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The influence of water dynamics on the distribution of 0-group herring in the Barents Sea

by

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Abstract

An attempt was made in the paper to investigate the influence of the Barents Sea circulation calculated with a numerical model on the distribution and abundance of 0-group herring.

The wind-driven and general circulation of the Barents Sea, as well as volume fluxes in the main currents, were calculated for every month from 1983 to 2004. The analysis of the fluxes and observed distribution of 0-group herring in the Barents Sea allowed us to choose parameters for searching for relations between dynamic conditions and a character of 0-group herring distribution. It was shown quantitatively that the Barents Sea circulation influences the character of 0-group herring distribution. The relations between the fluxes and indices of abundance (area index of abundance, index of absolute abundance, area of concentrations, northern and eastern borders of young fish distribution) were found. A possibility was noted of reconstruction of the area index of abundance for the previous years using the regression equations. Test predictions of the area index and index of absolute abundance were made for September 2005. Both predictions came true.

The paper is intended to be used for comprehensive studying herring abundance formation. The necessity was noted to use hereafter not only water dynamics but also additional parameters related to the species biology.

Introduction

Water circulation plays an important role in all processes taking place in the water environment and influences both directly and indirectly the oceanographic, meteorological and biological conditions of seas and oceans.

Physical processes, including water dynamics, determine not only the areas of young herring dwelling, but also the differences in its growth rate and time of maturity coming. This leads to the interannual variations of the commercial stock recruitment (Marti, 1956; Seliverstov and Penin, 1969). Therefore, the studying of the water dynamics influence on the transport of the Norwegian spring-spawning herring in the early ontogenesis is of current importance.

The aim of the paper is to study the influence of the Barents Sea circulation on 0-group herring distribution using a numerical model.

Materials and methods

The hydrodynamic model of the Barents Sea (Trofimov, 2000) was used to calculate its wind-driven and general circulation. Volume fluxes were calculated for sections crossing the main currents (Fig. 1, Table 1): in the upper 50-m layer – on the basis of the wind-driven circulation (wind-driven fluxes) and in the whole water column, from the surface to the bottom, – on the basis of the general circulation (total fluxes).

The monthly mean water density and atmospheric pressure for 1983-2004 were used as input data during the calculations.

The area index and index of absolute abundance for 1983-2004 (Anon., 2005) were used as indices of 0-group herring abundance. The area index represents a sum of two areas: an area occupied by scattered fish concentrations and an area occupied by dense concentrations, multiplied by 10.

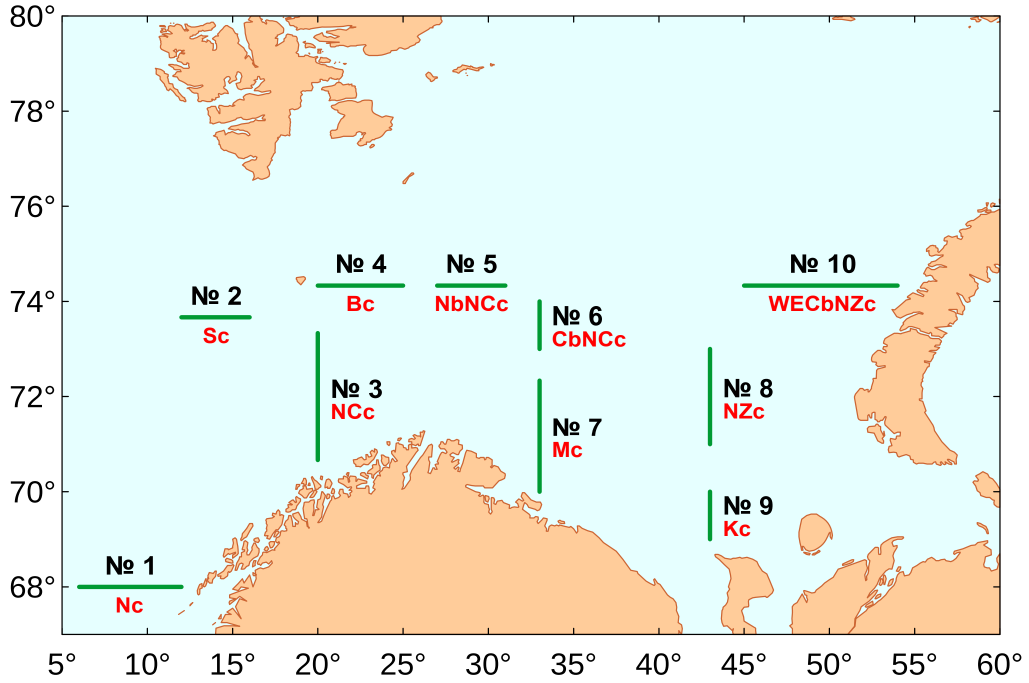

Fig. 1. The model domain and position of sections selected for calculation of fluxes.

Table 1. Sections used for calculation of fluxes

No. of section	Acronym	Name of current crossed
1	**Nc**	Norwegian Current
2	**Sc**	Spitsbergen Current
3	**NCc**	North Cape Current
4	**Bc**	Bear Island Current
5	**NbNCc**	Northern Branch of the North Cape Current
6	**CbNCc**	Central Branch of the North Cape Current
7	**Mc**	Murman Current
8	**NZc**	Novaya Zemlya Current
9	**Kc**	Kanin Current
10	**WECbNZc**	Western, Eastern and Coastal Branches of the Novaya Zemlya Current

Results

First, by the example of 1983-1998, the relations were found between fluxes (both wind-driven and total) and such parameters as the area index of abundance, area of concentrations, and the northern and eastern borders of young fish distribution. Then, by the example of a larger period (1983-2004), the relations between total fluxes and indices of 0-group herring abundance (the area index and absolute abundance) were found.

The correlation matrices were built for each section (see Fig. 1). They contain the coefficients of pair correlation between fluxes, calculated through the sections with different periods of averaging (from 1 to 12 months), and the indices of 0-group herring abundance.

Table 2 shows the regression equations obtained on the basis of the matrices. Roman numerals show a period of flux averaging.

Table 2. Regression equations indicating to the relationship between fluxes and indices of 0-group herring abundance (by the example of 1983-1998)

Parameter	Regression equation	Flux type	R^2
Area index of abundance, **Ind**	$\mathbf{Ind = 940.9 - 670.4*NCc_{VI\text{-}VII} + 3017.1*Kc_{VIII}}$	total	**0.61**
	$\mathbf{Ind = 149.7 + 8413.1*Sc_{VI\text{-}VII} + 2315.4*NCc_{VIII}}$	wind-driven	**0.52**
Area of concentrations, **S**	$\mathbf{S = 25.5 + 68.2*Sc_{VIII} - 130.4*NCc_{VI\text{-}VII} + 111.6*Mc_{VIII} + 508.6*Kc_{VIII}}$	total	**0.84**
	$\mathbf{S = 87.6 + 1130.2*Sc_{VI\text{-}VII} + 1142.6*NCc_{VIII} - 4864.9*CbNCc_{VIII} + 1533.2*NZc_{VIII}}$	wind-driven	**0.58**
Northern border of distribution, **Lat**	$\mathbf{Lat = 1/(0.0112 + 0.002/Sc_{VIII})}$	total	**0.64**
Eastern border of distribution, **Lon**	$\mathbf{Lon = 17.5 + 167.9*Kc_{VIII}}$	total	**0.50**
	$\mathbf{Lon = 42.1 + 231.3*NCc_{V\text{-}VIII}}$	wind-driven	**0.71**

For a longer period (1983-2004) it was decided to use only total fluxes when building the regression models. This decision was taken coming from the analysis of the correlation matrices and taking into account the above-stated results. This was caused by the fact that total fluxes describe the variability of the indices of 0-group herring abundance better than wind-driven ones.

As a result, the following relations were obtained for the indices of 0-group herring abundance (Fig. 2 and 3, Table 3).

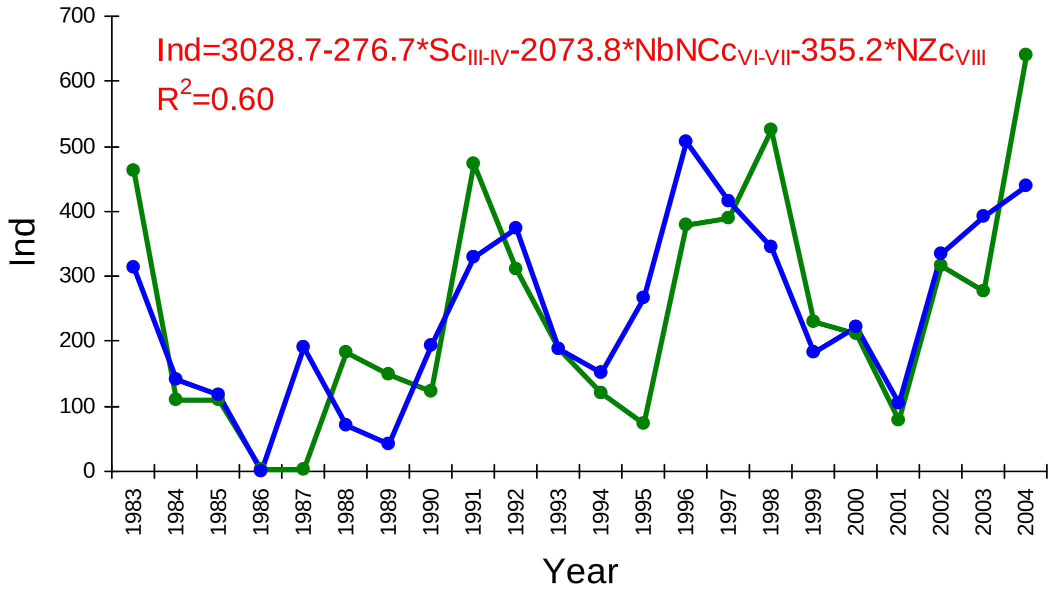

Fig. 2. The area index of 0-group herring abundance (Ind) observed and calculated with a regression equation.

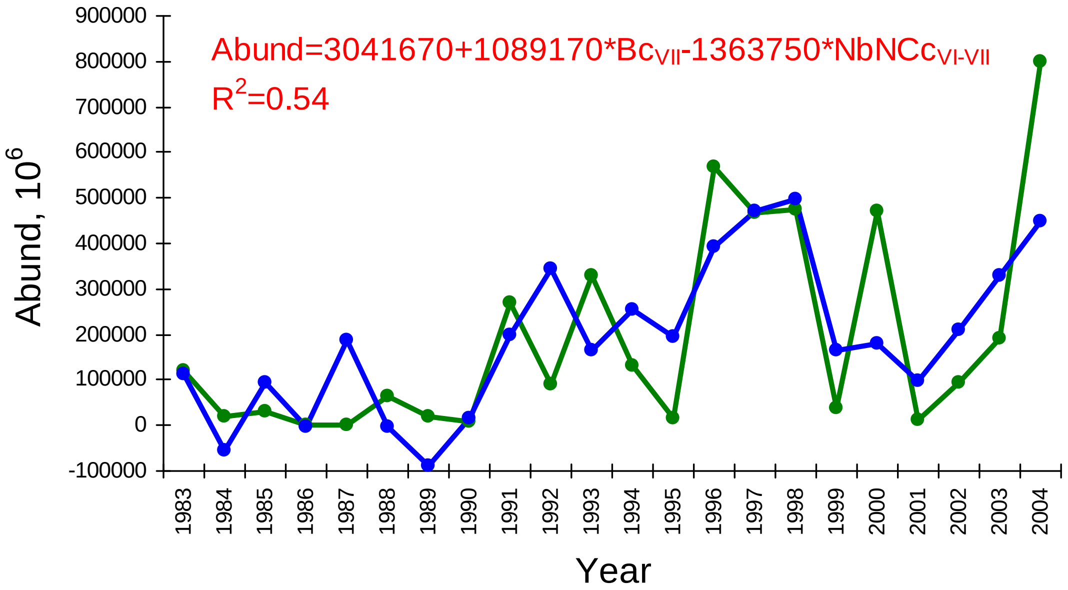

Fig. 3. The index of absolute 0-group herring abundance (Abund, 10^6 individuals) observed and calculated with a regression equation.

Table 3. Regression equations indicating to the relationship between total fluxes and the indices of 0-group herring abundance (by the example of 1983-2004)

Parameter	Regression equation	R^2
Area index of abundance, **Ind**	**Ind = 3028.7 - 276.7*Sc_{III-IV} - 2073.8*$NbNCc_{VI-VII}$ - 355.2*NZc_{VIII}**	**0.60**
Index of absolute abundance, **Abund**	**Abund = 3041670 + 1089170*Bc_{VII} - 1363750*$NbNCc_{VI-VII}$**	**0.54**

All coefficients in the presented regression equations (Tables 2 and 3) are statistically significant. It was estimated with the use of Student's test and a level of significance (Eliseeva and Yuzbashev, 2004). The acceptable values of Fisher's test and a significance level, which were also calculated when constructing the regression models, prove the adequacy of these models (Eliseeva and Yuzbashev, 2004).

To test the effectiveness of the regression models (Table 3), the comparison between their and climatic probabilities was carried out. There is an opinion that the application of a prediction method is appropriate only when the probability of an allowable error of ±0.674σ by this method exceeds the probability of the deviation from the long-term mean by not less than 18% (Anon., 1965). The probability of both regression equations (Table 3) was 68% that is 32% higher than the probability of the deviation from the long-term mean (36 %) at the same allowable error of ±0.674σ.

Discussion

Water dynamics has a certain influence on young herring abundance, but some additional predictors (a speed of larvae ascent, a spawning stock level, population fecundity etc.) are necessary for the complete description of the variability of 0-group fish abundance.

Analyzing the obtained equations one can assume that when fluxes, that is currents, decrease, drifting larvae and fries of fish adapt better to the varying environmental conditions and are transferred to the areas with unfavourable survival conditions to a lesser extent.

Test predictions of 0-group herring abundance indices were prepared for September 2005 on the basis of the data available in the PINRO database by August 1, 2005 (Table 4). Both predictions turned out to be reliable.

Table 4. Test predictions of 0-group herring abundance indices for September 2005

Index	**Factual value**	**Predicted value**	**Difference**	**Allowable error, ± 0.674 σ**
Area index of abundance	**205**	**299**	**- 94**	**± 118**
Index of absolute abundance, 10^6	**125 719**	**104 303**	**21 416**	**± 154 107**

Conclusions

The regression equations pointing out close relations between fluxes and 0-group herring abundance indices (area index of abundance [r=0.77], index of absolute abundance [r=0.74], area of concentrations, the northern and eastern borders of young fish distribution) were constructed.

Both wind-driven and total fluxes described the variability of the area of concentrations better than the area index of abundance, though in both cases the relationship was quite close (for wind-driven fluxes r=0.72-0.86, for total fluxes r =0.77-0.92).

The regression equations obtained in the paper can be probably used for restoration of missing indices of 0-group herring abundance.

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