctuation distribution which makes a specific generalised image of the output dynamic class pattern. We point out the signs of the chosen classes and probability of their appearance: class with signs (**R**, s)=(0.75; 0.28) has probability 0.13; (**R**, s)=(0.65;0.32)-0.14; (0.55;0.28)-0.30; (0.55;0.32)-0.30; class (0.45;0.38)-0.13. Stability of patterns indicate the natural development and relation of fluctuations. Of the known properties of logistic mapping, it follows that the rate of fluctuation growth is higher for the value of perturbed reproduction ($\mathbf{r} + \varepsilon_n$). Fluctuations of the order $\sigma \mathbf{x_n}$ are distributed accidentally and homogeneously in the time period. Global fluctuations of the order $\mathbf{K+3s_x}$ have a periodicity of the climatic trend and taking into account the rate of growth are distributed in the time period by secluded groups of one to two "splashes".

We discuss output values for **r** and σ. The high individual fertility of pink salmon is considered to be 2,000 eggs (Birman, 1985). If it is assumed that the sex ratio is close to 1:1 and for every thousands eggs, 5 spawners return, then $\mathbf{r_f} = 2{,}000 \times 0.5 \times 0.005 = 5$. This is not a bad correspondence allowing interpretation of $\mathbf{r_f}$ as a species reproductive maximum and equality $\mathbf{r} + 3\sigma = \mathbf{r_f}$ finds the meaning. On the other hand pink salmon population density regulation of reproduction is connected with the heterogeneous conditions for maturing and surviving and interspecies competition for the best habitat conditions (Birman, 1985). Thus the reproduction **r** of generations of low abundance will be greater, and the variability of reproduction σ smaller and their relationship is determined by the equality for $\mathbf{r_f}$, cited above. Will the obtained correspondence values of **r** and σ to theoretical distributions of reproductions for generations with different level of abundance (Fig. 3) be greatly strengthened, if it is possible to find an explanation of the fact that values of **r** appear to be equal for generations of the same eveness, independent of the region? Such explanation is found in the properties of logistic mapping (Haken, 1985; Shuster, 1988; Ahromeeva et al., 1992; Sharkovsky, 1964; May, 1976; Feigenbaum, 1979; Wull et al., 1984; Rabinovitch and Thieberger, 1988). A parameter **r** change leads to the consequent replacement of the dynamic types of quantity x_n. At $r = 2.5$, the value of x_n approaches a non-zero equilibrium, at $r = 3.25$ periodic oscillations appear in the dynamics, at $r = 3.25$ the number of harmonics begins to redouble to the chaos which appears at $r = 4.0$. The theoretical basis of the universality of bifurcation of values **r** is given by M. Feigenbaum (1979) (Feigenbaum, 1979), and the considered scenario of transition from equilibrium to chaos bears his name. Rabinovitch and Thieberger (1988) indicate that the influence of white noise on reproduction **r** in logistic mapping supports the scenario of Feigenbaum. Evidently any change of **K** is a simple transformation of the scale in the mapping, and also it cannot change the Feigenbaum scenario.

If the model represents nature, then when the density of spawning change is due to density regulation, there must be a transition from one type of dynamics to another according to Feigenbaum's scenario. Formally, we call this phenomenon the capability of pink salmon to adapt. Close location of r to bifurcation values speaks in favour of the existence of factors connected with abundance that at low level change chaotically and at high level relax after external influence on the equilibrium state. So, pink salmon generations with stable high abundance tend to depress fluctuations from outside, whereas generations with stable low abundance show the capability to increase fluctuations within. Such behaviour follows the reproductive strategy, the aim of which is to keep up the stock to an abundance level as high as possible for a specific region. In suitable external conditions, the strategy is able to lead to "dominant" generation replacement (Birman, 1985).

The presence of chaos and non-linearity in pink salmon returns indicated the problem of forecasting which can not be solved within the frameworks of traditional approaches. Discussing these problems is beyond the scope of this paper. May (1991) has worked out the non-linear dynamics of chaos forecasting and suggests the algorithm for a solution (May, 1991).

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TABLES AND FIGURES

Table 1. Optimum values of parameters of model (1) - (3) and criterion of quality $\mathbf{R}_{max}$ by level of significance $\alpha < 0.01$, corresponding to them.

Parameters values	Even year generations		Odd year generations	
	Region 1	Region 2	Region 3	Region 4
r	4.15 ± 0.01*	4.15 ± 0.01	2.70 ± 0.15	2.70 ± 0.15
σ	0.10 ± 0.05	0.10 ± 0.05	0.60 ± 0.30	0.60 ± 0.30
K	30.00 ± 0.10	10.70 ± 0.01	30.00 ± 2.50	20.00 ± 0.50
δ	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01
$\mathbf{R}_{max}$	0.90	0.85	0.80	0.85
$\mathbf{f(R}_{max}\mathbf{)}$, %	42	45	50	45

* range in which right mode in spectrum **f (R)** is maximum.

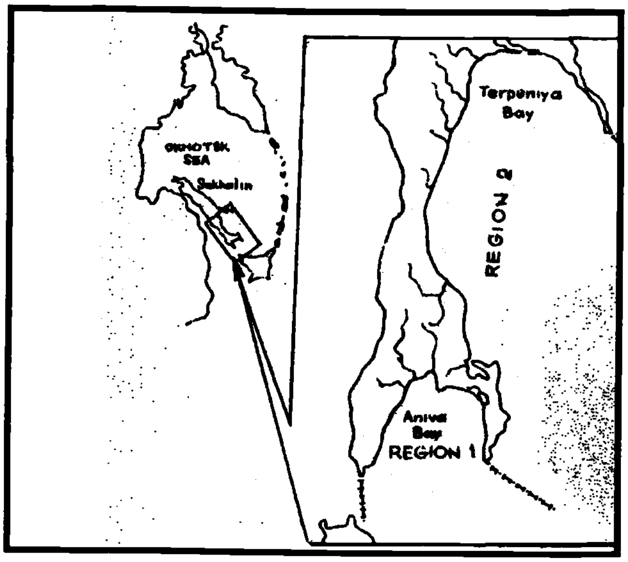

Fig. 1. The map-scheme of regions of pink salmon reproduction.

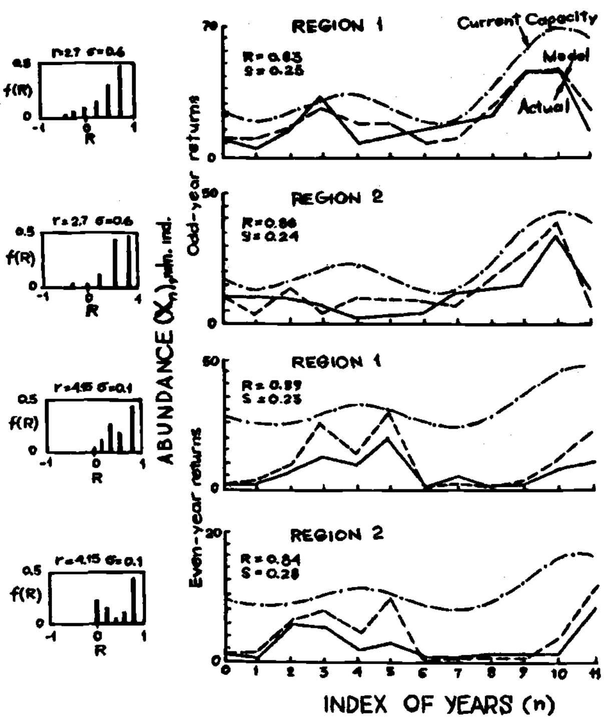

Fig. 2. Spectrums **f(R)** for optimal set of parameters of model (1)-(3) and model realizations with correlations $\mathbf{R}_{max}$ against the background of actual return dynamics by generations and regions for the period of 1970-1993 years.

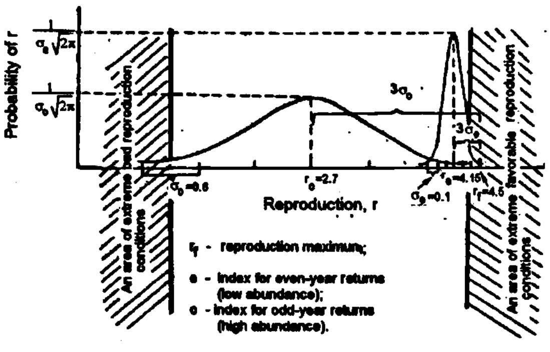

Fig. 3. Theoretical functions of parameter r distribution for generations with high and low abundance.

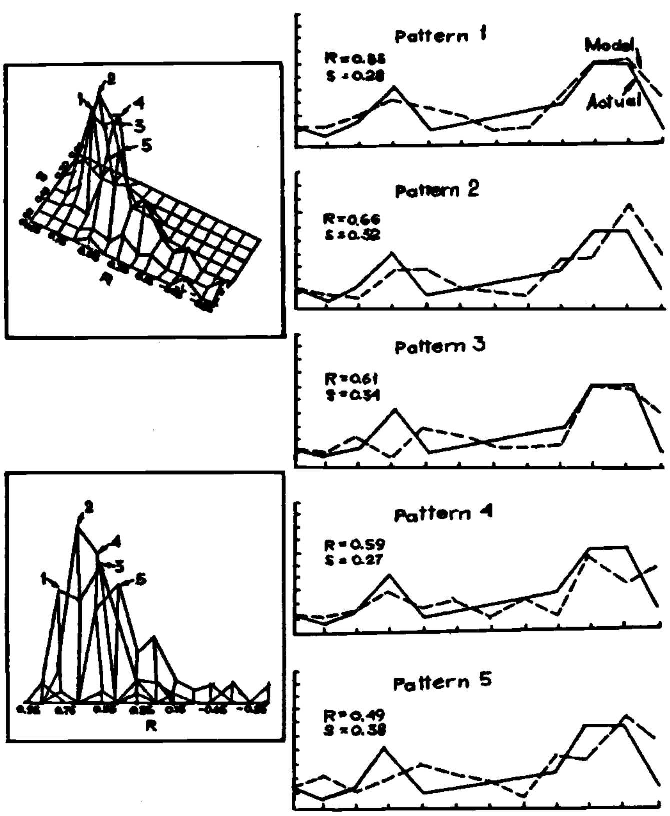

Fig. 4. Cross-tabulation of **R** and s with chosen model classes (**R**, s) and corresponding patterns for odd-year generation of the Region 1.

Fish-Culture of Pacific Salmons Increases the Number of Heredity Defects

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It is known that fish-culture decreases the salmon qualitative indices (Bardach et al., 1976). Natural fertilization is very important to maintain genetic diversity, however, fish-breeders ignore the importance of natural selection during artificial fertilization. Mutation pressure has permanent effects on populations, therefore, various heredity defects can cause large defects (death, abnormal larvae) and/or small defects which will be described in this paper. Gamete selection can be used to eliminate defects. Sperm selection is more promising than egg selection because males produce numerous quantities (hundreds of billions) of sperms (Smirnov, 1975). The aim of this work is to investigate the influence of the artificial fertilization of eggs on changes in Pacific salmon survival, ratio of males to females, fluctuating asymmetric growth rates and so on.

MATERIALS AND METHODS

Hatchery fertilization techniques of chum *Oncorhynchus keta*, pink *O. gorbuscha* and chinook *O. tshawytcha* salmon were investigated in 1985-1992 in the Sakhalin Primorskiy region and Kamchatka. Egg fertilization by the dry method is used for the control groups as well as some embryos and small fry are also observed as a second control group. In the experiments on sperm selection, treatments are performed that prohibit fertilization of eggs by defective sperms.

RESULTS

The data indicated that different individuals can contain different levels of defective genes. Generally, week individuals of chum and pink salmon did not matured until the end of spawning season these individuals are thought to have a greater number of defective genes.

The dry method of fertilization provides an equal opportunity for all sperms to fertilize an egg. The quality of fertilized eggs from late maturing males produce a poor quality of progeny. A significant amount of dead embryos and dead fry along with an increase in the of ratio of males were observed. Sperm selection (SS) results in a decrease of these indices (Tables 1 and 2). Apparently, salmons which have more gene defects grow slower and therefore they become matured later. If the sperms of late spawning males are selected against by sperm selection the quality indices of progeny is improved (Tables 1 and 2).

The use of SS from early maturing males reduces the number of dead embryos (Tables 4 and 5) and increases the of sizes and weight of fry of chum (Table 3).

Fluctuating body asymmetry (FA) of chum is found to indicate the presence of significant small genetic errors during development. The number of body spots along the sides of fry is not an important feature, however, when the level of spots FA is high, the gill raker FA is significantly reduced and the pores FA on pre operculum is the least high (Table 5). The indices of FA of progeny without SS is even lower than those of wild chum. The decrease of FA took place with the decrease progeny mortality and numbers of males. All these indices appear to reflect a process of reduction in the number of defective genes in progeny without SS.

The indices of FA indicates an increase in small gene errors during development. The FA indices are more sensitive than the other methods that we used. For instance, mortality because sperm selection also decreases the FA in progeny of early spawning salmons (Table 5). SS decreases the number of males too. According to Geodakyan (1987) the high number of males used is an index of the extent of population degeneration. It corresponds to the summarized data of FA change from our work. The FA decreases when male numbers decreases.

The method of sperm selection is also important to reproductive success for chinook *O. tshawytcha* of Kamchatka. The experiments are carried out using wild individuals from late spawning fish. The life history of chinook differs from other Pacific salmons as this salmon spawns in rapidly moving rivers waters and the sperm is more active than those of chum and pink salmon. Using the dry method of fertilization of chinook eggs (control) significantly decreases the of number of females (33.4%) which leads to an equal number of females and males. Thus, sperm selection leads to a decrease in the level of fluctuation asymmetry.

The connection of FA with viability and heredity of Salmon gairdneri is described in radiation ginogenesis experiments (Leary et al., 1985).

The SS method prevents the exposure of chum fry to unfavorable factors found in the environment such as oxygen deficiency. The SS influence on FA growth rate increases resistance to unfavorable factors from the environment which increases the number of females. We suppose that all these changes of features are based on small heredity defects in genes.

We suppose it to be important to discuss the differences of salmons of one population at the end and in beginning of spawning. N. Kulikova (1983) studied early and late spawning *Salmo gairdneri*. The survival of progeny from the late maturing females decrease to 63% fecundity (1,890 eggs) and the number of cells with chromosomes aberrations increases up to 23%. The progeny of females of early maturity is distinguished by high level of survival (87%) and fecundity (3,050 eggs) and also a decrease in the number of cells with chromosome aberrations (9%). Low levels chromosome aberrations is an important positive index. It shows stability of the heredity process. Thus, the early maturing Atlantic salmons produce more viable progeny.

CONCLUSIONS

1. Fertilization by late spawning male salmon using the dry method of fertilization of eggs leads to a significant high level of heredity defects in the progeny.
2. The method of sperm selection decreases the amount of large and small defects in the salmon produced and in the number males produced.

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TABLES AND FIGURES

Table 1. Mortality of progeny and number of females (late spawning pink salmon *O. gorbuscha*).

NN	variants	fertilized eggs,	mortality, %	% of females,
1	Control	843	43.4±2.2	44.6±1.5
2	SS	860	11.2±2.5	60.0±1.6
3	Control of factory	405	31.7±1.4	-

Table 2. Mortality of progeny (late spawning chum *O. keta*).

NN	variants	fertilized eggs,	mortality,
7	Control	3,120	30.1±1.1
8	SS	2,490	12.9±0.7

Table 3. Weight and size of fries of chum *O. keta*.

NN	variants	weight, mg size, cm	5-th month fries	6-th month fries
21	Control	mg	366.4±4.90	453.4±8.40
		cm	3.5±0.01	3.8±0.01
20	SS	mg	398.8±4.90	475.9±8.60
		cm	3.6±0.01	3.8±0.02
17	Control	mg	324.1±10.50	403.2±13.50
		cm	3.3±0.02	3.6±0.03
19	SS	mg	383.0±6.20	646.1±20.90
		cm	3.5±0.02	4.0±0.04

Table 4. Mortality of progeny and number of females (early spawning pink salmon *O. gorbuscha*).

NN	variants	fertilized eggs, number	mortality, %	number of females, %
5	Control	431	9.7±1.2	45.5±1.0
6	SS	752	5.8±1.0	65.5±1.1

Table 5. Changes of the indices chum after sperm selection (early spawning chum *O. keta*).

NN	Variant	Fertilized eggs, number fry,	Dead embryos, larvae, %	Fluctuating Spots, %	asymmetry Pores, %	Gill rakers, %	Number of females, %
17	Control	1392	6.7±1.2	143.0±0.3	21.3±0.3	36.9±0.2	43.7±0.3
19	SS	2092	4.1±0.8	84.0±2.4	9.9±0.1	18.8±0.1	58.3±0.2
21	Control	817	4.2±0.8	132.0±6.2	11.8±0.3	18.1±0.4	54.5±0.4
20	SS	920	2.5±0.2	103.2±1.2	10.3±0.1	13.0±0.1	55.6±0.2
	Wild	-	-	122.5±3.2	21.3±0.1	35.7±0.2	52.2±0.2

Abundance of Young Halibut along the West Kamchatka Shelf in 1982-1992

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The Sea of Okhotsk is a marginal habitat for Pacific halibut, thus, it is less abundant than in the Bering sea and Pacific waters where a specialized fishery occurs. In the past, Sea of Okhotsk Pacific halibut have not been targeted for special investigation. There is some biological data but information on abundance has not been available. The Sea of Okhotsk halibut occurs all along the shelf on the upper continental slope but relatively stable accumulations were only observed on the West Kamchatka shelf. Data collected by expeditions for fishes (other than halibut) and invertebrates were analyzed keeping in mind that the sampling scheme may not have been appropriate for use in determining halibut abundance.

Abundance calculations were made using the method of squares (Aksyutina, 1968), adjusted for a trawl efficiency coefficient of 0.4.

30-85 cm individuals at age 4+ - 9+ were 80-95% of the catch by longline and trawl (Table 1). Thus, the West Kamchatka shelf appears to be a region for young Pacific halibut feeding migration in the Sea of Okhotsk. In 1982 the estimated abundance was 1.7 mln. and by 1989 it increased to 13.1 mln., while distribution increased three times from 3,149 to 9,163 sq.mile (Table 2, Fig. 1). At the same time, the abundance of halibut in the Pacific waters of Kamchatka increased (Bakkala, 1993; Kodolov et al., 1994). The increases in both areas may have been due to a shift in abundance and distribution throughout the region as a result of better conditions for halibut. From the early 90s western Kamchatka halibut abundance decreased to 6.5 mln by 1992 and the distribution also decreased in the area.

It is difficult to determine what were the causes of the fluctuations from the data available. However, a comparison 1989 and 1993 length frequencies from trawl catches indicated a decrease in the 50-70 cm length category from 63.6 to 39.9% of the total. On this evidence, it can be proposed that in the early 90s there was a decrease in survival and a shift in the distribution from the mid-80s. Without direct evidence, however, it is difficult to know if there has actually been a shift in survival and distribution of Okhotsk halibut. Large individuals were mainly found near the Kuril Islands, along the West Kamchatka slope, in the north area of Sea of Okhotsk and eastern Sakhalin areas. Gill nets and trawls used to catch turbot, crab traps and the cod long-lines were likely responsible for removing halibut but the available data are poor. Thus, it is difficult to determine shifts in the migration of young halibut off West Kamchatka.

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Table 1. Size composition of Pacific Halibut of the Sea of Okhotsk in 1962-1968 (by Novikov, 1974), 1989 and 1991.

Year	Length, cm																			
	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120-150	N	M
1962-1968 trawl	1.3	3.8	14.0	21.9	15.3	10.2	6.4	1.3	5.2	10.2	2.6	-	2.6	2.6	1.3	-	-	1.3		49	59.6
1989 trawl summer		1.3	8.9	15.2	19.0	20.2	12.7	5.1	6.3	3.8	1.3	2.5	1.3	-	-	1.3	1.3			79	54.2
1991 long line summer		0.6	2.0	11.7	23.9	24.2	16.2	12.0	6.0	1.4	0.6	0.6	0.3	0.3	0.3					351	58.6
1993 trawl spring	1.0	8.2	26.7	20.1	10.3	12.3	8.9	5.1	3.4	1.9	1.1	0.4	0.1	0.2	0.1	-	0.1	-	0.2	6272	51.7

Table 2. Change of abundance and distribution of young Pacific halibut along the West Kamchatka shelf in 1982-1992.

Year	1982 July-Sept.	1983 April-May	1986 July	1988 May-July	1989 May-June	1990 January-March	1992 June-August
Abundance mln/sp.	1.7	0.5	7.4	4.0	13.1	8.7	6.5
Investigated area, sq.mile	14,000	10,800	14,200	14,400	15,500	11,900	12,900
including catches	3149	2129	8476	5644	9163	7109	6541
density, thous. sp/sq.mile	0.12	0.05	0.52	0.28	0.85	0.73	0.5

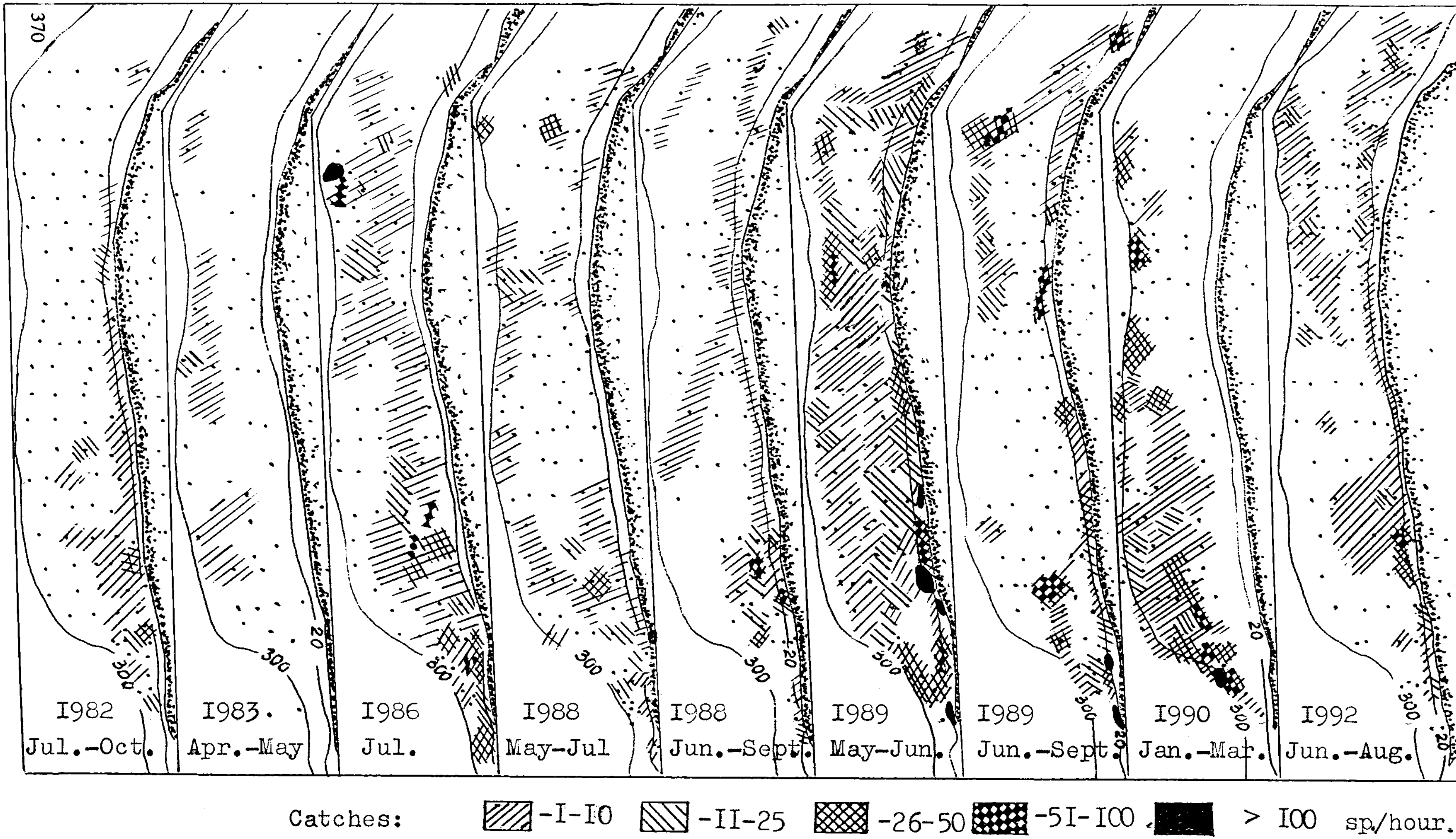

Fig. 1. Distribution of young Pacific halibut on the shelf of western Kamchatka in 1982-1992, specimens per hour trawling.

Living Conditions of Golden King Crab *Lithodes aequispina* in the Okhotsk Sea and near the Kuril Islands

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In 1968 fishery information on golden king crab became available from Japanese vessels under a special pot fishery contract in the central part of the Okhotsk Sea (55°- 56°N, 147°-150°E). The first TINRO research on this crab on the continent slope of West Kamchatka was in August-September 1969 when a trawl survey was carried out at depths of 250-850 m to collect information on the biology, distribution and commercial importance of golden king crab (Rodin, 1970). Further investigations in the Northeast Okhotsk Sea were carried out in 1972, 1973, 1975-1977 but they did not focus on the golden king crab. In the spring-summer of 1989, an extensive trawl survey of the Okhotsk Sea to a depth of 2,000 m was carried out, except for the zone adjacent to the Kuril Islands. For the first time samples were collected of golden king crab over the continental slope throughout the Okhotsk Sea (Nizyaev, 1992). In 1991 a survey for golden king crab stocks in the Kuril Islands was undertaken using commercial crab vessels equipped with deep-water pots. Thus, directed research on golden king crab in Okhotsk Sea only started in the last 5-7 years but was limited to depths less than 200-300 m. There are always a number of difficulties with developing an investigation on the biology of a species where samples were collected from 200-600 m. and until recently crab pots were the main gear used by commercial fisheries and research. The pots are a highly size selective and some biological measurements are difficult to obtain unless the catching methods are modified to overcome the problem.

MATERIALS AND METHODS

Data were collected during trawl and pot surveys in the Okhotsk Sea from 1989-1994. Samples were collected using a 48-m trawl towed at 3 knots for one hour and by modified standard American trapezium pots of 175x175 cm in base, 90x90 cm in upper edge and 80 cm in height. Analysis of the data was according to "Guidance of studies of the Far-East Seas commercial Decapoda" (1979).

RESULTS AND DISCUSSIONS

From the 1989 trawl survey golden king crab was caught near West Kamchatka and to the west along the north coast of the Sea of Okhotsk to 142°30' E (Fig. 1). A high percent of crab was also caught by commercial nets for halibut near Northeast Sakhalin. Trawl catches of commercial crab averaged 10-20 per trawl. Crab caught from a stock discovered by trawling on Kashevarov bank averaged from 21 to 35 per pot. As a whole, the distribution of golden king crab in the open part of the Okhotsk Sea was similar from West Kamchatka to East Sakhalin except along 152°E where females and small males were absent and catches of commercial males did not exceed 1-2 per trawl.

In the area of Kuril Islands golden king crab was distributed all along all the ridge and near a group of islands. The greatest concentrations were found near the islands of Shiashkotan, Ushishir, Simushir and Iturup. Pot catches of commercial crab were 25-35 per pot.

The spatial structure of golden king crab was generally associated with local reproductive groups. Distribution of non commercial males and mature females was more local than that of commercial males. Non commercial males (of small size) were usually found near breeding areas in association with juvenile females the group that tended to migrate the least of all size groups. Mature females concentrated in high densities together with mature males. Some of the mature males located with the females took part in spawning while another assemblage of males were located in the outlying area of the female assemblage representing a reproductive potential.

Differences between golden king crab living conditions in the open part of the Okhotsk Sea and near the Kuril Islands were determined, mainly, from non-biological factors. With rare exception, the open area of the Okhotsk Sea is a plateau without sharp changes in depth allowing migration over long distances between different groups resulting in a mixing of genetic material. The Kuril Islands area on the other hand has sharp changes in depth on the bottom resulting in groups being isolated by restricting movement and the exchange of genetic material.

The genetic link between groups can also be kept up through larvae transport. Larvae of such crab species such as red king crab (Paralithodes camtschatica) and blue king crab (P. platypus) drift in the surface layer of the sea where they are dependant of surface currents. Golden king crab larvae behaviour is thought to be different by many authors. Somerton (1981) compared the developed yolk sac of Lithodes couesi (a close relative of golden king crab) with the red king crab larvae and expressed doubt of the necessity of Lithodes couesi larvae to migrate to the photic zone. Somerton and Otto (1986) advanced the hypothesis that the large size of golden king crab larvae in contrast to red king crab larvae allow them to go without food for longer periods and feed on large organisms. In the early stages of larvae development golden king crab may be lecythotrophic feeders resulting in a demersal type of existence, while shallow living shelf species larvae are planctotrophic. This idea is confirmed from the behaviour of the larvae of the deep-water crabs of genus Lithodidae which have not been found in the plancton layer, while larvae of red and blue king crab have been found in large numbers in the sea surface layer (Hoffman, 1968; Kurata, 1964; Marukawa, 1933; Takeuchi, 1962). In the Kuril Islands there is almost complete lack of crabs that have planktotrophic larvae. This is thought to be related to the powerful currents which could carry the larvae away from areas where they could settle to the bottom. Golden king crab is common to these areas which suggests that larvae development is independent surface currents. Thus, in the Kuril Islands the golden king crab is isolated by the topography and through larval drift limiting genetic exchange compared to the stocks living in the open part of the Okhotsk Sea.

High concentrations of crab on small isolated areas near the Kuril Islands may produce high catches per effort but lead to a false impression about the size of the stocks. Intensive harvesting would result in a sudden reduction of catch rate and it would take years to recover the lost biomass. On the plateau near the Shiashkotan and Lovushka Islands the average catches per effort decreased from 28 to 9 per pot over three years and the mode of males decreased from 210 for 175 mm carapace width. Lower harvest rates by adjusting commercial pressure on isolated stocks that are not connected need to be implemented to prevent over fishing and to allow recovery of stocks that have already been over exploited. Stocks in the open Okhotsk Sea remain more stable unless fishing pressure becomes to great for the rate of replacement of the stock biomass.

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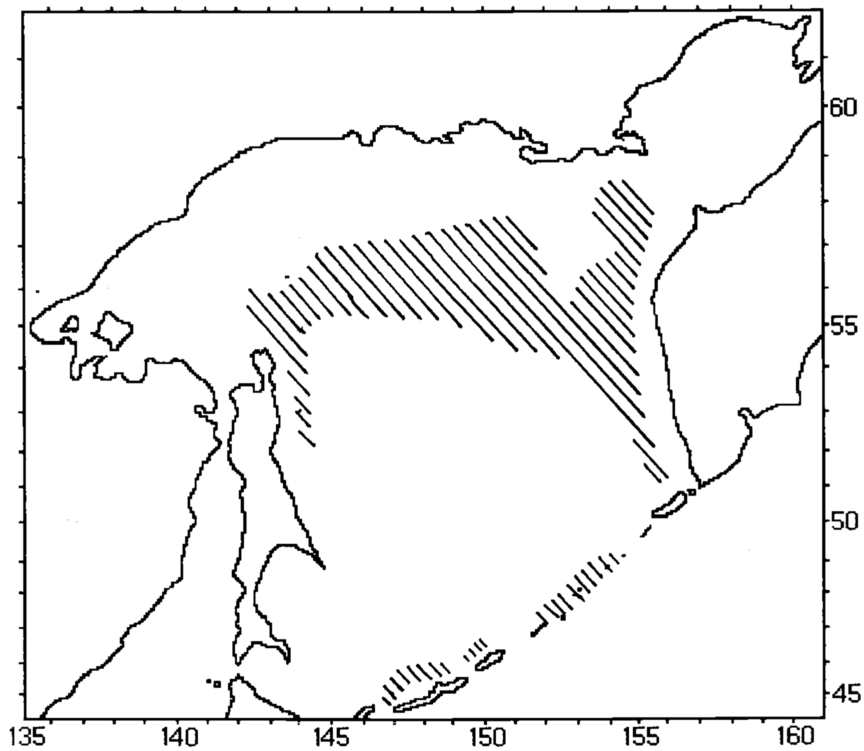

Fig. 1. Distribution of golden king crab in the Okhotsk Sea.

Settlements of Japanese Scallop in Reid Pallada Bay (Sea of Japan)

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INTRODUCTION

Reid Pallada Bay (northwestern part of Possjet Bay of the Sea of Japan) is the major scallop cultivation area in eastern Russia. The cultivation of the scallop *Mizuhopecten yessoensis* (Jay) involves collection of spat, spat rearing in nursery-cages for one year and the transfer of juveniles to the bottom culture sites for 2-3 years until they are an acceptable size (100 mm)(Belogrudov, 1986). Usually cultured juveniles are seeded in low density natural scallop populations. Over the last 20 years, cultured scallop in the bight of Reid Pallada Bay have replaced native populations. The purpose of this study was to delineate the stocks, the percentage of cultured and natural individuals, age and size composition and to compare the growth rates of seeded and natural scallops at six sites in Reid Pallada Bay.

MATERIALS AND METHODS

A Scuba survey of Reid Pallada Bay was undertaken along transects perpendicular to the coast line to 15 m depth. The number of natural and introduced scallops were counted in a 1 m wide band or in a 1 m frame, depending on the settlement density. To determine the growth, size and age structure of population 106-500 individuals were collected.

The shell height, wet weight, tissue weight and adductor muscle weight were determined. The age and linear growth of each scallop were determined from the microsculpture of the surface of the upper valve (Silina, 1978). The same method was used to reconstruct the individual linear growth of each scallop and to estimate the mean growth of scallops from each site. Scallops seeded into natural settlements were distinguished from the natural individuals by the presence of a noticeable mark in the elementary growth ring of the microsculpture in the upper valve surface which was caused during transport and seeding on the bottom. The year of transfer to the grounds of each scallops was determined from their age. The growth of cultured scallops in different years was compared with resident individuals.

RESULTS

All sites had an irregular strip like distribution of scallops with density 0.1-7.0 (in the main 0.5-5.0) per m. This was considerably higher than in natural settlements due to seeding to increase profits. The scallop shell height was 30-165 mm (1-12 years old) (Table 1) but the size and age distributions of the seeded scallops were differed from natural scallop. The maximum age in each population was found to occur in the cultured scallops but cultured scallops were smaller at age than resident (Table 2). The highest growth rates were in the northwest part of Reid Pallada Bay and in

Temp Bay, where they reached the commercial size at 3 years old. On the other studied sites scallops reached the harvest size at 4. The total number and weight of scallops on all six sites (127 hectares) was about 1,200,000 individuals weighing 240 tons. During August 1990 the estimated harvestable biomass was about 98.1 tons total weight and 17.8 t muscle weight.

DISCUSSION

An irregular strip like distribution was characteristic for cultured scallops in the study sites due to the method of seeding. Cultured scallops had a smaller shell height than the resident individuals of the same age (about one year) at the time of transfer, which was due to slower growth of juveniles in the nursery cages during the first year. After transfer the scallops need time for adaptation to new conditions and for regeneration of the growing edge of the shell which was usually broken during transportation to the grounds. The resulting difference in shell height usually remains throughout life (Pozdnyakova and Silina, 1993; Pozdnyakova et al. 1992; Silina et al. 1994). The growth rate of cultured scallop in the studied sites of Possjet Bay was slower than in most other areas of Peter the Great Bay (Silina and Pozdnyakova, 1986; Silina, 1990; Silina et al. 1994). The high water temperature (16 to 26 C) in July-September is thought to inhibit growth (Silina, 1983; Silina and Pozdnyakova, 1986) which means the scallops were not harvest size until about 4 years old.

The number of the resident scallops before introducing cultivated juveniles was small at five of the sites studied. The encouragement of natural scallop settlement on the bottom of Possjet Bay enhances productivity of commercial beds and there is good production of spat for artificial collection and rearing in nurse-cages for later seeding. This reduces the need for cultivation and transportation to the grounds which reduces the expenses as well as the adaptation after seeding.

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TABLES

Table 1. Composition of Japanese scallop Mizuhopecten yessoensis settlements in Reid Pallada Bay (Sea of Japan).

Sites	Age, years	Shell height, mm	Stock, thousand of individuals	Percentage of cultured scallops
Astafjev Cape	1-9	45-165	1.2	20.6
Between Astafiev Cape and Temp Bight	2-4	84-109	220.0	89.9
Temp Bight	2-6	88-131	1.5	48.8
Klykov Bight	2-8	77-154	500.0	87.5
Mininosok Bight	1-12	61-143	117.3	74.5
Northwestern part of Reid Pallada Bay	1-7	30-162	360.0	42.5

Table 2. Size and weight of Japanese scallop Mizuhopecten yessoensis in Reid Pallada Bay (Sea of Japan).

Sites	Age, years	Shell height, mm		Wet weight, g	
		natural	cultured	natural	cultured
Astafjev Cape	2	81.3±3.0	65.4±4.2	49.8±4.4	33.8±4.6
	3	98.3±3.2	-	99.8±5.6	-
	4	112.8±3.0	-	162.5±5.3	-
Between Astafie Cape and Temp Bight	2	84.2±5.6	-	52.7±12.4	-
	4	109.0±4.9	107.2±1.2	125.0±17.3	113.8±6.1
Temp Bight	2	88.2±3.9	-	74.1±9.5	-
	3	108.8±3.8	103.1±5.2	130.0±26.7	125.2±21.7
	4	116.0±4.1	118.2±3.3	-	195.7±26.7
Klykov Bight	4	109.8±4.8	100.2±1.9	119.3±5.4	103.9±12.0
Mininosok Bight	2	88.6±7.2	74.0±3.4	-	40.7±4.4
	3	103.5±2.7	96.8±1.9	84.1±6.2	-
	4	105.7±3.9	111.8±3.1	112.0+12.5	128.4±12.4
Northwestern part of Reid Pallada Bay	2	90.1±3.4	87.1±3.9	78.4±4.6	79.8±9.5
	3	108.7±2.3	103.3±2.0	-	129.8±5.3
	4	119.3±3.3	-	201.5±21.3	-

Data are shown as mean ± s.e.m.

Features of the Southwest Okhotsk Sea Herring

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A number of independent herring populations with different levels of abundance, in the Far-East Seas, are in the process of changing (Svetovidov, 1952). Herring inhabiting Sakhalin waters differ from others because they have a more complex intraspecies structure (Frolov, 1950; Rumyantsev, 1967; Pushnikova and Rybnikova, 1991). Some authors have studied the population structure and tried to separate populations into groups using a number of ecological features. Frolov (1964) concluded from morphological characters that there are two groups of herring in Sakhalin waters; marine (Sakhalin-Hokkaido) and lake. Rumyantsev (1967) studied herring scale structure and came to conclusion that there are ocean, marine and lagoon groups. Other researchers (Sokolov, 1962; Drujinin, 1963) denied the existence of any groups of herring other than the Sakhalin-Hokkaido. Japanese researchers suggest two groups, oceanic and local herring and to separate local herring into lake and neritic herring (Iizuka and Morita, 1991).

This paper examines data on herring, inhabiting the southwest Okhotsk Sea along the Sakhalin coast and the Tatar Strait. Analysis of morphometric, biological and biochemical parameters suggest the presence of herring populations in the area of Sakhalin-Hokkaido, Terpeniya bay, Aniva bay, Sakhalin bay, Northeast Sakhalin coast bays, De-Kustry bay, Tunaycha lake, Nevskoye lake and Ainskoye lake (Pushnikova et al., 1987; Rybnikova, 1987; Zverkova et al., 1991). The data indicate that Sakhalin-Hokkaido herring differ from others by the greatest number of parameters and the stock occupies the largest area. Lake populations are characterized by the smallest number of parameters and smallest occupied area. The two groups differ from each other by the rate of growth, sex maturity, fecundity, location in waters of a different hydrochemical structure. Fish of other populations had intermediate biological and ecological parameters. Thus, biological and ecological parameters allowed the separation of the population into oceanic, local and lake.

The largest annual catch from the oceanic herring was one million tons, local populations 12 thousand tons and lake 200 tons (Table 1). Catches were reduced to 0.9, 0.08 and 0.001 thousand tons when the stocks decreased.

The maximum age of the different groups of herring are: oceanic 18, local 11 and lake 9. The longest body length is: oceanic 44 cm, local 32 cm and lake 29 cm. Recently, the abundance of the oceanic herring (largest stock) has been greatly depressed and the maturity age of all herring groups has been reduced to 2. Oceanic herring usually mature at 4, local at 3 and lake at 2 when the stocks are not depressed (Table 2).

Lake herring have the lowest rate of growth rate of all the groups(Fig. 1). The body length of 1 year olds was: lake 8 cm, local 10 cm, oceanic a little more than 12 cm. The maximum difference of body length at age 1 was 4 cm between oceanic and lake herring. This difference reaches 7cm at 4-years old and 10 cm at 8. For example, data on Sakhalin-Hokkaido herring (oceanic), on De-Kastry herring (local) and Tunaycha Lake herring (lake) are presented in Fig. 1.

Eighty percent of the lake group herring mature by 13.0 cm and mature local and oceanic groups of herring appear in small numbers by 19 cm when all the lake group was already mature (Fig. 2). Eighty percent of the local group is mature by 20 cm and 80% of the oceanic by 24 cm. The body length increased by 6 cm from the beginning to 100% maturity for lake and local herring but oceanic did not fully mature for 8 cm. The maturity rate of oceanic herring is slow in comparison with other groups. The slow rate of oceanic herring maturity compared to the other groups is, evidentely, an illustration of the deep intrastructure transformations that has happened in the Sakhalin-Hokkaido herring over the 40 year depressed period.

Fecundity data were different between the three herring groups. The average number of eggs of 19-25 cm lake group females was the highest among individuals this size group(Fig. 3). Further, with increasing of body length and fecundity of the same size groups of oceanic herring grows at a great rate, practically along the straight line at an angle about 60° to absciss axis. At the same time, the increase in the rate of lake herring fecundity is lower. When body length reaches 28 cm and more lake herring has the lowest number of eggs per female. The greatest fecundity oceanic herring is more, than 120 thousands eggs (body length - 35 cm), for local a little more than 60 thousands eggs (body length - 31 cm) and for lake herring less than 50 thousands eggs (body length - 29 cm).

The number of eggs per oceanic female is higher at all ages compared to local and lake herring (Fig. 4). Fecundity of local herring at 2 years old (the beginning of maturity for this groups) is lower compared to the lake group (2 years old is the age of greatest maturity). Further fecundity of the same age group of local herring increases and during the period of ontogenesis exceeds the index values of the lake herring.

The winter and spawning conditions of herring greatly differs among the three groups. Oceanic and local groups over winter in the open sea near the slope and slope areas, at 150-300 m depth. Lake herring over winter in lakes where the salinity does not exceed 12‰. Oceanic herring spawning takes place in open littoral areas, at depths of 1.0-10.0 m, mainly, on sea plants and brown algae. Salinity on the spawning grounds changes from 24.8 to 33.7‰. Local herring spawning occurs on open littoral areas, in bays, creeks and lagoons at depths of 0.5-4.0 m on sea grass, brown and red algae. Water salinity on the spawning grounds varies from 9.9 to 33.2‰. Lake herring spawn at sea, in low salinity which vary from 9.0 to 21.4‰ in the immediate neighbourhood of channels mouths joining lakes in the sea at depths of 1.0-2.0 m on sea grass and brown algae.

The oceanic group of herring inhabit the North Japan Sea, south and middle parts of the Okhotsk Sea and Pacific waters adjoining the South Kuril Island and Hokkaido at different stages of ontogenesis (Rumyantsev and Frolov et al., 1958). Local herring did not make extensive migrations as the Sakhalin-Hokkaido group but remain in De-Kastry, Aniva bays, Terpeniya, Sakhalin and bays and lagoons of the northeast coast of Sakhalin (Nabil, Nyivo, Chaivo, Piltun). Lake herring did not make extensive migrations and differ from other groups by feeding in open sea areas and returning to lakes in the winter. Herring populations of lakes Tunaycha, Nevskoye, Ainskoye form the lake groups.

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TABLES AND FIGURES

Table 1. Historical catches of ecological herring groups.

Ecological Groups	Catches, thousand t.	
	max	min
OCEANIC	1000	0.9
LOCAL	12	0.08
LAKE	0.2	0.001

Table 2. Biological parameters of the ecological herring groups.

Ecological Groups	Age limit	Length, cm		Age of sexual maturity	
		max	model	beginning	mass
OCEANIC	18	44	26 - 29	2	4
LOCAL	11	32	23 - 26	2	3
LAKE	9	29	18 - 21	2	2

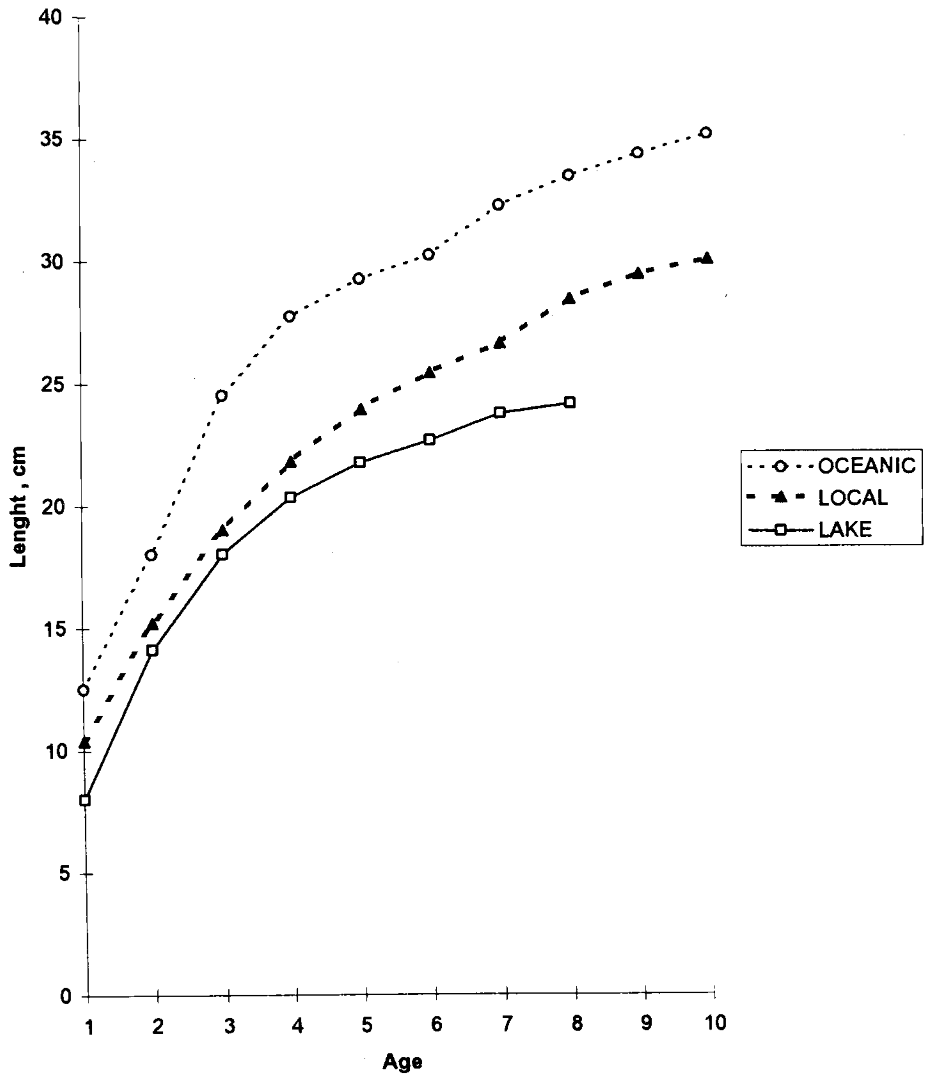

Fig. 1. Herring growth.

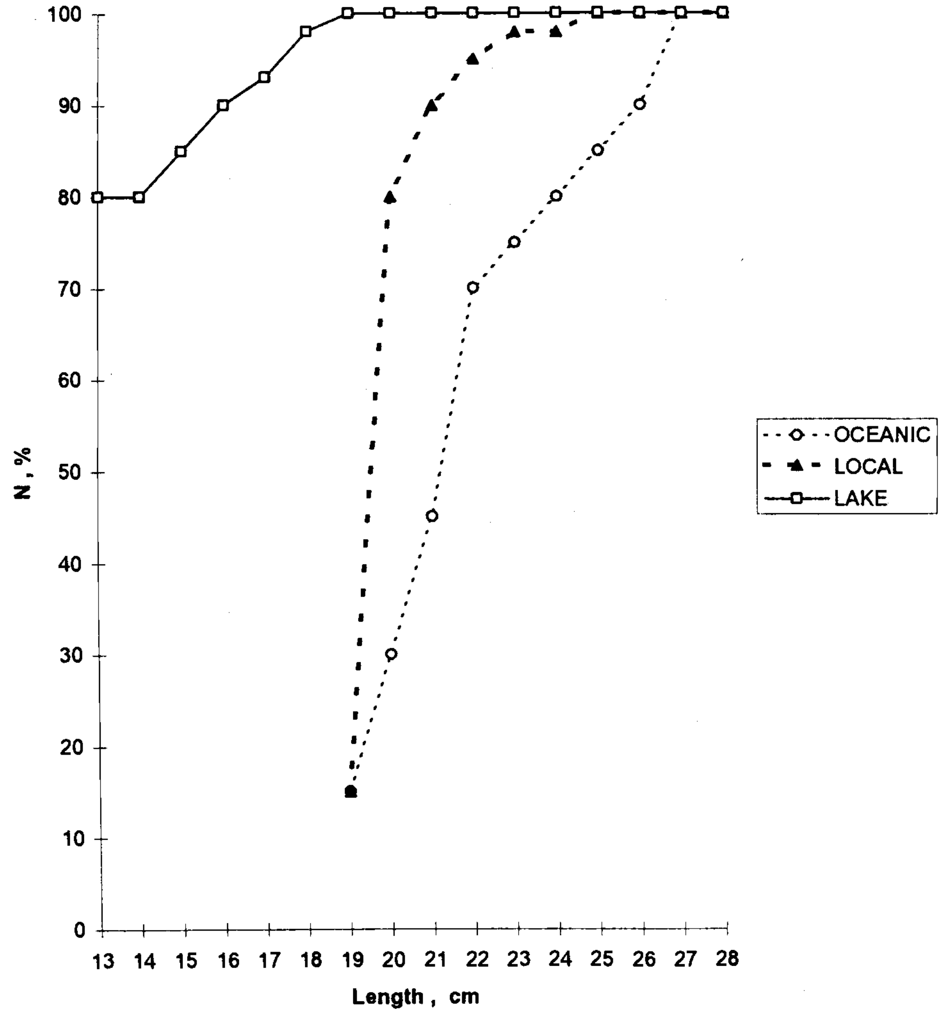

Fig. 2. Maturity rate of the herring.

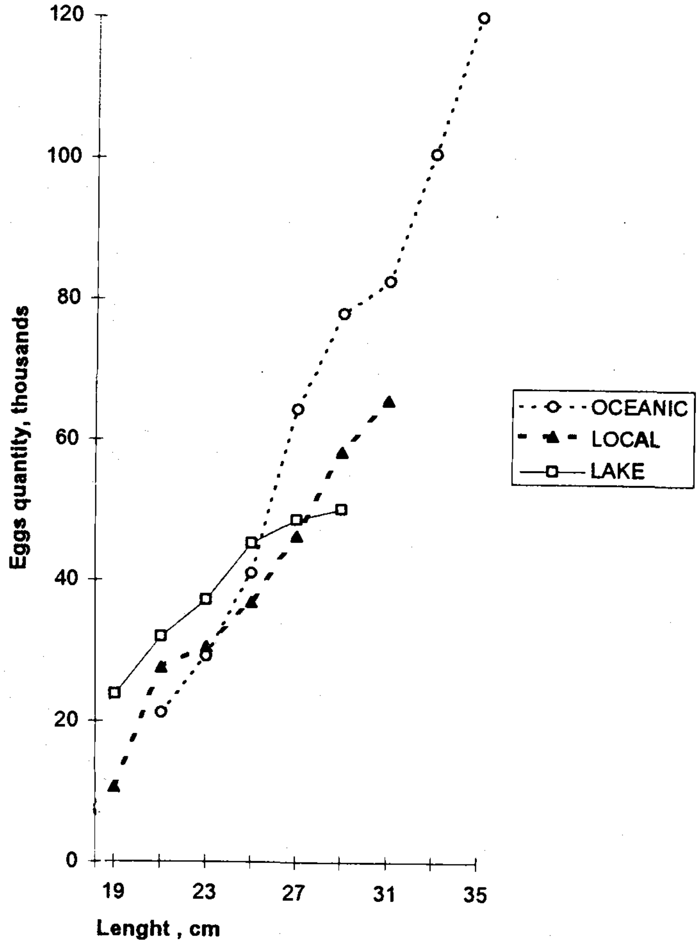

Fig. 3 Herring fecundity.

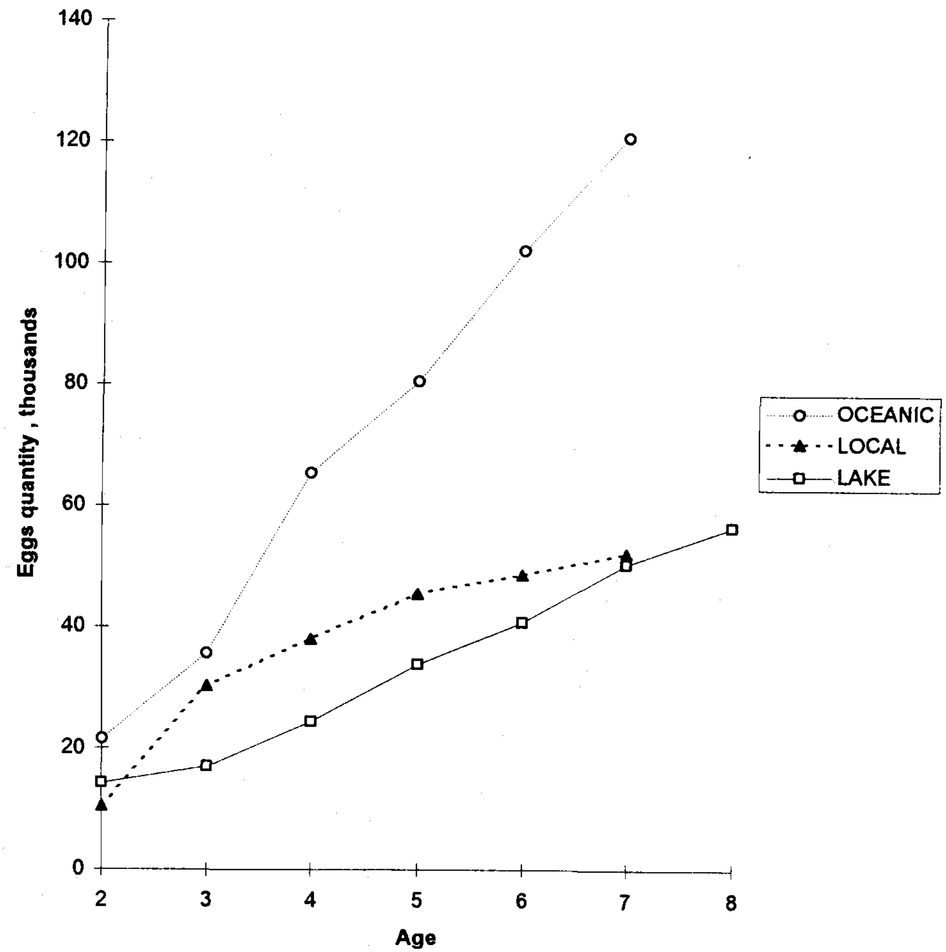

Fig. 4. Herring fecundity.

Present State of the Okhotsk Herring Stock and Fisheries Outlook

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Pacific herring was one of major fisheries developed during the initial period of the Russian marine fisheries in the Far-East in the early 1950s. The Sea of Okhotsk the herring fishery has been based on two large stocks: Okhotsk and Gizhiginsky-Kamchatkan. Catch of Gizhiginsky-Kamchatkan herring quickly increased to the highest possible level and has sharply decreased since 1960s. The Okhotsk herring were the subject of large scale fisheries until the second half of the 1970s. By 1963 the annual catch by Soviet fishermen was in excess of 200 thousand tones and by 1968-1969 reached a peak of 417.9-424.4 th. t. The combined Russian and foreign catch was about 600 th. t. During this period, herring contribute 42.7-45.0% of fish production caught by the USSR in the Sea of Okhotsk (Shuntov, 1985).

The development of a large scale herring fishery stimulated the formation of the national marine fishing fleet in the Far-East. Historically, it has played an important role in Russian fisheries management strategy in the Pacific Basin. Planned increases in fish catch, resulted in the decline of herring stocks as well as for other traditional species (salmon, flounders, etc.) caught in the coastal areas and shelf, which caused a movement to fish walleye pollock. The presence of a powerful fishing fleet resulted in a shift of fishing efforts to the resources of the continental slope and offshore waters. This strategy was caused by an additional stimulus with the introduction of the 200-miles economic zone by most countries of Pacific region in 1978. In the mid 1980s, the walleye pollock became the most important fishery in Russian and in the world (Gershanovich et al., 1990).

An analysis of the stock dynamics of herring and walleye pollock, the two most abundant fish species of Far-Eastern Seas pelagic zone, reveals that an increase in abundance of one coincides with a decrease in abundance in the other (Shuntov, 1986, 1991; Naumenko et al., 1990). By the early 1990s, North Pacific walleye pollock biomass decreased, particularly, in the northern area from 20-25 to 6 mln. tons in the Bering Sea pelagic zone and from 14 to 5 mln. tons in the North Sea of Okhotsk. The cause of this significant decrease was periodic global climatic oceanographic change in the pelagic ecosystems of the Far-Eastern Seas, as well as, a corresponding change in the structure of the hydrobiont communities and the number of dominant fish species (Shuntov et al., 1993).

The majority of the herring populations throughout the Pacific region increased in abundance from the early 1990s. There is evidence of increases in herring stocks inhabiting the Gulf of Alaska and waters of British Columbia (Collie, Spencer, 1993; Schweigert et al., 1993). Data from a survey of the Korfa-Karaginsky herring stock in 1993, in the west Bering Sea, indicates a increase of about two times compared to the second half of the 1980s. Analysis indicate 286 thousand tons of herring occur within the shelf at depths more than 50 m. and 120 mln. fingerlings were found in the Karaginsky Bay. If in 1986-1987 the ratios of the numbers of walleye pollock to herring fingerlings were from 100:1 to 25:1 then in December 1993 it was 2:1. Data collected in fall of 1994 indicates that the ichthyofauna in the eastern Olyutorsky Bay was predominantly small herring (fork length 13.6-27.0 cm), about 37% of the estimated fish biomass while the walleye pollock was 29%.

From data collected in the eastern Bering Sea groundfish surveys, the estimated herring by-catch in 1988 as compared with that in the early 1980s increases by three times (Bakkala 1993). These data are mainly related to the herring from the Bristol Bay sub-population being about 80% of total numbers in the eastern Bering Sea. Some indirect data also provides evidences of the growth of this stock. In July 1992, a large group of herring (modal group of 32-33 cm) arrived in the Russian economic zone north of 58°N. The walleye pollock fishing fleet caught up to 60 tones per hour of which the catches sometimes contain up to 60% herring as by-catch. The herring are also distributed in open waters of the Aleutian Basin up to 100 miles off the shelf. In the fall of 1994, a similar large mass of herring was found by the r/v "Shursha" in Anadyr Bay. In the 1980s, the abundance and migration pattern of the East Bering Sea herring is less pronounced and the distribution is limited to the northern shelf. The abundance in the western Bering Sea did not exceed 35 mln. fish and the biomass was 8 th. tons or 2.5-3.0% of Korfa-Karaginsky herring.

Assessments of the Okhotsk herring stock were accepted until recently. The results of epipelagic ecosystem studies in the Sea of Okhotsk in 1984-1990 indicate a biomass in the order of 1 mln. tons (Shuntov et al., 1993) and herring are concentrated on the northern shelf. A recent assessment by scientists from the Magadan Branch of TINRO recommends a catch of 100 th. tons for the Okhotsk herring (Yolkin, 1988). In the early 1990s, there was an expansion of the feeding area of the Okhotsk herring to the south of West Kamchatka and north of Sakhalin. In November-December of 1993, herring biomass is estimated at 2.5 mln. tons by the volume method from a trawl macro-survey by the r/v "Professor Kaganovsky". However, the location of the survey area and the density of echo-records and catches (which is characteristic of hibernating herring) provides grounds for doubt of the estimation. In March-April of 1994, the trawler "Novokotovsk"(a small area 1.34 thousand sq. km) caught 45-160 tons (average for 24 trawls was 11.8 tons per hour) while surveying for walleye pollock. The average density of herring within the grounds is estimated to be 66.8 tones per sq.km and the biomass about 90 thousand tons. The boundary of herring concentrations is to the south, where herring is not found south of 57°N and to the southeast where catches are 2 tones per hour in TINRO Basin. In August 1994, when dispersed herring are feeding in the North Okhotsk Sea the r/v "Professor Levanidov" operating mainly to the south of 54°N caught up to 10 tones per hour to the northeast of Sakhalin, in an area where, in the 1970s-1980s, feeding herring was not typical (Yolkin, 1988).

The most complete information on the stock status, age composition and distribution of Okhotsk herring during active feeding migrations was collected from 498 thousand sq. km including 57 stations during a 25 day cruise of the r/v "TINRO" in September-October of 1994. A comprehensive survey of oceanographic conditions and the distribution of plankton, fish and squids was conducted. At each deep-water station, surface trawls and stepped trawls within a layer of 50-280 m were carried out using a rope trawl RT 108/528 equipped with a fine mesh cod end of 6 to 30 mm. On the outer shelf (depths more than 100 m) one half hour trawls were carried out in the surface layer and in the layer of echo-recordings. Only surface trawls were carried out over the shallow shelf. The average fish density was quite high at 12.7 tones / sq. km (Table 1). More than 95% of the biomass is from three species; walleye pollock (52.7%), herring (36.0%) and northern smooth-tongue (8.2%). A pronounced reduction of the walleye pollock occurs from 75.0-84.3% of the biomass in the latter half of 1980s and an increase of the herring is found from 3.5-9.7% (Shuntov et al., 1993). The herring biomass is greater than that of other fish species within the 0-50 m depth zone as well as in the coastal zone (Table 1). Herring were quite widely distributed in the North Sea of Okhotsk during the survey; 80.7% of 53 trawls on 46 stations contained herring. The major concentrations of herring occurs in the shelf zone of the northern part of the investigated area (Fig. 1). 99.3% of the herring biomass was concentrated in regions Nos. 1, 2 and 5 including 60.1% in Tauisky where the fishing fleet caught herring located to the south of the mouth of Tauisky inlet. The density was 92 tones per sq. km, on average, in an area of 4.3 sq. km. The catch from that station was 52.5 tones of 24-32 cm in length. In region Nos. 6 and 7 the herring were dispersed (echo-records) and catches were not more than 90 kg per hour.

Size composition of herring varies insignificantly in the different areas. The 25-28 cm length group predominate: 62.4 - 94.3% of total numbers in the regions which average 85.2% over all. The modal length class is 27 cm: 28.3-53.7% which average 52.1% (Table 2). The average length of herring varies insignificantly from 26.2 to 26.8 cm with mean 26.7 cm. The Gizhiginsky- Kamchatkan herring are longer, 35 cm versus 33 cm for Okhotsk herring. The portion of fish greater than 28 cm is 18.3% in the Shelikhov Bay and 11.8% in the Tauisky region. The proportion of small herring in the Shelikhov Bay is more than in the Tauisky region: 13.4 % versus 0.4% for fish length less than 24 cm. The feeding grounds for fingerlings and maturing Okhotsk herring is in the Ayan-Shantar area and Sakhalin Bay.

Herring fingerlings were also caught in trawls in Gizhiginsk Inlet (up to 10.8 kg per hour) and at the coastal stations from Tolstoi Cape to Alevin Cape (single specimens). The length varies from 7.5-10 cm (some specimens reach 12 cm) with mean 8.74 cm (weight was 5.8 g) in large catches. In small catches the fingerlings vary from 5 to 7.3 cm. The low level of fingerlings in the Tauisky region may have been caused by commercial fishing which may have caused the biomass and numbers of herring fingerlings to be underestimated; 16.7 mln. for the Okhotsk stock and 0.2 mln. for Gizhiginsky-Kamchatkan. The herring biomass is calculated both by the areal method and from echo-records. Similar estimations have been obtained; approximately 1.9-2.0 mln. tons for Okhotsk and 0.27- 0.30 mln. tons for Gizhiginsky-Kamchatkan.

Based on the estimates of mature Okhotsk herring biomass, it is recommended that the quota could be increased during the herring feeding period because in early October, in the area of dense echo-records (55.2 thousand sq. km), a biomass of 715 thousand tons was estimated which would allow a fishery of 200 thousand tons without damage to the stock. A part of the herring stock is dispersed and another part is outside the range of the survey in a third (Okhotsk-Lisyansk) region serving as a "reserve". Based on the Okhotsk herring maturing by 5 years old, the age composition of the catch (Table 3) shows the spawning stock of about 1.5 mln. tons.

Herring spawning usually occurs in the coastal bays and inlets. The spawning success sharply decreases with a high density of spawners as was evidenced by the low hatching rate of larvae at high spawning density. Tyurnin (1980), concludes that a stock over 1 mln. tons requires more extensive use of available resources.

Based on data available, the recommended catch, in 1994, was increased to 120 th. tons for the Okhotsk herring stock. However, in the late October, due to the low levels of catch, an unrestricted (including trawling) fishery for herring was permitted by the "Glavrybvod" (Department of fish stocks conservation of Russian Ministry of Fisheries). Unfortunately, the weather over the North Sea of Okhotsk is extremely bad in December which prevented fishing.

Forecasting the Okhotsk herring catches for 1995 and subsequent years is under discussion due to data from air flights on herring spawning grounds which was not provided in a timely manner. The estimated spawning biomass of herring in the late spring early summer of 1994 is 700 thousand tons which implies a low level of stock exploitation (10% level). About 70% of the mature herring abundance is from the 1988 yearclass which spawned for the first time in 1994. From marine survey data (Table 1) the 1989 yearclass will spawn at age 6+ in 1995 and their portion was 61.5% in the fall of 1994 with biomass of 980-1030 th. tons. The biomass of the 1988 yearclass (28.4% of the abundance) is estimated at 530-560 th. tons. Thus, a large part of the spawning stock of the Okhotsk herring is not accounted for on the spawning grounds in 1994.

High density of Okhotsk herring during the feeding and hibernation periods is determined by the appearance of two abundant cohorts that are smaller in length and weight at age than other year-classes. The average length of the herring spawners at the ages of 5+, 6+ and 7+ are 266, 277 and 287 mm respectively (Yolkin 1988). Samples of herring going to hibernate in the winter at five, six and seven are 254, 264 and 273 mm long, respectively. The fork length of 8+ herring, on the average, is 306 mm, close to the long-term average of 303 mm. A small numbers of fish 8+ could imply an increase in the rates of natural mortality of elder age groups due to density dependent factors. Similarly, a reduction in fecundity of Okhotsk herring (average number of eggs spawned by one female) might also be caused by density dependent factors (personal communication R.K. Farkhutdinov).

Another indication of the considerable growth of herring is the massive occurrence of adults in late October in the vicinity of the TINRO Basin and Kashevarov Bank. Yolkin (1988) observed that herring migrate to the North Sea of Okhotsk shelf by the middle of September. The expansion of populations of herring causes an expansion of the inhabited area boundaries for the period of high abundance (Timofeyev-Resovsky et al., 1973). The resources (space, food) of neighboring habitat (including open ocean) which are chiefly used by walleye pollock in 1980s, are an immediate reserve. In the most cases, an expansion of herring towards open waters occurs at the expense of feeding migrations of mature fish (Blaber 1991).

Detailed discussions of results obtained from a cruise in 1993-1994 allows the doubling of the Okhotsk herring catch for 1996 to 120 th. tons. One can understand the reasons for caution when reminded of the sharp reduction of the Okhotsk herring abundance in the second half of 1970s which is thought to be caused by over harvesting and non-registered catches from the driftnet fishery. At the same time, recent studies show that a natural decline of herring abundance caused by global climate change and oceanic conditions occurs during the same period (Shuntov, 1991; Radchenko, 1994). The increase in Okhotsk herring abundance, in the early 1990s, appears to have been the result of a shift in conditions from what is expected in the long-term. It should also be considered that, unlike the usual gradual abundance increases, declines from high levels are usually abrupt. Evidently, it is determined by the sharp increase of natural mortality rates for productive generations after approaching of the limiting age.

The sustainable exploitation of marine biological resources provides for the removal of excess production. The actions should be even more promptly taken to remove surplus biomass which could cause the degradation of feeding and spawning conditions and density-dependent and intraspecific mechanisms leading to population productivity reductions, late maturation and low viability of embryos, larvae, etc. The Okhotsk herring quota should be increased for 1995. In 1996-1997 a change from a conservative approach of setting catch limits to a more pragmatic approach would annually allow a harvest of not less than 200 thousand tons of Okhotsk herring.

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TABLES AND FIGURES

Table 1. Density of fish biomass distribution (metric tones per sq. km) and portions (%) of dominant species in diverse regions of the northern Sea of Okhotsk, 14.09-8.10.94.

Region	Depth (m)	Area (sq.km)	Fish biomass density	Portions of dominant species			
				pollock	herring	capelin	smoothtongue
1	up to 100	63.9	3.3	16.1	64.1	19.0	-
	100 - 200	32.1	15.2	85.5	8.0	6.0	-
	>200, layer 0-50	4.0	0.08	75.9	-	-	-
	>200, layer 100-50	4.0	0.4	90.9	-	9.1	-
2	100 - 200	43.7	42.8	26.6	73.0	0.02	-
	>200, layer 0-50	18.3	0.26	21.6	76.6	-	-
	>200, layer 280-50	18.3	40.8	99.8	0.1	-	-
5	>200,layer 0-50	160	1.8	4.1	12.8	-	75.7
	>200, layer 200-50	160	11.0	59.7	38.8	-	0.1
6	>200, layer 0-50	120	0.4	36.8	21.3	-	7.1
	>200, layer 280-50	120	6.7	60.8	0.2	-	36.4
7	up to 100	32.5	0.4	17.5	-	37.8	-
	100 - 200	9.7	2.3	15.9	4.3	11.7	-
	>200, layer 0-50	13.8	0.4	24.8	32.2	0.9	-
	>200, layer 280-50	13.8	6.0	81.4	0.9	0.1	-

Remarks: limits and numbers of regions are traditionally given in practice of ecosystem research of TINRO: 1 - Shelikhov Bay; 2 - Tauisky region; 5 - Kashevarov bank and adjacent shelf; 6 - TINRO Basin; 7 - West-Kamchatkan shelf and continental slope northwards of 54°N.

Table 2. Length composition (%) of herring catches in the northern Sea of Okhotsk in September-October of 1994.

Regions	Fork length (cm)																			Mean
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	N	length
1	-	-	+	0.9	4.3	3.3	4.8	6.0	20.6	28.3	13.5	5.1	2.5	2.7	3.6	1.2	1.5	1.7	16406	26.6
2	0.4	-	+	+	+	+	0.5	3.5	23.4	40.5	22.4	4.9	3.1	0.9	0.4	-	-	-	268590	26.6
5	-	-	-	-	-	-	+	2.0	22.3	51.9	20.3	3.0	0.5	+	+	+	-	-	25203	26.5
6	-	-	-	-	-	-	-	1.7	24.4	48.7	20.7	3.1	0.9	0.5	-	-	-	-	1059	26.6
7	-	-	-	-	-	-	0.1	7.0	39.9	37.3	12.8	2.1	0.6	0.1	0.1	-	-	-	1689	26.2
All:	0.4	-	+	0.1	0.2	0.2	0.7	3.6	23.2	40.7	21.7	4.7	2.8	0.9	0.5	0.1	0.1	0.1	312947	26.6

Table 3. Age composition of herring (%) in diverse regions of the Sea of Okhotsk.

Regions	Age							N
	2+	3+	4+	5+	6+	7+	8+	
1	-	1.0	22.2	49.9	17.9	7.6	1.4	16129
2	+	0.1	5.2	61.0	29.6	3.8	0.3	266255
5	-	-	3.1	74.4	22.5	-	-	24554
6+7	-	-	3.5	67.4	24.8	4.3	-	2738
All regions	+	0.2	5.9	61.5	28.4	3.7	0.3	309676

Distribution of the Barnacle *Balanus Rostratus Eurostratus* Near the Coasts of Primorye (Sea of Japan)

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INTRODUCTION

Balanus rostratus eurostratus Bronch occurs subtidally near the Sakhalin coasts of the Sea of Japan not farther north than 50°N and near the Japanese coasts (Tarasov and Zevina, 1957). This species is long-lived and one of the largest barnacles. It can form a large biomass on a small base. It inhabits stones, boulders, rocks as well as the shells of mollusks including commercially important species (Ovsyannikova, 1989; Silina and Ovsyannikova, 1995). This species is often found to foul the water intakes of hydro-technical construction (Gorin, 1975; Brykov et al., 1980), but it never settles in a ship bilge (Tarasov and Zevina, 1957). Barnacle larvae are generally food for fish and adult individuals for invertebrates and birds. The data on the biology and distribution of *B. rostratus eurostratus* are extremely scanty and fragmentary.

The purpose of this study was to analyze the data (about 90% of total), including data from the literature, on the distribution of the species near the coasts of Primorye on the substrate (bottom and hydro-technical construction), attached to organisms and to the mobile Japanese scallop *Mizuhopecten yessoensis* to study the occurrence of species in terms of the time spent in an area with increasing anthropogenic pollution.

MATERIAL AND METHODS

The study of the distribution of the *B. rostratus eurostratus* was conducted from 1973 to 1995 near the south coast of Primorye (from the west coast of Possjet Bay and Furugelm Island to Nakhodka Bay) and northeast of Povorotny Cape to Vladimir Bay. Barnacles were sampled by scuba divers at a depth of 0-40 m (most often at 0-20 m).

Measurements of the carinorostrum diameter of the shell base and the shell height by the carina plate for adult individuals were done using a slide gage. Juveniles were measured under a binocular microscope. The weight of concretions (druses) and individuals were determined.

RESULTS

In the northwest part of the Sea of Japan, *B. rostratus eurostratus* is found only in Peter the Great Bay (Table 1). North of Povorotny Cape, recognized as a boundary between the north and west Japan Sea districts of the Manchuria biogeographic province, is devoid of this species (Table 2). Similarly, the species is not found west of Povorotny Cape in the open part of Peter the Great Bay where there are strong currents and a small amount of organic detritus on the bottom(Table 2). The barnacle is not found to foul vessels. *B. rostratus eurostratus* most often occurs in protected and semiprotected bays, near capes of bays or near islands where currents or wave action is significant. It was found that the barnacle attaches to the grotto walls or in the shade of large boulders and rocks.

B. rostratus eurostratus is generally found in concretions consisting of several barnacle generations along with the mussel *Crenomytilus grayanus*, and *Modiolus kurilensis*. The oyster *Crassostria gigas* inhabiting Possjet, Amur, and Ussuri bays also occurs in the concretions. Such concretions are generally attached to boulders, rocks and at the base of stones and mollusc shells on muddy and sandy bottom. A concretion found in Vostok Bay of *B. rostratus eurostratus* weight 1,232 g. The concretions with mussels and oysters found in the vicinity of Peschany Cape in Amur Bay are 75 cm in diameter and weigh about 5 kg. In addition to natural substrates, B. *rostratus eurostratus* colonizes objects, such as buoys, barrels, anchor chains, piers, rubber, glass and on cultured mollusk shells. The barnacle usually appears on buoys in the first month of life. In Possjet Bay, B. *rostratus eurostratus* together with other organisms form a biomass fouling hydro-technical constructions . For instance in Vityaz Bay up to 65 kg per meter of which 21 kg is B. *rostratus eurostratus* are found fouling anchor chains. The mass of single individuals did not generally exceed 85 g. The shell base is no more than 65 g and the carina height did not exceed 65 mm.

The greatest biomass of *B. rostratus eurostratus* occurs in areas where domestic and industrial sewage is discharged, i.e., in areas with high organic material. Significant changes in the timing of settlement is observed in these areas. In Amur Bay, near the city of Vladivostok, with a million population, pollution is increasing and substantial changes have occurred to *B. rostratus eurostratus* and to the Japanese scallop. In 1982, only few individuals of *B. rostratus eurostratus* are encountered, whereas, by 1987 this species is dominant, having a biomass of up to 550 g and up to 180 specimens per scallop shell. After flourishing since 1990, *B. rostratus eurostratus* has declined. It should be noted that in the more open parts of Amur and Possjet bays, there is a gradual tendency for the bottom to become increasingly muddy. Under these conditions there is an increase in occurrence of B. *rostratus eurostratus* settling on Japanese scallop. On muddy bottom, the shell changed to lily-shaped and it grows higher and sometimes its carina reaches a height of 76 mm and the shell base is 48 mm.

DISCUSSION

This study confirms the presence of a boundary where there is a noticeable change of species composition in the area of Povorotny Cape. These findings do not agree with the suggestions made for bryozoans (Kubanin, 1981) and polychaetes (Bagaveeva, 1988) that the boundary lies farther north in the area of Sokolovskay Bay. North of Povorotny Cape the influence of the cold Primorskoe Current (from the northern part of the Sea of Japan) on the presents of the species is considerable. In the innermost parts of unprotected bays, the water temperature increases to over 17-18°C for a short time to allow spawning of B. *rostratus eurostratus* to take place (Korn, 1985). Evidently, the need for a fairly high temperature, for reproduction, prevents it from existing farther north.

B. rostratus eurostratus forms large concretions on its own, on bivalve mollusks and on barnacles and serves to provide a refuge for other organisms. Seaweeds, bryozoans, hydroids, sea anemones, juvenile mollusks, other barnacle species and tubeworms attach themselves to the concretions. Between the "branches" of the concretions, polychaetes, various crustaceans, and nemertini are found. This increases the bioproductivity of polluted areas and enhances food for fish species. Barnacles and bivalves, being sestono-feeders favor clean water. At the same time, these aggregations can cause problems for mariculture installations and hydro-technical construction.

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Table 1. Habitat of the barnacle *Balanus rostratus eurostratus* near the coasts of Primorye in the northwestern part of the Sea of Japan.

Areas	Biotope	Depth, m	Years of investigation
Possjet Bay			
Expeditziya Bight	M	6	1993
Novgorodskaya Bight	H	1	1970
Reid Pallada Bight	B,S	2-6	1962,1990-1992
Vityaz Bight	H,M,Sh	2-20	1974-1985
Amur Bay			
innermost part	O	1	1986
Screbtsova Island	B,M,O	4-8	1981
middle part			
western cost	B,M,S,Sh	4-15	1990-1995
eastern cost	S,H,Sh	1-6	1982-1995
open part	B	1-20	1973-1975
Slavyanski Bay			
Severnaya Bight	C,S	0-15	1985
Russki Islans	S	4	1994
Popova Island	B,S,C	6-15	1973-1995
Rejneke Island	B,S,M	4-8	1973-1994
Ussuri Bay			
Lazurnaya Bight	H,B,M,O	2-10	1974-1995
Tikhaya Bigh	B	1-2	1978
Vostok Bay	B,M	1-2	1973-1993
Nakhodka Bay	H	0-6	1970

B - stones, boulders, rocks; S - scallops; M - mussels; O - oysters; Sh - shells of other molluscs; H - hydrotechnical constractions; (piers, bouys, chains); C - maricultural cages.

Table 2. Areas in the northwestern Sea of Japan where *Balanus rostratus eurostrats* was not found.

Areas	Biotope	Depth, m	Years of investigation
Possjey Bay			
Furugelm Island	B,S,Sh,M	0-18	1973-1995
Gamov Cape	B,Sh	0-40	1979
Vityaz Bight	B,S	20-30	1979-1980
Alekseev Bihgt	B,S,Sh	10-17	1979-1980
Amur Bay			
Zolotoi Rog Bight	H	1-3	1970
Antipenko Island	B,S,Sh	6-15	1987-1990
Sibirtzeva Island	B,S,Sh	1-12	1987
Bolshoi Pelis Island	B,S,Sh	1-12	1987-1995
Stenina Island	B,S,Sh	6-18	1980
Anna Bay	S	4-12	1988-1992
Rifovaya Bay	B,S,Sh	0-10	1990-1992
Northward of Povorotny Cape			
Kaplunova Bay	B,S,Sh	1-15	1990
Usprniya Bay	B,S,Sh	0-22	1990
Olga Bay	B,S,Sh	0-20	1980
Vladimira Bay			
Severnaya Bight	B,S,Sh,C	1-16	1987-1990
Srednyaya Bight	B,S,Sh	0-12	1988-1990

B - stones, boulders, rocks; S - scallops; Sh - shells of other molluscs;
H - hydro-technical construction; (piers, bouys, chains); C - maricultural cages.

Dependence of Urchin *Strongylocentrotus Intermedius* Reproduction on Water Temperature

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The sexual development and growth rate of urchins is, in many respects, determined by their environment and ecological factors. Temperature plays one of the most important roles in the complex of ecological factors regulating sexual activity of invertebrates (Korringa,1957; Milyakovsky, 1970; Kaufman, 1976; Wilson and Simons, 1985; Maru, 1985; Kasyanov, 1991; Hotimchenko, 1993). Reproduction responds to daily and seasonal temperature fluctuations and salinity is not considered as important (Mori, 1975; Yakovlev, 1976; Milyakovsky, 1981; Fretwel, 1987; Motavkine et al., 1990).

The purpose of work was to study the influence of the temperature on the reproductive process of gray urchins *Strongylocentus intermedius* inhabiting the coast of north Primorya (from Cape Gold to Cape Belkina).

MATERIAL AND METHODS

The object of the research was to collect samples by diving for gray urchins in their habitat from Cape Gold to Cape Belkina. The reproductive process is studied throughout the spring-summer-autumn during 1992-1993. The influence of temperature on gonad development is investigated using histology examination to determine the stage of ripeness and to compare this to a gonad index. The samples are fixed using 10% neutral formalin, filling with melted paraffin and 5 microns slides are prepared for viewing by washing with hematoxilin Arlih and aozin.

RESULTS AND DISCUSSIONS

Research of gray urchins gametogenesis inhabiting the coast of north Primorye indicate that water temperature is an important influence on the reproductive process, especial, in the formation eggs.

Growth and development of gametes is influenced by two time periods: the autumn when temperature of the water decreases and the spring when the temperature increases. The most active growth of gametes is observed at low positive but constantly rising temperature. During the winter, the low negative temperature prevents duplication and the main mass of sexual cells is reabsorbed.

Active growth of sexual cells is observed when the water begins to increase at the end of April beginning of May from Cape Gold to Cape Belkina (Fig. 1). Temperature of water did not exceed 1.5-2.5°C and the gonadal index values are from 1% up to 7-10% where cells are observed in the early stages of growth, "active gametogenesis" and "before spawing". Spawing males and females first appear in the region at the beginning of June. With increases in the temperature of water, the growth of sexual cells becomes more active. The most intensive growth is observed when the temperature of the water is 4-8°C which is observed at northern sites from the end of May to the end of June. In this period, spawning females appear from the end of June to the beginning of July. The percent of the ripeness increases to 20. Spawning of the urchins, from Cape Gold to Cape Belkin, are from mid-July to mid-August. The maximum temperature during reproduction is 12-16°C. After spawning the eggs that remain in the gonads are reabsorbed and a 1.5 month period "of relative rest" occurs in which gonad physiological reorganization took place. When temperature decreases in the second half of September a new reproductive cycle begins with active growth of gametes. In autumn, different stages of reproductive growth of gametes is observed where the gonad index is from 1-10% and the percentage with ripe gonads reaches 60. In December, the low water temperature (up to 0°C) slows development of sexual cells. Temperature of approximately 0°C is critical for development of the gametes of gray urchins.

The development of invertebrate gonads depends on the water temperature and in particular the variation of the temperature during development determines when spawning occurs (Kaufman, 1977; Uki and Kikuchi, 1984). The water temperature is summed over the active period of sexual cell development. In the first phase of gametogenesis (autumn - winter), the degree days are summarized in intervals of 14. In the second phase, in the spring - summer, development of takes place from 0°C to spawning temperatures. Temperatures lower than 0°C cause re-absorption of cells, thus, zero is the critical temperature for gamete development. In the first phase, development of sexual cells of grey urchin requires 600-650 degree days (Fig. 2). In the second phase the effective temperature in this region increases development up to 800-850 degree days. In general, the development of sexual cells takes about 1,400-1,450 degree days.

It is necessary to emphasize that the sum of the effective temperature for development of sexual cells is constant and annual fluctuations in the spawning season depends on the seasonal changes of the water temperature(Yakovlev, 1976; Kasyanov, 1991). On northern plots, the peak spawning of urchins is the end of July beginning of August. Growth of larvae and spat settling generally occurs at a temperature of 15 - 18°C (Agatsuma et al., 1989; Kasyanov et al., 1983). At northern sites, the time to heat the water to the required temperature for urchin development to the larval stage compresses the spawning season. The importance water temperature in the process of development of sexual products is seen by the fact that urchins inhabiting areas on shoals, where the seasonal temperature rise occur earlier than at greater depths, spawn earlier (Milyakovsky, 1981; Kasyanov, 1991).

The dependence of urchin reproduction on other ecological factor and the external environment is a problem for further research.

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FIGURES

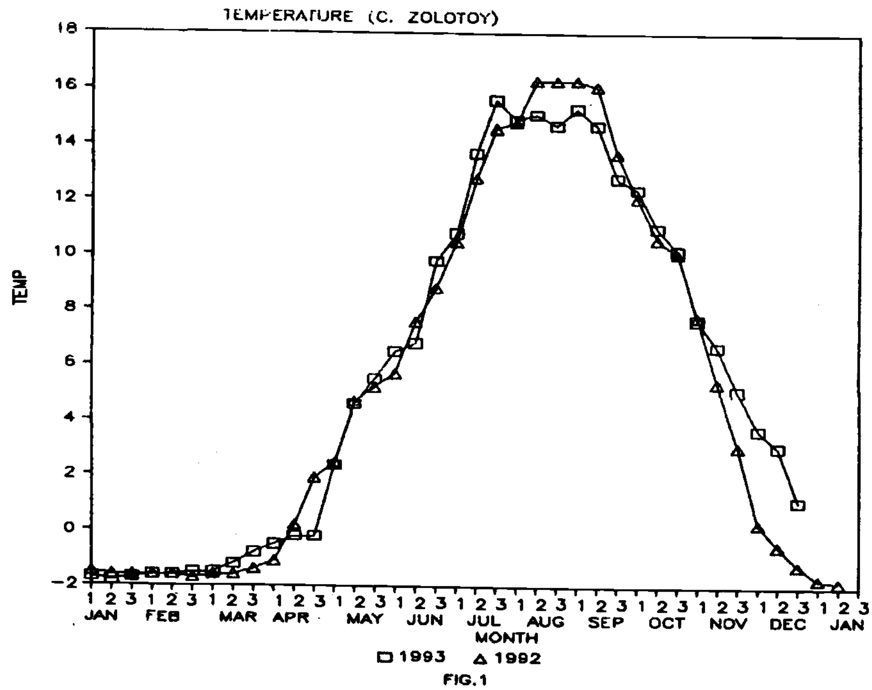

Fig. 1. Water temperature changes from Cape Gold to Cape Belkina.

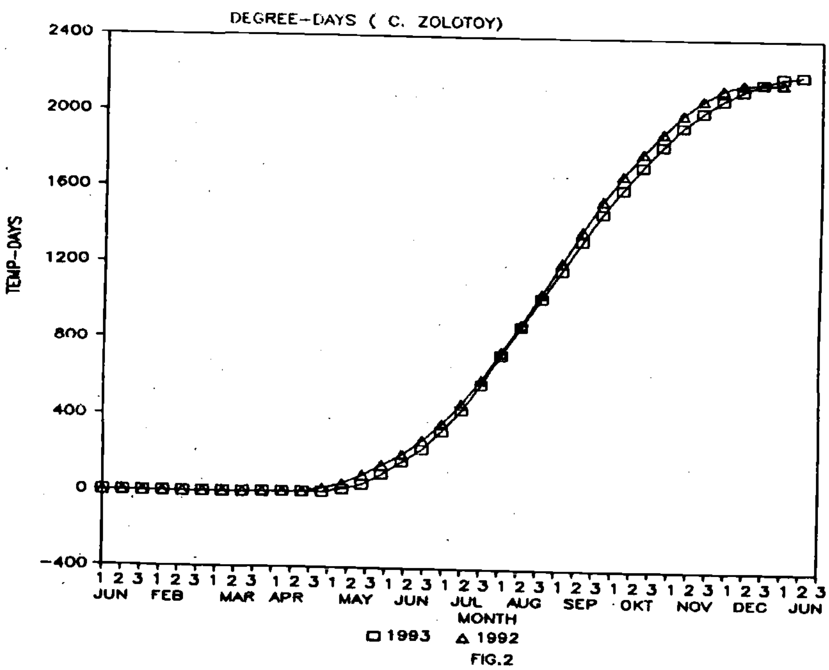

Fig. 2. Degree-days.

Feeding Habits of Pacific Salmon in the Sea of Okhotsk and in the Pacific Waters of the Kuril Islands in Summer 1993

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PINK SALMON

Pink salmon feeding in the Sea of Okhotsk was investigated. One-2 species predominate in the food of pink salmon (Synkova, 1951; Andrievskaya, 1957; Gorbatenko and Chuchukalo, 1989). Euphausiids are the predominated food item in the diet of pink except for West Kamchatka where hyperiids are the most important item eaten. Nekton proved to be a minor item and squid did not exceed 2% of the total food weight. Fish is also insignificant excepting near the Eastern Sakhalin, where it composed about 50% of the total weight of food eaten.

The Sea of Okhotsk plankton differ from Bering Sea and northwest Pacific by the high abundance of Euphausiids (Volkov, 1986; Shuntov et al., 1993). Feeding studies indicate that walleye pollock feed, mainly, on Euphausiids in the Sea of Okhotsk and copepods in Bering Sea. Similarly, the share of Euphausiids in the diet of salmon increases in the Okhotsk Sea, while the species composition of stomach content is simple. It is known, that many species of Euphausiids are unavailable to salmon because they descend to 100 m in the daytime and at twilight when most salmon are feeding (Volkov, 1994). In the summer of 1993, in the south Okhotsk Sea, common Euphausiids *Thysanoessa longipes* stay in patches of large mature specimen (from echo sounder tracings) in the epipelagic layer (0-50 m) during daytime. These crustacea, the most abundant among Euphausiids in the macroplankton are the main food of pink salmon.

In 1994, in almost all areas the stomach fullness of pink salmon was high. The species composition of food varies more in the Pacific waters of the Kuril Islands than in the Sea of Okhotsk. The nekton share in the diet is appreciably higher and Myctophids are the main item in the nekton, while squids are insignificant (up to 8%).

Euphausiids predominate in the diet near the Kuril Islands and *T.longipes* is the most numerous in the diet in the Okhotsk Sea but both *T.longipes* and *Euphausia pacifica* are abundant in the Pacific waters. The former in ocean ward areas and the latter in the waters adjacent to the Kuril Islands. A similar situation is observed in the plankton. The common hyperiids species *Parathemisto pacifica* is dominant in the food of salmon in all areas surveyed. The hyperiids are in the middle of the food group organisms but they are more common when stomach fullness was low. Fullness by hyperrids is higher (2.8-18.4%) among small fishes (40 -50 cm) and 3.0-7.6% for larger fish.

The proportion of pteropods in the diet of pink salmon is similar throughout the survey area. The highest share (14.4-33.7%) is observed over the deep water area where hyperiids are the most abundant in the plankton. Although the biomass of *Limacina helicina* is almost equal to *Clione limacina*, pink salmon prefer the former.

The Copepods *Calanus cristatus, C. plumchrus, Eucalanus bungii* and *Metridia pacifica* frequently occur but are insignificant in the stomachs, except for *C.cristatus* which is 2.4-10.8% of the stomach contents.

In general stomach fullness is lower in the ocean than in the Sea of Okhotsk.

CHUM SALMON

The composition and dominance of some species in the diet of chum are similar among all size groups (30-70 cm). Stomach fullness decreases with increasing body length. The nekton is a minor part of the food similar to pink salmon (Gorbatenko and Chuchukalo, 1989). Euphausiids *(T.longipes)* dominate in the diet of chum 59-78% and hyperiids constitute 15-30%. Pteropods, hyperiids and ctenophores are also present in increasing importance. *C. plumchrus* is significant among the copepods in the deep water zone.

In the Pacific waters of the Kuril Islands chum feeding is similar to the west Bering Sea and Pacific waters of Kamchatka. Pteropods such as *Clione* and *Limacina* are dominant in the diet and abundant in the plankton (6-13 and 5-12 mg/m^3 respectively) but the biomass is lower in most of Okhotsk Sea (0-6 mg/m^3). The pteropods in the chum's diet is an important part of the diet in summer of 1992 although it is lower than in 1993 (20-47%). Euphausiids (*T.longipes and E.pacifica*) and hyperiids (*P.pacifica*) are the second and third most abundant items in the plankton. Ctenophores (*Beroe cucumis*) sometimes exceed 50% of the stomach content wet weight. Jellyfish (mainly *Aglanta digitale*) also frequently occur but is insignificant in the total diet.

In general, the stomach fullness in the ocean is lower than in Okhotsk Sea.

We estimate the daily rate of chum and pink feeding using fullness, the share of empty and little filled stomaches and the fresh food in the stomach contents. Most pink had empty and half-empty stomaches from 00 to 7-8 a.m., when the least fullness is observed. The share of empty stomaches began to decrease after 9 a.m. The most fresh food occur from 1 p.m. to 00 o'clock. Chum salmon has a similar but lower daily rate of feeding. A classic daily rate of chum's feeding is established in the Bering Sea, where pteropods are the main food.

COHO AND CHINOOK SALMON

Data on the feeding behavior of these two species are sparse, so the average is calculated for south Okhotsk Sea and Pacific waters of the Kuril Islands. In 1993 the length of fishes range from 50 to 70 cm. Coho fed, mainly, on nekton (77-84%) but fish and squids are also found in fish from the Pacific Ocean and only fish in coho from the Okhotsk Sea. Euphausiids are also considerable (13-27%), while hyperiids and pteropods are scarce. Stomack fullness is high everywhere 146-181$\%_{oo}$.

Chinook salmon stomaches often had little food or are empty. Nekton is the most common food item 67-70% (mainly fish) in the ocean and euphausiids, fish and squids are eaten in the Sea of Okhotsk.

It is interesting to note that small chinook (less than 30 cm) only fed on nekton in the Okhotsk Sea in the fall-winter period and no plankton is not found in their stomachs.

CONCLUSIONS

Owing to differences in the composition of plankton communities in the Okhotsk Sea and Pacific Ocean, some distinctive feeding behavior is observed in salmon. Species composition in the diet is similar for plankton but a diversity of other species dominate. During migration in summer (June-July) pink salmon actively feed on nekton (juveniles, small fishes and squids) and large zooplankton (euphausiids, pteropods). Sometimes copepods are an appreciable (25-38%) amount of the food consumed. Euphausiids dominate in the pink diet in the Sea of Okhotsk, while the nekton is low. There is less euphausiids in the stomachs in Pacific waters of the Kuril Islands due to an increase of hyperiids and pteropods. Squids are insignificant in the total diet.

Chum feed, mainly, on euphausiids (*T.longipes*) in the Sea of Okhotsk and pteropods, hyperiids and nekton are a minor part of the food consumed (up to 25%). Pteropods, ctenophores and jelly-fishes dominate in the diet in Pacific waters, while euphausiids are a minor part of the food items.

Coho (50-70 cm) feed, mainly, on nekton (fish and squid). Chinook (50-70 cm) eat nekton (fishes) in Pacific waters of the Kuril Islands and euphausiids in the Sea of Okhotsk.

Copepods are a minor part of the salmon diet and the abundant chaethognaths are absent in the salmon diet.

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Okhotsk Sea Walleye Pollock Stock Status

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The stock status of the walleye pollock in the North Okhotsk Sea (to the north of 50°N) was analyzed using commercial fishery statistics and production models. Modelling of the catch enabled estimates of production parameters which were applied to concrete numerico-temporal conditions. The objective of this paper is to extend the previous study by Zverkova and Oktyabrsky (1994) using a longer time series and different assumptions. The time series and assumptions used in the previous study yielded an upper limit of the walleye pollock fishery stock at 7.4 mln. tons and the estimated maximum sustainable yield was 1.7 mln. tons for the optimum exploitation. The presented paper contains fewer limiting conditions than the previous one but still retains some model stability problems due to the short data time series.

MATERIAL AND METHODS

The walleye pollock found in the North Okhotsk Sea is relatively isolated and a single resource (Zverkova, 1993). The fishery has traditionally been conducted in the two regions. The first region is located in the eastern part of the sea and bounded by East Kamchatka and the North Kurils. The second region is located in the northwest part of the Okhotsk Sea and includes the area near Taui Inlet, Shelikhov's Bay and the highseas part of the Okhotsk sea, where largescale uncontrolled international fisheries are ongoing. Within the first region, fishing pressure has been a factor for approximately twenty years. The second region fishery, which began in 1981, developed into a large scale fishery by 1983. The fishery statistics used to run the model are summarized for the whole region starting from 1981. The cumulative walleye pollock catch for both the North Okhotsk Sea and the two fishery regions is shown in the Table 1.

The walleye fishery within the first region has always been more diversified than in the second region. The fleet fishing within the first region is by small, medium and large tonnage vessels and in the course of time the small vessels were replaced by more productive larger vessels as the medium tonnage fleet was updated. As these changes occurred, the walleye pollock resource became more available to the fishing fleet and catches were more representative of the effort expended. The medium tonnage fleet is used as a reference for the first region based on the significant impact they had on the total harvest. A hypothetical medium tonnage vessel is used to represent the fleet, ranging in characteristics from seiner-trawler to medium tonnage trawler. These vessel types proved to be the most productive in terms of walleye pollock harvesting and their unit effort is comparable with that of the large tonnage fleet. The walleye pollock fishery in the northern Okhotsk Sea has a seasonal cycle of catch and catch rates starting in November-December and finishing in April-May. The temporal distribution of catch per unit effort as corresponds to the efficiency of the fishery approximates a the convex function. However, due to the poor quality of the data and the need to consolidate it within one calendar year, it is assumed that the fishery efficiency is uniform during the fisheries season. For those years where we do not have annual data, average catch per unit effort is taken as the geometrical mean for those months where data is available excluding the last month in the season. Fadeev and Smirnov, (1994) data from sources other than ours are used based on a uniform distribution.

The fishing effort that best describe efficiency of the reference medium tonnage vessel operation is catch per vessel day in the first region (Table 1). The standartization of the effort for a long time period would be a difficult task to solve, so it is assumed to be taken by the vessels of the seiner trawler and meduim tonnage trawler types.

The walleye pollock fishery in the second region is mainly by large refrigerator trawlers. Recently, the contribution of the medium tonnage fleet increased and has become dominant in the fishery. The catch of this fleet is more representative than the cumulative ones for the first region. The 1985-1992 time-series of the catch per unit effort for the second region is constructed based mainly on data taken from Programs ..., (1989). These data contain catch per unit effort obtained from the Russian large tonnage fleet in terms of tons per vessel day for the fishery. A hypothetical average vessel is developed combining the features of the large refrigerator and large autonomous freezer trawler types as a reference for the second region using vessel day as a unit of fishing effort.

Catch information from the high seas fishery is obtained partly from Li (1994). Since 1991, medium and large tonnage vessels have played a major role in the large-scale walleye pollock fishery. In 1991-1992, foreign vessels similar to the Russian large refrigerator trawlers and large autonomous refrigerator trawlers are used to calculate the averaged catch per unit effort. In 1994, due to the lack of data, the fishing efficiency in the high seas is assumed to be similar to that attained for the Russian large tonnage fleet in the second region. It is assumed that the whole catch was taken by the vessels of the reference type. Catch per unit effort by vessels of the reference type of vessel is shown in the Table 1.

Based on the assumptions for the walleye pollock fisheries in the two regions, a hypothetical fishing effort can be expressed as: $f_i = Y_i / Y_{f,i}$ where i denotes the fishing regions. After summarizing the data for each region, the standartization is performed by the two methods:

$$\text{a) } Y_{f,st} = Y_{f,1}^{v1} \times Y_{f,2}^{v2} \quad \text{and} \quad \text{b) } Y_{f,st} = Y_{f,1}^{1/2} \times Y_{f,2}^{1/2} .$$

Where V1 and V2 are the mean values of the statistical weights for the fishing effort made by the reference vessels for the first and second regions, respectively. Expression "b" the geometrical means are given.

The aim of the study is to select a Production Model that would yield the best fit for the data series available. The models selected are Shaefer's model in linear Yf = Yf(fe), and least square Ye = Ye (f, f2), and Ye = Ye (Yf, Y2f) versions and the generalised Fox model in two versions: Yf = Yf(fn) and Ye = Ye(f,fm). Estimated values are calculated using least square method, an approximation method by Kramer and the Shaefer method. The calculations are carried out using two software packages PROD (5) and ME202AUR (6).

The process of calculation and their results

The standardized values of fishery efforts: f = Y / Yf are calculated based on the sum of catches for the two fishery regions and the standardized walleye pollock catches for the North Okhotsk Sea. Then the walleye pollock stock for the whole North Okhotsk Sea is calculated using the Production Models. Of the different modelling options the most acceptable results are obtained with V1 = V2 where catch per unit efforts and efforts are standardized according to version "b" above (Table 1) using the Shaefer Production model.

The input was the time-series 1981-1994 using the differential model versions:

Ye,t = Bt x (1 - 0.1(6)Bt) mln T.

Where Ye,t is the equilibrium catch; Bt the average biomass of the fishery portion of the walleye pollock stock for the year t; the maximum fishery biomass Bmax is taken as equal to 6 mln. tons, and instanteneous production increment rate (k) as 1 (year-1). Along with production parameters, the catchability q = 2.06*10-5 (vessel day {for the vessel of MLT type}-1) is calculated. Note that MLT means, a hypothetical vessel combining characteristics of both medium tonnage and large tonnage fleet on a 50-50 basis. An equation of equlibrium state or working model of Shaefer proper has the form:

Ye = 4.8 X 104 Yf - 389 Yf2.

The equation yielded the following parameter values for the optimum exploitation: MSY (maximum sustainable yield) Yopt = 1.5 mln. tons, Yf, opt = 62 tons per vessel-day for MLT vessel type, fopt = 24 thousand vessel days for MLT vessel. Using q, we obtain the instanteous fishing mortality rate Fopt = 0.5 per year and the fish stock level Bopt= 3 mln tons.

The actual catch and that is obtained by the model and the theoretical mean values for the northern Okhotsk Sea walleye pollock stock for the period 1981-1994 are calculated by: Bi = Yi / Fi, where i represents a particular year (Fig. 1). Since 1984, actual catches exceed the sustainable yield and the stock has declined while catches for a number of years since have been near MSY with great deviations from it recorded in 1988 and 1990. The stock is underexploited for 11 years, according to Shaefer's model. In 1992, due to the international fisheries, the actual exploitation rate greatly exceeded MSY. The strength of the walleye pollock stock slightly exceeds the optimum level and that's why the pressure of the international fishery, exerted in 1992, left it at, the optimum level.

During the last two years the stock has remained at the optimum level and the harvest has been at the optimum exploitation. In view of this, it would be reasonable not to exceed the level of cumulative catch obtained by the nations fishing in the northern Okhotsk Sea so as not to overexploit the stock of walleye pollock and bring it below the optimum level.

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Table 1. Fishery data from walleye pollock harvested in the northern Okhotsk Sea.

Years	Ya	Yf,1,m	Yf,2,l	Yf^	fg	Y1	Y2
1981	583.1	78.2	75.1	76.6	7.61	481.5	101.6
1982	710.7	96.5	71.8	83.2	8.54	572.1	138.6
1983	811.7	117.1	80	96.8	8.39	704.4	107.3
1984	1391.1	99.9	84.7	92	15.12	935	456.1
1985	1437.1	96.6	84.6	90.4	15.90	975.4	461.7
1986	1439	87.7	97.6	92.5	15.55	693.2	745.8
1987	1514.6	81.5	86.5	84	18.04	786.1	728.5
1988	1241.1	81.6	90.2	85.8	14.47	646.4	594.7
1989	1375.7	62.8	84.9	73	18.84	691.2	684.5
1990	1263	67.5	86.2	76.3	16.56	446.6	816.4
1991	1514	69.3	73.6	71.4	21.20	573	941
1992	1964.9	59.1	75.1	66.6	29.50	760.2	1204.7
1993	1591.4	60.9	71.9	66.1	24.05	827	764.4
1994	1411.7	71.2	64.8	67.9	20.78	695.7	716

Where:

Ya - total annual catch: Y1 and Y2 total annual catch for each region in thousands of tons.

Yf,1,m - the catches per unit effort by the Russian medium tonnage fleet in Y1 and Yf,2,l, large tonnage fleet in Y2 in tons per vessel day.

Yf^ - mean geometrical catch per unit effort in tons per vessel day.

fg - cumulative fishing effort by hypothetically averaged vessel with mean geometrical unit effort expressed in thousands of vessel days.

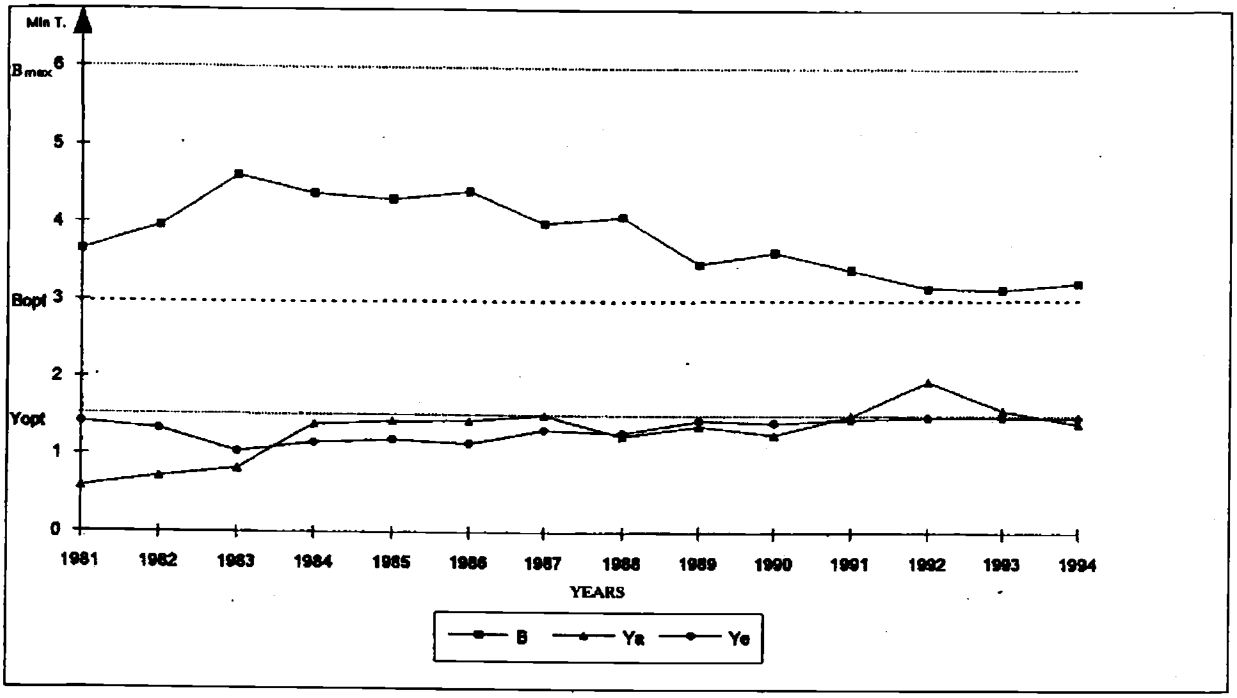

Fig. 1. Okhotsk Sea walleye pollock catches: Ya - cumulative catch for the northern Okhotsk Sea; Ye - equilibrium catch; B - biomass of the stock for 1981-1994 shown with respect to optimum catch levels (Y opt) and optimum stock (B opt); maximum stock biomass - B_{max}.

Water Soluble Polysaccharides of some Far-Eastern Seaweeds

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Seaweeds contain a large number of different polysaccharides that are of interest to mankind. These substances perform a broad spectrum of functions in seaweeds. They serve as energy resources, take part in the formation of cell walls, of outer capsules and in the internal matrix and cause selective cation absorption. The water extracts obtained from seaweeds and polysaccharides isolated from these extracts were shown to possess immunomodulatory and anti-tumor activities and to be able to bind some heavy metals, etc. (Colwell, 1985). These polysaccharides have enabled scientists to develop modern biotechnology tools and techniques (Reen, 1993). Although the results of many studies ascribe different physiological properties to these polysaccharides few can be found in the literature and few, if any, have ever reached commercial importance.

The abundant supply of algae and the large variety of their species make it possible to exploit the Russian Far-Eastern seas algae on an industrial scale. The main regions for commercial seaweed harvesting are the coasts of Primorye, Sakhalin Island and South Kurile Islands (Kizevetter et al., 1981).

Laminarans, fucoidans and alginic acids are the main polysaccharides of brown seaweeds. Their contents vary from 50 to 80% of alga dry weight. During seaweeds processing, these valuable water-soluble polysaccharides are waste despite the fact that they are widely used in the food industry and in medicine.

Term "laminaran" describes a group of the reserve, water-soluble $1\rightarrow3$; $1\rightarrow6$-β-D-glucans with low molecular mass isolated from seaweeds of Phaeophyta. Laminarans from different sources are well known to vary considerably in both content, and structure (Zvyagintseva et al., 1994). The study of 1, 3-β-D-glucanases and their substrates $1\rightarrow3$-β-D-glucans are explained by the direct participation of these substances in animals and plant immunity.

Fucoidans are the sulfated polysaccharides composed mainly of α-$1\rightarrow2$ or α-$1\rightarrow3$-linked L-fucose residues and they can also contain residues of galactose, mannose, xylose, and glucuronic acid. Fucoidans are nontoxic polyelectrolytes. They can be used like alginic acids for heavy metal binding or, like dextran sulfate for HIV infection treatment (McClure et al., 1992), etc.

The purpose of this study is to investigate the content and structure of laminaran and fucoidan collected from the most widely distributed Far-Eastern seaweeds: brown algae *Laminaria cichorioides, L.gurjanovae, L.digitata, L.japonica, Fucus evanescens*, and grass *Zostera*. Recently, a simple method for separation and isolation of $1\rightarrow3$; $1\rightarrow6$-β-D-glucans and fucoidans was developed in our laboratory. It allows the isolation of laminarans from very dilute solutions and to effectively separate them from fucoidan. A sample from dry powdered alga fronds is successively extracted with cold (t° ~20-25°C) and hot (t° ~70-80°C) water and the resultant extracts are separately subjected to hydrophobic chromatography. Structures of the laminarans and fucoidans isolated are studied using specific enzymes, and by means of gel-filtration, IR-, mass- and ^{13}C-n.m.r. spectroscopy, by methylation analysis, and other standard methods of carbohydrate chemistry. The monosaccharide contents of these glycans are determined by means of carbohydrate analyzer after the complete acid hydrolysis.

The yield of polysaccharides from seaweeds appreciated concerning the dry weight of fatless frond (Table 1). The laminaran content varies from species to species and depends on the season. The greatest quantities accumulate in *Laminaria cichorioides* in the autumn.

The ^{13}C-n.m.r spectra of polysaccharide fractions provide evidence of the presence of 1→3; 1→6-β-D-glucans in almost all except for the hot extract fraction from *L.gurjanovae*, representing a linear 1→3-β-D-glucan (Table 2). The signal in the substituted C-1 (around 103.0 p.p.m.) and C-3 (85.0-87.0 p.p.m.) regions are complex for the majority of glucans and indicate their branched structures (Table 2).

All glucan fractions are treated with exo-(1→3)-β-D-glucanase from *Eulota maakii*. This enzyme produces D-glucose upon sequential hydrolysis of laminaran from the non-reducing end circumventing the β-(1→6)-linkages as they appear at the terminal end and attacks the adjacent β-(1→3)-linkages liberating gentiobiose. The molar ratio of gentiobiose to glucose estimated during enzymatic hydrolysis reflects the degree and localization of the glucan branching. Enzymatic hydrolysis products are analyzed by h.p.l.c. Besides the contents of 1,3-β- and 1,6-β-linked glucose residues are determined by methylation analysis and by ^{13}C-n.m.r. spectroscopy. The findings indicate that laminarans from the alga studied differ considerably in the ratio of 1, 3-β-linked glucose residues to 1, 6-β-ones (from 2:1 to 49:1) (Table 3).

The laminarans under study are also found to differ considerably in molecular mass reaching, in some cases, the value of about 50 kDa (Table 3, laminarans isolated from *Laminaria digitata* and *Zostera*).

All glucans under study are optically active and have negative rotation except for laminaran II from *Zostera* (Table 3). The water solution rotates in the polarization plane to the right but the solution in 0.05 M sodium hydroxide is optically inactive. This observation indicates that laminaran II from *Zostera* probably has an ordered triple-helical structure in neutral solutions.

So, neutral polysaccharides from the brown alga examined aree mainly 1→3; 1→6-β-D-glucans which differ considerably in the degree of branching, molecular-weight distribution, the value of specific rotation, the availability to enzymatic hydrolysis.

All seaweeds studied also contained a considerable quantities of fucoidan (Table 1). Fucoidans were the high sulfated heteropolysaccharides: IR-spectra showed characteristic absorption-peak at 842 cm^{-1}. Their molecular masses varies in a wide range. IR- and ^{13}C-n.m.r. spectra of fucoidans isolated from different sources differed including their monosaccharide compositions (Tables 1 and 4). One of the fucoidan fractions isolated from *Fucus evanescens* involved attention due to the following peculiarities: L-fucose content is diminished, but galactose content is raised; mannose is absent, but the presence of unidentified monosaccharide X was noted.

Brown alga *Laminaria cichorioides* seems to be a rich source of laminaran, and *Fucus evanescens* contained the greatest quantity of fucoidans differing in their structures.

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TABLES

Table 1. The contents and some characteristics of glycans isolated from different sources.

Source, glycan		Yield, % of dry weight	Monosaccharide content, %
Laminaria	laminaran	10-12	Glc
cichorioides	fucoidan	15	Glc (5); Xyl (-); Gal (18.7); Fuc (64); Man (4);
(Troitsa Bay, Sea of Japan)			Rha (1.5); X* (1)
Laminaria	laminaran I	4.5	Glc
gurjanovae	laminaran II	0.5	Glc
(Academiya Bay,	fucoidan	19	n.d.
Sea of Okhotsk)			
Laminaria	laminaran I	0.32	Glc
digitata	laminaran II	0.45	Glc
(Sea of Okhotsk,	laminaran III	0.08	Glc
near Magadan)	laminaran IV	0.78	Glc
fucoidan		n.d.	n.d.
Laminaria	laminaran	1.0	Glc
japonica	fucoidan	12	Glc (2); Xyl (5); Gal (31); Fuc (55); Man (-);
(Troitsa Bay, Sea of Japan)			Rha (3)
Fucus evanescens	laminaran	3	Glc
(Sea of Okhotsk, Kraternaya Bay)			
	fucoidan I	24	Glc (3); Xyl (2); Gal (13.1); Fuc (62); Man (3); Rha (2); X (1)
	fucoidan II	0.5	Glc (5); Xyl (9); Gal (23); Fuc (42); Man (-); Rha (5); X (13)
Zostera	laminaran I	0.61	Glc
(Sea of Japan,	laminaran II	0.087	Glc
Troitsa Bay)			

Table 2. The chemical shifts of the carbon atoms in ^{13}C-N.M.R.-spectra of laminarans obtained from different sources.

Source,	fraction	β-linkage type	C1	C2	C3	C4	C5	C6
Laminaria cichorioides	laminaran	1→3	103.0	73.8	85.1	68.8	76.6	61.4
		1→3,6	103.3	74.1	85.6	70.3	75.2	69.4
		mannitol						63.8
L. gurjanovae	laminaran I	1→3	103.0	73.8	85.1	68.8	76.3	61.4
		1→3,6			85.6	70.3		
		mannitol						63.8
L. gurjanovae	laminaran II	1→3	103.0	73.8	85.1	68.8	76.6	61.4
		1→3,6				70.3	75.2	
		mannitol						63.8
Fucus evanescens	laminaran	1→3	103.0	73.8	85.1	68.8	76.6	61.4
		1→3,6	103.3	74.1	85.6	70.3	75.2	
		1→6	103.3	74.1	76.2	70.3	75.6	69.4
		mannitol						63.8
Zostera	laminaran I	1→3	103.6	74.3	85.8	69.4	76.8	61.9
Zostera	laminaran II	1→3	103.6	74.4	85.8	69.4	76.6	62.1
					86.2			
		1→3,6	103.9	74.9	77.1			69.8
		mannitol						64.2

Table 3. Some characteristics of laminarans isolated from different sources.

Source	glycan	Molecular-weight distribution, kDa	Contents of 1→6-linked Glc, %	Value of specific rotation, °
Laminaria cichorioides	laminaran	3-6	10	-12
Laminaria gurjanovae	laminaran I	3-4.5	2	n.d.
	laminaran II	5-50	10	n.d.
Laminaria digitata	laminaran I	35.5-45	0	-146.5[1] (0.07)[2]
	laminaran II	35.5-50	10	-18.9[1] (0.54)
	laminaran III	22.5-40	6.5	-60.6 (0.12)
Laminaria japonica	laminaran	4-5	10	n.d.
Fucus evanescens	laminaran	5-9	35	-44.3 (0.07)
Zostera	laminaran I	5-8	6	-19.6 (0.09)
	laminaran II	4-50	0.1	-26.3 (0.08)

1 - the optical rotation of solution was measured in 0.05 M NaOH;
2 - the laminaran concentration, %.

Table 4. The chemical shifts of the carbon atoms in ^{13}C-N.M.R.-spectra of fucoidans obtained from different sources.

Laminaria cichorioides	*Laminaria japonica*		*Fucus evanescens*	
		[6]	I	II
16.5 16.8 17.1 17.3	16.7 17.2 17.3	18.14 18.32 18.46	16.8 17.1	16.5
	28.0		22.0	
62.1				62.6 62.1
	64.3			66.4
67.2 67.8 68.2	68.2		68.5	67.8 68.2
				69.5
	70.9			70.6
71.5	71.1	71.06 71.39	71.1	71.6
	72.4	72.35	72.5	
74.4	74.1	73.82 74.42 74.65 74.86		73.1 73.6 73.9 74.3
		75.89 75.97		
	77.2			76.8 77.0 77.7 78.4
79.9	79.0		79.0 79.5	
	81.0		83.2	
		95.18	94.67 96.4 98.0	98.2
99.1	101.0	99.19	99.8 100.5 101.1	99.8 101.8
			102.1	104.4