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Dynamics of distribution and abundance of demersal fish in the Barents Sea based on Russian bottom trawl surveys 1998-2010

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Introduction

Changes of climate have a significant impact on marine ecosystems, as a whole, including populations of different fishes. Water temperature, as well as its salinity, is the main factor immediately influencing the changes in distribution of different fish species. Variations of water temperature lead to change in different species distribution areas and, hence, in fish communities structure and interspecific relations.

Since 1982 Polar institute (PINRO) conducted the survey of demersal fish in wide areas of the Barents Sea in October-December. Originally only commercially important fish species were objects of investigations, and since only 1998 all fish species from catches began to be investigated. It allows analyzing changes of abundance and distribution of most fish species in the Barents Sea during last decade.

Main objective of the present work was to study of abundance dynamics and distribution peculiarities of various fish species in thee Barents Sea during warm period conditions as a result of influence of different oceanographic characteristics.

Material and methods

The data of autumn-winter research survey on estimation of juvenile year classes and demersal fish stocks carried out by PINRO in the Barents Sea in October-December since 1982 were used in the paper. Totally 400-500 bottom tows were carried annually.

Relative occurrence of a fish species (number of tows with the species as a percentage from total number of tows carried), the maximum and minimum latitude and longitude were used as characteristics of each species distribution in the Barents Sea.

Bottom water temperature on several standard oceanographic sections which are carried out by PINRO as well as some characteristics of frontal zones were used for the characteristic of fish habitat conditions and an indicator of climatic changes in Barents Sea (Figure 1).

Bottom water temperature was measured by using of CTD-unit before or after trawling stations.

An index of frontal zone (IFZ), a mean gradient (MG) and average water temperature of frontal zone were used as characteristics of frontal zones. These parameters were separately calculated for depths of 50 and 100 m.

Results and discussion

The data on water temperature on the standard oceanographic section «Kola meridian» which is carried out since 1900 are traditionally used as indicator of heat content of the Barents Sea waters.

Dynamics of mean annual anomalies of bottom temperature on this section have shown that last years (2000-2010) were estimated as warm or abnormally warm referred to their heat content and some years were the warmest for more than centenary observation period (Figure 2).

1. Short description of climatic conditions in the Barents Sea during 2000-2010

The data on water temperature on the standard oceanographic section «Kola meridian» which is carried out since 1900 are traditionally used as indicator of heat content of the Barents Sea waters (Karsakov, 2009).

Dynamics of mean annual anomalies of bottom temperature in active layer on this section have shown that last years (2000-2010) were estimated as warm or abnormally warm referred to their heat content and 2006 was the warmest for more than centenary observation period (Figure 2).

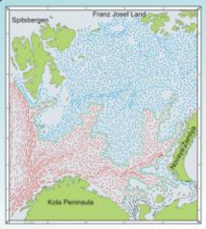

Figure 3. Scheme of currents in the Barents Sea (Tantsura, 1959)

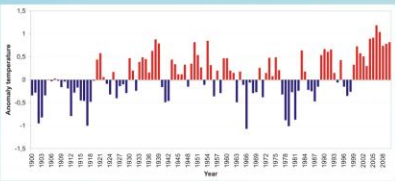

Figure 2. Mean annual anomalies of water temperature on the Kola sections in 0-200 m layer in 1900-2010

2. Dynamics of fish species abundance

Some relationships in dynamics of abundance of various fish families in 1998-2010 have been revealed (Figure 4).

Six families (Rajdae, Clupeidae, Macrouridae, Cyclopteridae, Liparidae, Zoarcidae) from 31 families showed the tendency to decrease in their mean catches while mean catches of other 2 families (Gadidae and Scorpaenidae), on the contrary, were increased. For other families obviously expressed relationships in their dynamics were not observed.

Dynamics of abundance in these families could be caused by various factors (stock state, reproduction level etc.). But at the same time for some families distinct relations between changes in their abundance and oceanographic parameters has been revealed.

So, an inverse relationship between mean catches of Rajidae and both mean annual temperature and its anomalies on the Kola section, average water temperature of frontal zone on 100 m depth, temperature on the section 37 (the Novay Zemlya current) and water temperature in the main branch of the Murmansk current (R^2 0,54-0,68) were revealed. Besides, relations between abundance of Cyclopteridae (inverse) and Myctophidae (direct) and mean gradient of frontal zone on 50 m and 100 m depth (R^2 0,58-0,61). Mean catches of Macrouridae decreased at increasing of water temperature at the section 3 (the Nordkap current) (R^2 0,64). In Liparidae direct relation to the index of frontal zone on 50 m depth (R^2 0,59) and inverse relation to mean water temperature of frontal zone on 100 m depth (R^2 0,51) were found.

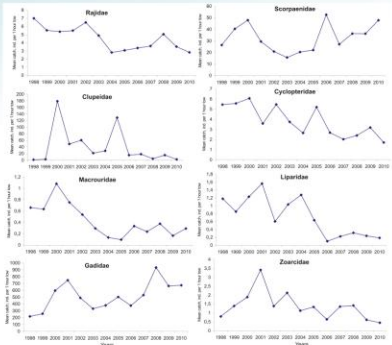

Figure 4. Dynamics of mean catches of fish species from various families in 1998-2010

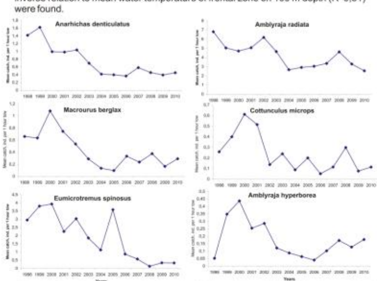

Figure 5. Dynamics of decreased catches of mainly boreal (Anarhichas denticulatus, Amblyraja radiata), boreal (Macrourus berglax), mainly arctic (Cottunculus microps) and arctic (Eumicrotremus spinosus, Amblyraja hyperborea) species in 1998-2010

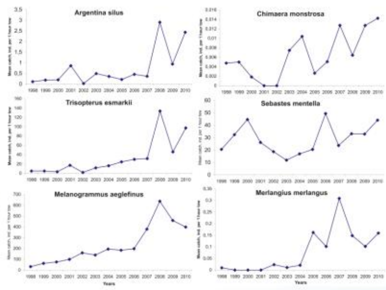

Figure 6. Dynamics of increased catches of boreal (Argentina silus, Chimaera monstrosa, Trisopterus esmarki), mainly boreal (Sebastes mentella, Melanogrammus aeglefinus) and southern boreal (Merlangius merlangus) species in 1998-2010

Differences in dynamics of abundance of species from different zoogeographical groups were also observed (Figure 7). So, practically almost wide distributed and southern boreal species showed the tendency to increase in their mean catches. In contrast, most of Arcto-boreal, mainly Arctic and Arctic species (from 66 to 86 % of species in these groups) decreased in abundance, while abundance of only small parts of species (from 33 % among Arcto-boreal to 8 % among Arctic group) essentially hadn't changed, and only at one Arctic species (Ulcina olriki) showed slight increasing of catches. Simultaneously the most numerous and widespread in Barents Sea groups (mainly boreal and boreal species) had almost equal ratio of species increased and decreased their abundance 38-50 % and 43-51 %.

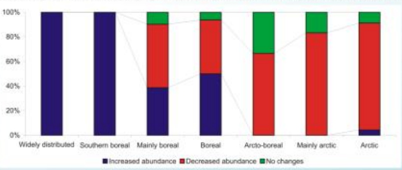

Figure 7. Ratio of species with various dynamics of catches in 1998-2010 in various zoogeographical groups

The ratio of warm-water and cold-water species sharply changed during 1998-2010. Generally the domination on number of warm-water kinds (from widely distributed to mainly boreal species) approximately in 93 times was observed. At the same time their domination was rather moderated from 3 to 18 times until 2005. In 2006 and 2009-2010 the ratio has increased to 311-376 times and abundance of warm-water species exceeded abundance of cold-water species in 25-76 time even in years with some its decreasing (2007-2008).

At the same time various characteristics of frontal zones on different depths had the greatest influence on abundance dynamics of species from different zoogeographical groups (R^2 0.51-0.66) – an index IFZ (for boreal and southern boreal species), a mean gradient (for widely distributed species) and mean temperature of frontal zone (for mainly Arctic species).

3. Habitat conditions of fish species

The analysis of average temperatures of various fish species habitat and their range showed that at the majority of species occurred in the wide range of temperatures – from 1-2°C in witch flounder *Glyptocephalus cynoglossus* and Atlantic herring to 10°C in cod, long rough dab and thorny skate (Figure 8) was marked. At the same time distinct differences in average habitat temperatures weighed to catches of each species were accurately expressed. The most cold-water species were leatherfin lumpsucker *Eumicrotremus derjugini* and gelatinous snailfish Liparis fabricii which occurred mainly at temperature below 0ºC. The maximum average temperatures of habitat have been observed in lemon sole *Microstomus kitt*, greater argentine *Argentina silus*, Norway redfish *Sebastes viviparous* and Norway pout *Trisopterus esmarkii*.

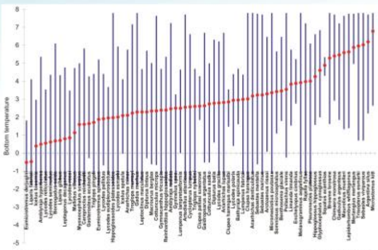

Figure 8. Mean weighted by catches values and range of habitat temperature of various fish species in the Barents Sea in 1998-2010

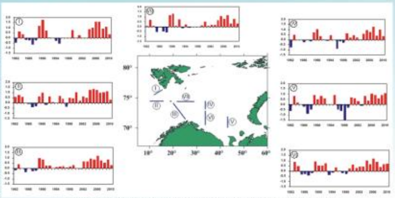

Figure 1. Dynamics of anomalies of bottom temperature in active layer on the standard oceanographic sections in the Barents Sea in 1982-2010

4. Distribution of various fish species in the Barents Sea

Commonness degree, and also indirectly the distribution area size in Barents Sea of each species is rather well characterized by number of tows with occurrence of this species related to total number of tows conducted (Figure 9).

The most common and widespread species in Barents Sea are long rough dab and cod which in average occurred in 93,4 and 93,2 % all tows respectively. The range of changes in their distribution size was rather small and even in years they had less wide distribution they occurred in not less than in 87-89 % of tows. The next 3 species (haddock, thorny skate and Greenland halibut) occurred in 54-75 % of tows, however a range of changes of their distribution was much higher compared to the previous group (from 48-56 to 65-91 %). Other 18 species occurred in 10-48 % of tows while rest of species (91 species) - in less 10 %.

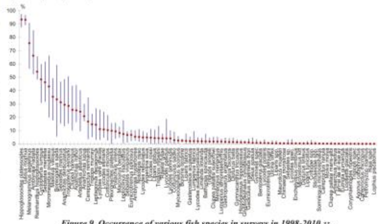

Figure 9. Occurrence of various fish species in surveys in 1998-2010 zz., % from total number of tows

The analysis of relationships between relative abundance of various fish species and their occurrence in surveys has shown an existence of such relation in the most of fish species, high values of the Pearson's coefficient (R2>0.5) were observed in 66 of 86 species or about 76 % investigated species (Figure 10).

But a portion of species with distinct relationships was different in various zoogeographical groups. In coldwater species (Arctic, mainly arctic and arcto-boreal groups) such relation occurred in from 80 to 100 % of species. In warm-water species (southern boreal group) this portion was slightly smaller (75 %). In the most widespread in the Barents Sea species (mainly boreal group) similar relation has been revealed only in 67 % of species. So, cod and haddock didn't show such strong relationships that possibly related to not completely covered by surveys area of distribution of these species.

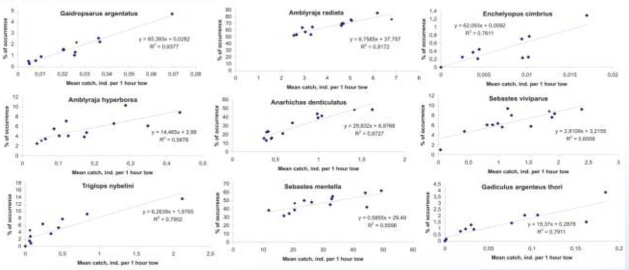

Figure 10. Relationships between relative abundance and distribution area size cold-water, warm-water species and species with wide range of temperature

5. Influence of oceanographic characteristics on fish distribution

The temperature growth due to the increased advection of warm Atlantic waters results in the increase in abundance and wider distribution in the Barents Sea with widening the boundary of the area of warm-water species northwards and eastwards. At the same time, with the increased inflow of the Atlantic waters the area of cold water arctic species (arctic skate, Careproctus-species, most of eelpouts, bigeye sculpin and others).

Strong relations between various characteristics of fish distribution (the minimum and maximum latitude and longitude, range of latitude and longitude) and oceanographic parameters (an index, a gradient and mean water temperatures of frontal zones on 50 and 100 m depth, water temperature on 7 standard oceanographic sections) are revealed. Such relationships were observed in 62 fish species, however the greatest numbers of the revealed pair dependences were observed in White Sea herring (49), grey gurnard (28), round nose grenadier (24), greater argentine (22), four-bearded rockling (14), arctic sculpin (12), sail ray (10) and whiting (9).

The closest relationships have been revealed between oceanographic characteristics and distribution in fish species which have rather limited distribution area in the Barents Sea, both in cold-water and warm-water species. So, the majority of distribution characteristics of White Sea herring and four-bearded rockling depended on various characteristics of frontal zones on 50 m and 100 m depth and water temperatures on adjacent sections (Table 1).

Table 1. Pearson R^2 values of relationships between distribution parameters of White Sea herring and four-bearded rockling and oceanographic parameters in the Barents Sea

Oceanographic parameters	Latitude			Longitude		
	Min	Max	Range	Min	Max	Range
Clupea pallasii marisalbi						
Kola section (mean temperature)	0.22	**0.95**	0.36	0.21	**0.82**	0.00
FZ index 50 m	**0.97**	**0.61**	0.07	**0.96**	0.05	**0.68**
FZ gradient 50 m	**0.53**	0.00	**0.87**	**0.53**	0.43	**0.89**
FZ mean temperature 50 m	**0.90**	**0.74**	0.01	**0.89**	0.13	**0.54**
FZ index 100 m	**0.93**	**0.70**	0.03	**0.92**	0.10	**0.59**
FZ gradient 100 m	**0.98**	0.42	0.19	**0.98**	0.00	**0.84**
FZ mean temperature 100 m	**0.56**	0.00	**0.85**	**0.56**	0.40	**0.91**
Section 3, st. 2-6,0-200 m	**0.61**	**0.97**	0.05	**0.60**	0.43	0.21
Section 52, st. 5-7,0-200 m	**0.75**	0.04	**0.68**	**0.75**	0.22	**0.99**
Section 31, st. 6-9, 0-200 m	0.19	**0.93**	0.39	0.19	**0.84**	0.00
Section 29, st.8-12,0-200 m	**0.75**	**0.89**	0.01	**0.75**	0.28	0.35
Section 37, st. 12-18, 0-bottom	0.03	**0.74**	**0.65**	0.03	**0.98**	0.05
Kola section, st. 8-10 0-bottom	**0.95**	0.23	0.38	**0.96**	0.03	**0.96**
Kola section, st.3-7- 0-bottom	**0.99**	**0.52**	0.12	**0.99**	0.02	**0.76**
Enchelyopus cimbrius						
Kola section (mean temperature)	0.11	0.02	0.15	0.18	0.28	0.06
FZ index 50 m	0.03	0.41	0.33	0.02	0.25	0.16
FZ gradient 50 m	0.25	0.25	**0.55**	0.02	0.16	0.40
FZ mean temperature 50 m	0.17	0.05	0.25	0.30	0.12	0.08
FZ index 100 m	0.32	0.31	**0.70**	0.06	0.31	**0.50**
FZ gradient 100 m	0.31	0.29	**0.66**	0.03	0.17	0.38
FZ mean temperature 100 m	0.26	0.12	0.44	0.06	**0.56**	0.20
Section 3, st. 2-6,0-200 m	0.10	0.04	0.02	0.14	0.27	0.01
Section 52, st. 5-7,0-200 m	**0.63**	0.01	**0.56**	0.41	0.33	**0.62**
Section 31, st. 6-9, 0-200 m	0.08	0.19	0.00	**0.50**	0.06	0.01
Section 29, st.8-12,0-200 m	0.42	0.05	0.14	**0.54**	**0.61**	0.08
Section 37, st. 12-18, 0-bottom	0.07	0.01	0.07	0.18	0.14	0.03
Kola section, st. 8-10 0-bottom	**0.84**	0.01	0.46	0.39	0.48	0.40
Kola section, st.3-7- 0-bottom	0.05	0.01	0.02	0.07	0.27	0.01

Bold - statistically reliable values

Conclusions

Thus, strong fluctuations of relative abundance of various fish species were observed in the Barents Sea during warm and abnormally warm period 2000-2010.

Generally the increase mean annual catches of warm-water (widely distributed, southern boreal) species and reduction of catches of cold-water (arcto-boreal, mainly arctic and arctic) species were revealed.

Distribution of fishes in the Barents Sea and their distribution borders are mainly defined by temperature preferences of various species and oceanographic characteristics (bottom water temperature, characteristics of frontal zones) in various parts of the sea.