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Trends in oxygen saturation of near-bottom layers in the Barents Sea: a possible indicator of long-term variations in the primary production?

by

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ABSTRACT

It is a common knowledge that a reduction in oxygen content in near-bottom layers generally results in an increase in the primary production and water bloom. In the ocean, the biochemical consumption of oxygen for destruction of organic matter is practically equal to its production by photosynthesis, i.e. it is proportionate to the primary production. Therefore, a possible explanation for a periodic decrease in oxygen concentrations in near-bottom layers in the Barents Sea is an increase in its biochemical consumption for destruction of organic matter subsiding from the photic zone.

In the Barents Sea, oxygen saturation of the near-bottom water have been periodically measured in the Kola Section. In 1957-2009, about 300 series of measurements were carried out. Year-to-year variability in anomalies of oxygen saturation of the near-bottom layers is characterized by deep minima alternating with more long-lasting periods when aeration is slightly above normal. There is an insignificant negative trend in variations in oxygen saturation of the near-bottom layers. Besides, over the past decades during warming in the North Atlantic, aeration in the near-bottom layers has decreased. Long-term variations in oxygen saturation of near-bottom layers in the Kola Section generally correlates well with the key features of oxygen conditions in the Barents Sea.

There is a statistically significant relationship between oxygen saturation of near-bottom layers and such characteristics of climate variations as water temperature and ice coverage as well as important indicators of variations in the Barents Sea ecosystem such as abundance of the Northeast Atlantic cod.

The majority of authors believe that warming in the North Atlantic caused an increase in the primary production and sedimentation of organic matter into the near-bottom layers over the Nordic Seas, including the Barents Sea. According to model estimates, the annual primary production in the Barents Sea can be increased by the tens of percent during the periods of warming.

A possible relationship between variations in oxygen saturation of near-bottom layers and those in the primary production and other effects of current climate variations in the Barents Sea is studied in this paper.

Keywords: Barents Sea, oxygen saturation, primary production.

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INTRODUCTION

Oxygen content in the seawaters appears to be affected by biochemical processes in the water column. It is a common knowledge that a reduction in oxygen content in near-bottom layers generally results in an increase in the primary production and water bloom. In the ocean, the biochemical consumption of oxygen for destruction of organic matter is practically equal to its production by photosynthesis, i.e. it is proportionate to the primary production. Therefore, a possible explanation for a periodic decrease in oxygen concentrations in near-bottom layers in the Barents Sea is an increase in its biochemical consumption for destruction of organic matter subsiding from the photic zone. The majority of authors believe that warming in the North Atlantic caused an increase in the primary production and sedimentation of organic matter into the near-bottom layers over the Nordic Seas, including the Barents Sea. According to model estimates, the annual primary production in the Barents Sea can be increased by the tens of percent during the periods of warming. Therefore, a decrease in oxygen saturation of near-bottom layers in the Barents Sea might be expected against climate warming during the last decades.

Saturation of the Barents Sea bottom waters by oxygen.

The content of oxygen in the Barents Sea waters expressed in absolute values (ml/l) is more often a “mirror reflection” of water temperature (Titov, Nesvetova, 2003). Therefore, in this paper we focus on the studying of the long-term dynamics of saturation by oxygen (%) characterizing the content of oxygen in relation to its equilibrium content in water with pressure, salinity and temperature *in situ*. The saturation of bottom waters in the southern Barents Sea (Atlantic origin water, the NEA cod habitat) by oxygen fluctuates within the limits of 80-100% and is characterized by considerable year-to-year variability (Fig.1).

Long-term changes in saturation of the Barents Sea bottom waters by oxygen from the data of observations on the Kola section.

Fig.1 presents the position of Stations 3-7 of the Kola section (70º30’N, 71º00’N, 71º30’N, 72º00’N, 72º30’N; 33º30’E, 215-280m depths). The time series of oxygen content in the seawater on the Kola section is the most long-term and provided by data as compared to those ones for standard sections in the Barents Sea. In 1957-2009, the section was made 259 times (Fig.2).

The content of oxygen in seawater was measured on each station of the section applying Winkler’s method immediately after sampling in the vessel laboratory.

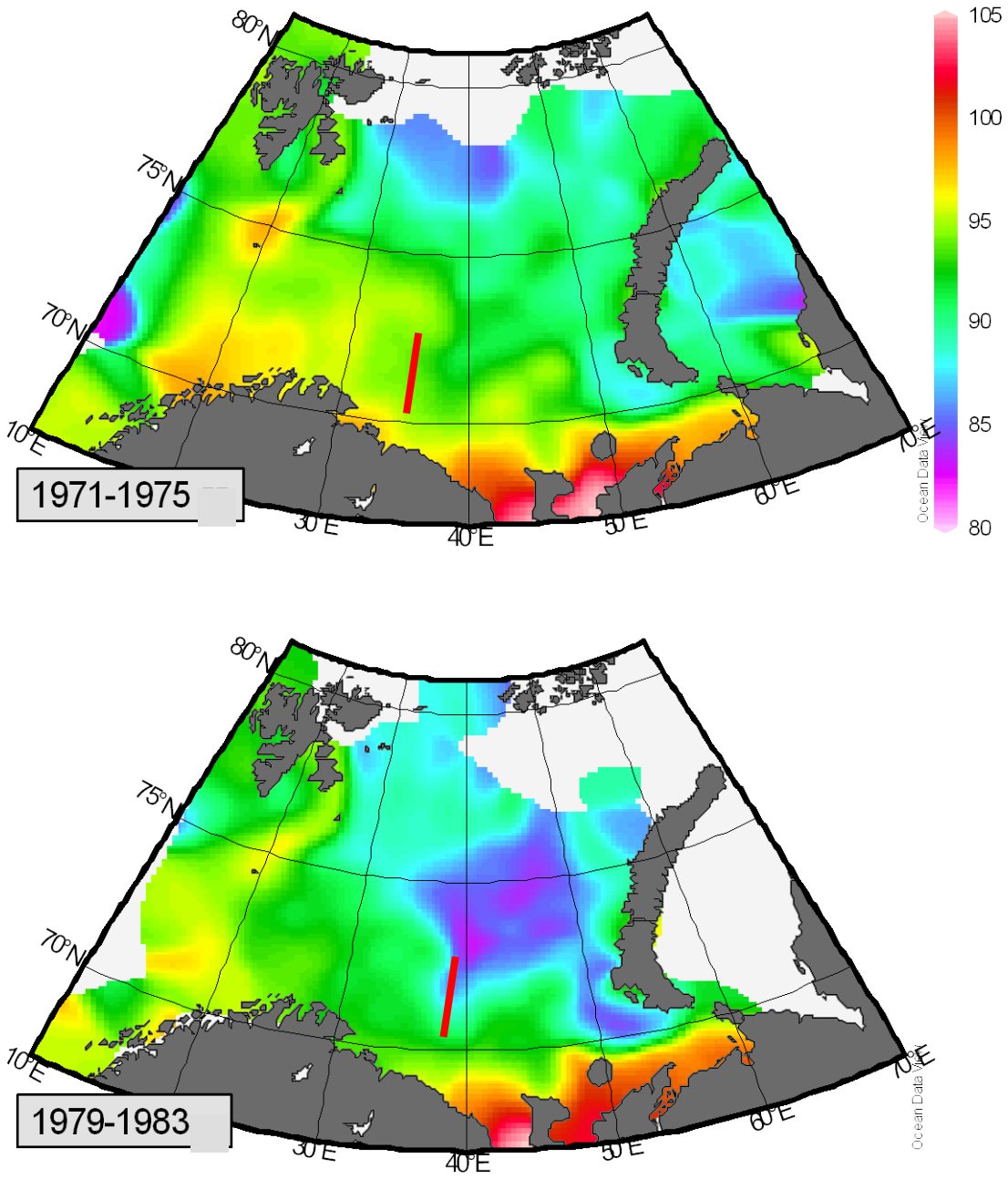


Fig.1 Saturation of bottom layers by oxygen (%) averaged for a number of years. The red line shows the position of the Kola section.

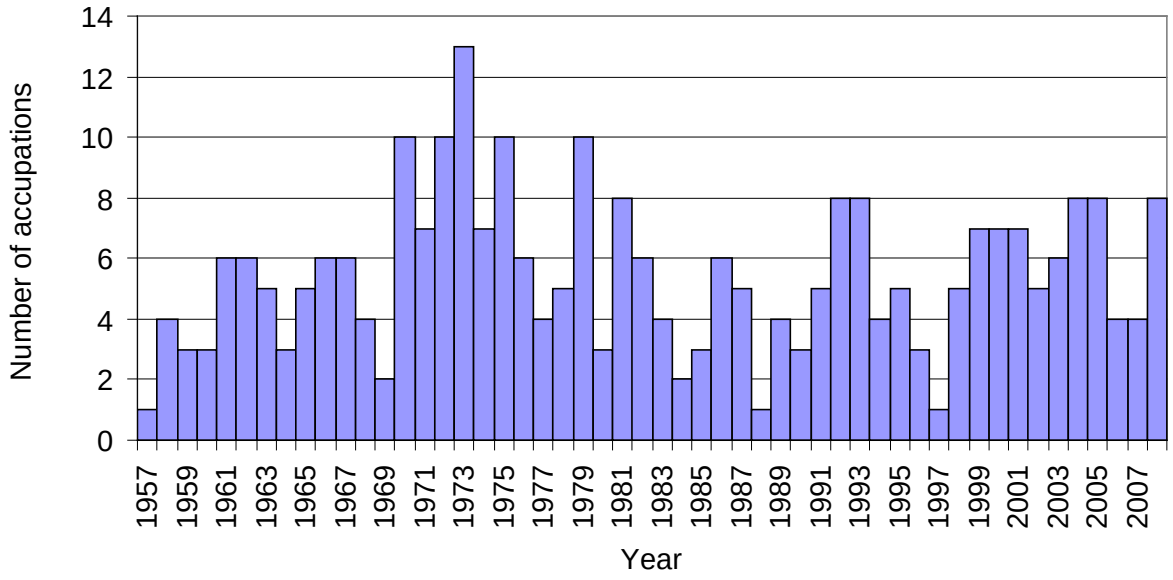
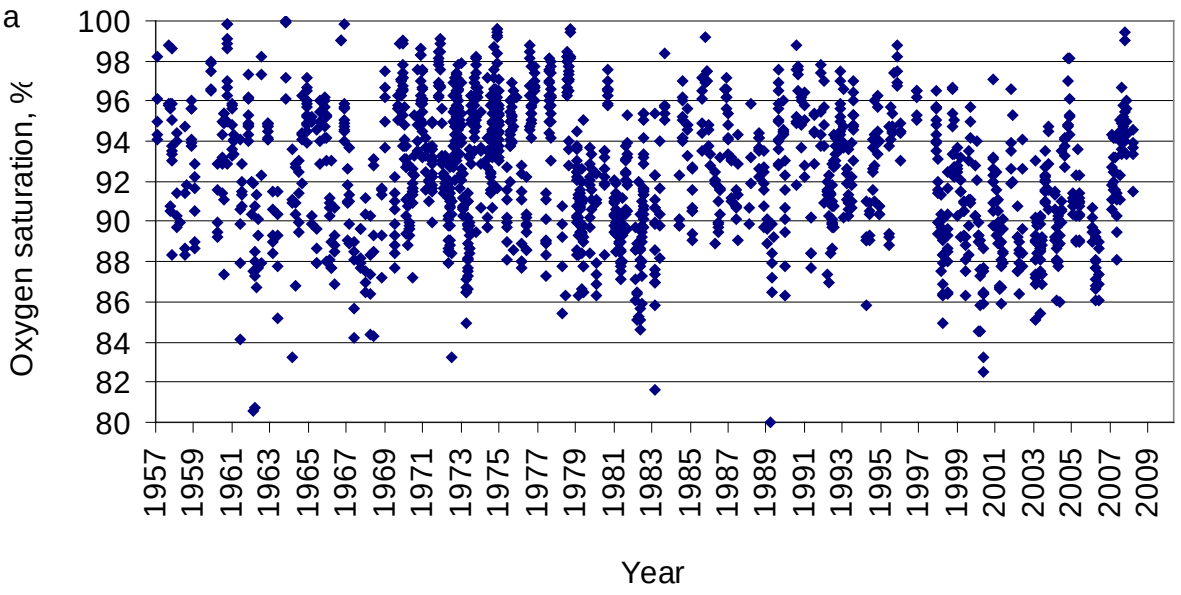


Fig.2 Number of observations over oxygen content on the Kola section in 1957-2003

Fig.3a shows the results of oxygen saturation measurement in bottom layers of the Kola section. To filter seasonal variations the anomalies of oxygen saturation were calculated (Fig.3b). Then they were smoothed (Fig.3c).



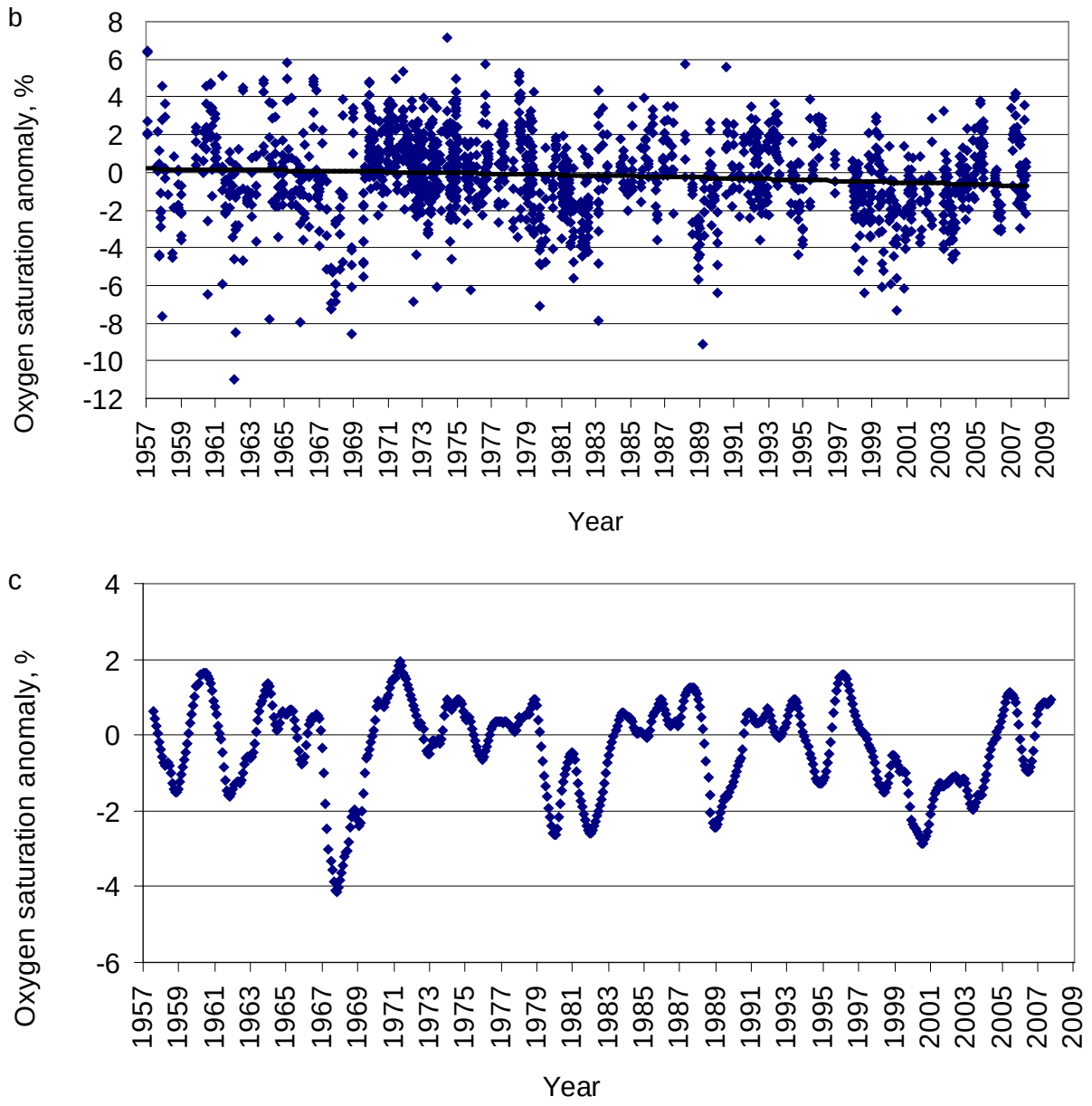


Fig.3 Saturation of bottom layers by oxygen on Stations 3-7 of the Kola Section *in situ* (a), anomalies (b), anomalies smoothed by averaging for Stations 3-7 and by moving-average method for the previous year (c). The line of the quadratic trend in figure 3b is displayed with bold colour.

Visual analysis of figures shows that year-to-year variability in anomalies of oxygen saturation of the near-bottom layers is characterized by deep minima alternating with more long-lasting periods when aeration is slightly above normal (Fig.3b,c). The line of the quadratic trend displayed with bold colour in Fig.3b indicates that the oxygen saturation of the near-bottom layers in the Barents Sea has decreased in nearly 1 % over last 50 years. Besides, most variations were observed during the last decades.

Interactions between long-term variations in oxygen saturation of near-bottom layers in the Barents Sea and physical and biological characteristics

It was earlier indicated (Titov, 2001) that variation in oxygen saturation (Fig. 3c) is not correlated with variations in air temperature and ice coverage in the Barents Sea while it may be related related to index ITa characterizing interaction between these parameters.

Index ITa was used as a characteristic of intensity of interaction between the Arctic and boreal oceanic systems on the shelf of the Barents Sea. This index was calculated by means of numerical comparison between variations of the thermal status of atmosphere in the southern part of the Barents Sea and its ice coverage applying the method of linear regression (Titov, 2001). Parameters of the linear regression model, describing the changes of ice coverage in the Barents Sea, were calculated by variations in air temperature. After that, the differences (remainders) of mean monthly values of ice coverage and analogous values derived by the known parameters of the regression equation were calculated.

It was also stated (Titov, 2001; Titov, 2007) that the change in cod recruitment was related to aeration of bottom layers in a complex way. The principal characteristic of such interaction was the fact that abundant year-classes of cod followed the periods of relatively low oxygen saturation at the stage of increased oxygen saturation in near-bottom water layers.

Fig.4 characterizes interrelations stated above.

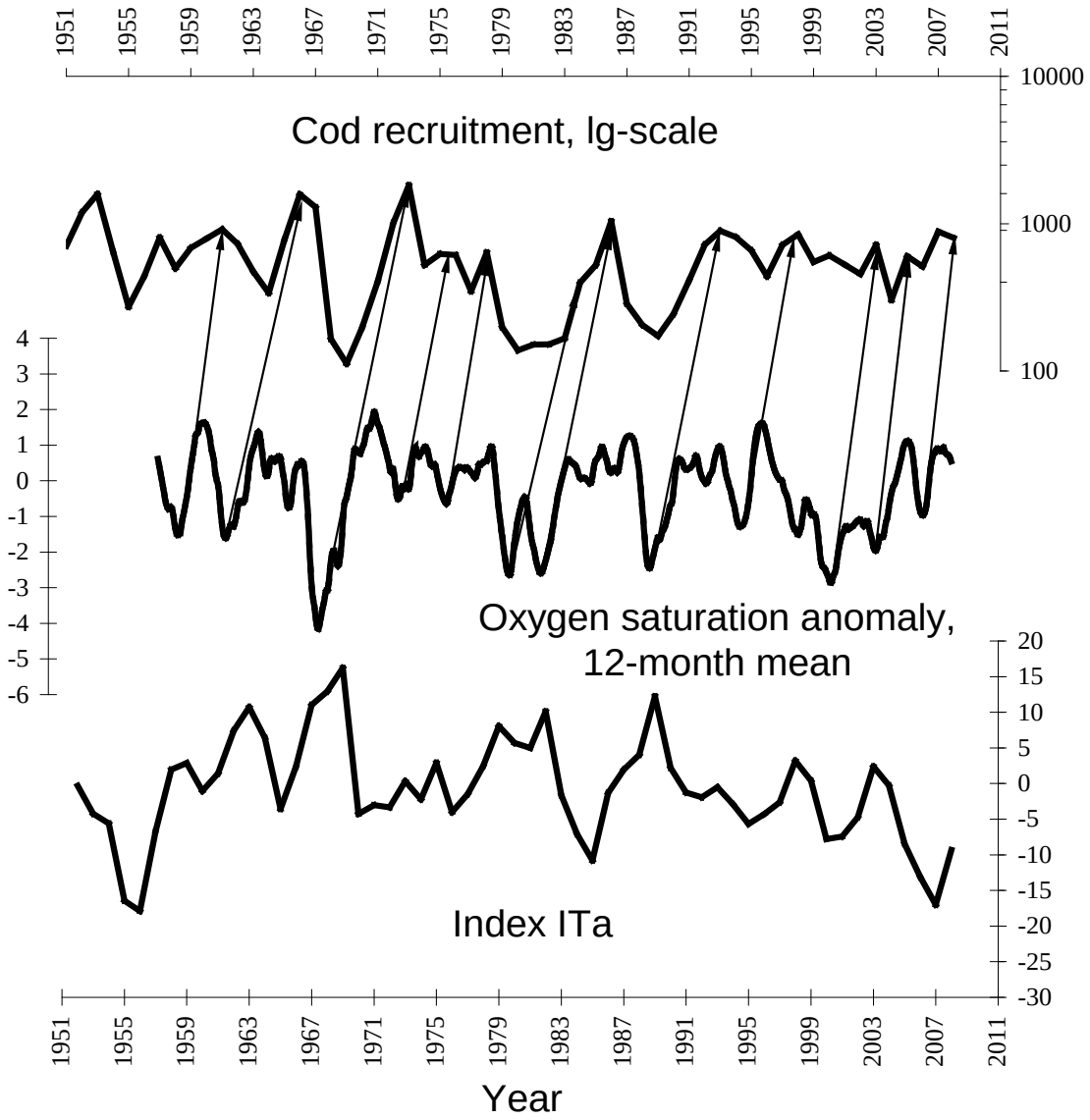


Fig. 4. Interrelation of changes of annual (beginning of the year) values of abundance of cod aged 3 considering cannibalism (above, Anon, 2009), 12-monthly mean anomalies of saturation by oxygen of near-bottom water layers at 3-7 stations of the Kola Section (in the centre, Titov, 2009), index ITa (at bottom, Titov, 2009). Arrows indicate time lags between minima of oxygen saturation and maxima of cod abundance.

Discussion

It is a common knowledge that a reduction in oxygen content and hypoxia in near-bottom layers of fresh-water basins generally result in an increase in the primary production in the surface layers. According to Ivanenkov (1980), in the ocean, the biochemical consumption of oxygen for destruction of organic matter is practically equal to its production by photosynthesis, i.e. it is proportionate to the primary production. Therefore, a possible explanation for a periodic decrease in oxygen concentrations in near-bottom layers in the Barents Sea is an increase in its biochemical consumption for destruction of organic matter subsided from the photic zone. Possible effect of biological processes on the long-term periodicity of variations in oxygen saturation in near-bottom layers of the Kola section was supposed by A.M. Norina (1980). However, there is an outstanding problem: whether oxygen saturation of the near-bottom layers results in increased production or decreased consumption of organic matter in the surface layers.

Correlation of effect from physical and biological characteristics on long-term variations of aeration in near-bottom layers can not be presently estimated in view of lack of experimental studies. However, a hypothesis of the reverse interrelation between values of the primary production in the southern part of the Barents Sea and oxygen saturation of the bottom layers can be considered as consistent. Consumption of oxygen for destruction of organic matter in the Barents Sea must be high enough, since intense sedimentation of organic matter in the Barents Sea is correspondent, at the least, to the range of values observed in the World Ocean (Vinogradov et al.,2000) and can exceed averaged values of the World Ocean by 3-8 times (Nesvetova, 1990).

The majority of authors believe that warming in the North Atlantic caused an increase in the primary production and sedimentation of organic matter into the near-bottom layers over the Nordic Seas, including the Barents Sea. According to model estimates, the annual primary production in the Barents Sea can increase by the tens of percent during the periods of warming. Therefore, a decrease in oxygen saturation of near-bottom layers in the Barents Sea might be expected against climate warming during the last decades. Year-to-year variability in anomalies of oxygen saturation of the near-bottom layers in the Barents Sea is characterized by the trend to decrease. Moreover, this decrease appeared to be the highest in the last decade against the climate warming (see Fig.3b).

Index ITa was used as a characteristic of the intensity of a relationship between the arctic and boreal oceanic systems of the Barents Sea. It is known that year-to-year variations of air temperature and ice coverage of the Barents Sea are in close relations. Therefore, the positive values of ITa index mean that air temperature exceeds its characteristic “balance” value at values of the Barents Sea ice coverage existing at the moment of observations and, correspondingly, that the Barents Sea is covered by ice at greater extent than usual under a certain thermal condition of atmosphere in the area of the Barents Sea. There are grounds to assume that increased values of ITa index coincide in time with the increase in horizontal gradients of water temperatures in the area of the Polar Front (Titov, 2001, Titov, Ozhigin, 2005).

In view of a good reverse relation between oxygen saturation of near-bottom layers and index ITa, we can suppose that the increase in the primary production is caused by intensive frontal zones in the Barents Sea.

Fig.4 shows that cod recruitment becomes large after a certain time period (3-4 years, in the mean, Titov, 2001), when oxygen saturation in near-bottom layers is decreased. Therefore, it is logical to assume that abundant year-classes of cod form following increase in the primary production in the surface layers and most organic matter subsided in the near-bottom layers.

In conclusion we assume that the hypothesis of the direct interrelation between intensive frontal zones, increased primary production and abundant year-classes of cod appeared in the Barents Sea needs further theoretical and experimental approval. However, this hypothesis being the basis for the model of the cod recruitment prognosis is presently practiced at AFWG ICES.

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