THE INFLUENCE OF WATER DYNAMICS ON THE DISTRIBUTION OF 0-GROUP HERRING IN THE BARENTS SEA

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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): 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.

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

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.

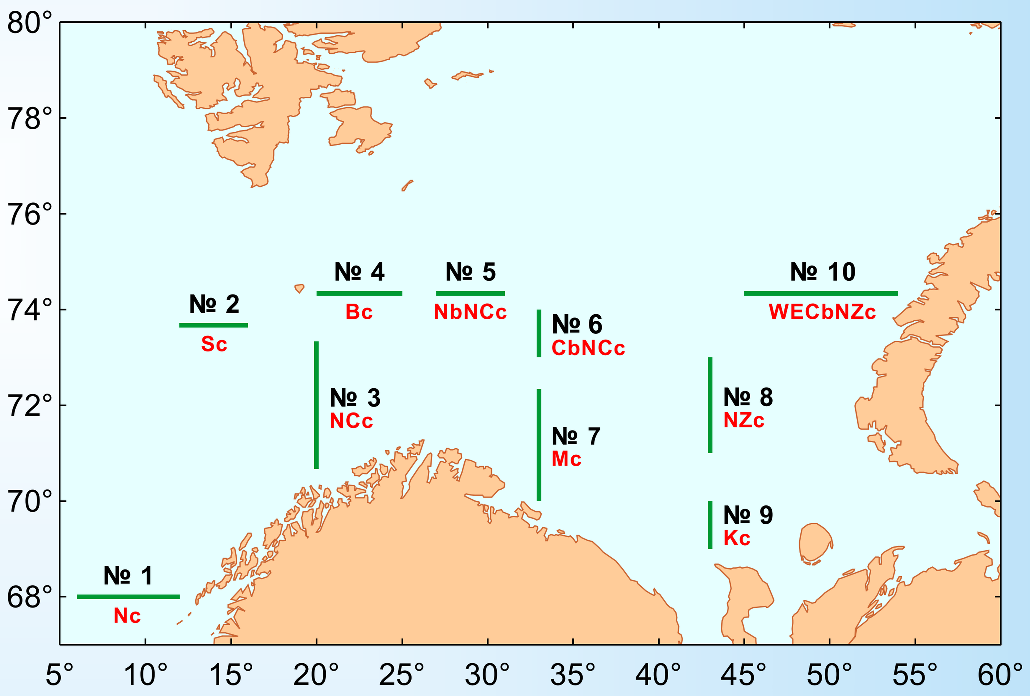

Fig. 1. The model domain and position of sections selected for calculation of fluxes.

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 (Table 2). For that, the correlation matrices were built for each section (see Fig. 1). They contained 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. Regression equations indicating to the relationship between fluxes and indices of 0-group herring abundance (by the example of 1983-1998). Roman numerals show a period of flux averaging.

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

Then, by the example of a longer period (1983-2004), the relations between total fluxes and indices of 0-group herring abundance (the area index and absolute abundance) were found (Fig. 2 and 3).

It was decided to use only total fluxes when building the regression models (see Fig. 2 and 3). 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.

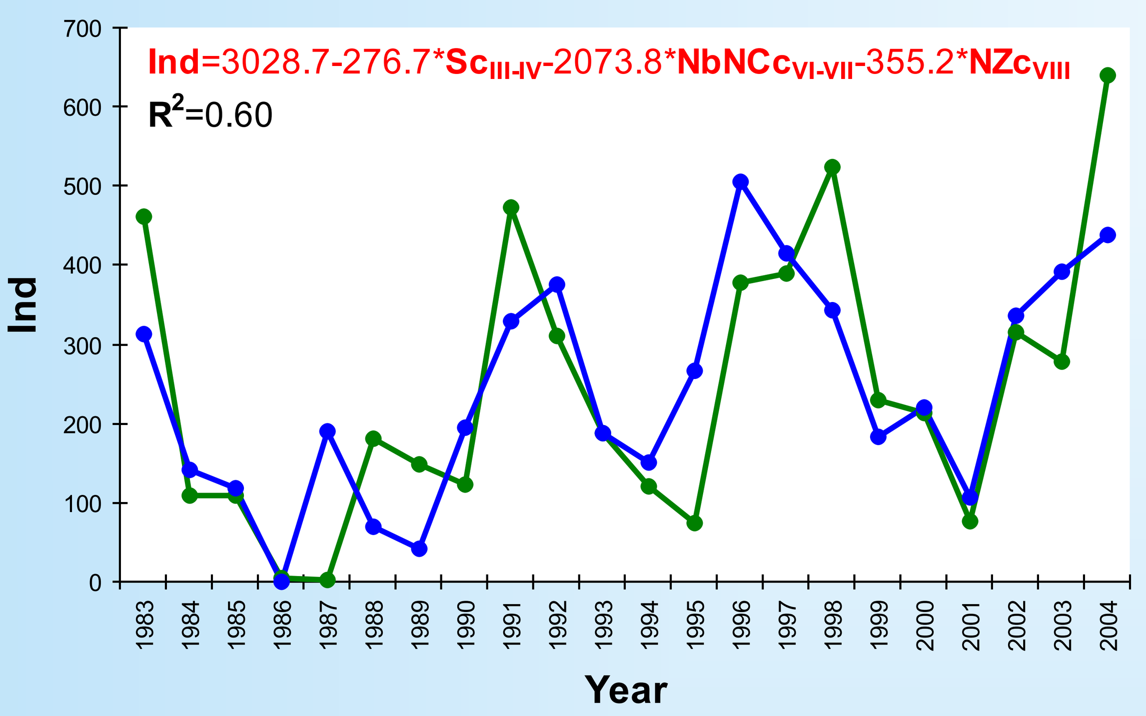

Fig. 2. The area index of 0-group herring abundance (Ind) observed and calculated with a regression equation.

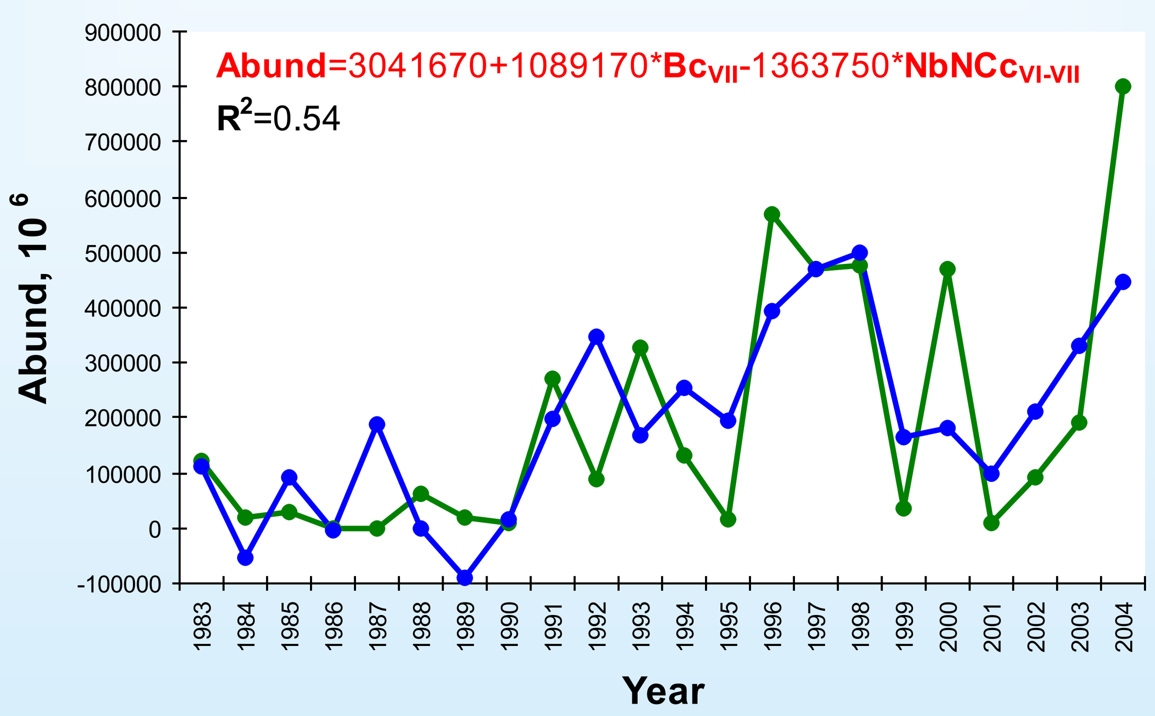

Fig. 3. The index of absolute 0-group herring abundance (Abund, 10^6 individuals) observed and calculated with a regression equation.

All coefficients in the presented regression equations (see Table 2, Fig. 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 (see Fig. 2 and 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 ±0.674y 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 (see Fig. 2 and 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 ±0.674y.

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 3). Both predictions turned out to be reliable.

Table 3. Test predictions of 0-group herring abundance indices for September 2005.

Index	Factual value	Predicted value	Difference	Allowable error, ±0.674y
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, absolute abundance, 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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