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On Relationships of Some Commercial Fish Species Year-class Abundance and Hydrological Conditions in the Northwest Atlantic

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Abstract

Year-class abundance variations of silver hake, cod, pollock, haddock, herring and capelin in several areas of the Northwest Atlantic were studied in relation to interannual water temperature variability during 1977–91. The relationships are discussed based on the hypothesis that different hydrological structures of oceanographic conditions impact the abundance of fish year-classes. Qualitative, direct and inverse relationships were revealed to suggest that the year-class abundance of warm-water fish species is more related to the warm water advection on the shelf, than to the cold water structures. Conversely, the year-class abundance of the cold-water fish species was related to the cold water advection from the major water currents in the areas.

Key words: Abundance, environment, temperature, year-class

Introduction

It is known, that abundance of commercial fishes in fishing grounds of the world oceans show significant interannual variations. In conditions of optimal fishery, assuming no excessive removal, the above-mentioned variations should be strongly related to the environmental conditions, the impact of which on the fish life cycle could be hardly overestimated. Thus one of the most important tasks of fishery oceanography is to reveal those conditions and particular environmental factors which directly or indirectly affect the abundance of commercial fish year-classes.

The Northwest Atlantic is one of the most suitable areas to observe relationships between fish year-class abundance and environmental conditions (particularly oceanographic ones). This is supported by the fact that this is an area of interaction of two strong boundary currents, which create hydrological fronts with extremely high temperature, salinity and other gradients, separating waters of different climatic zones. These oceanographic peculiarities provide the extremely high biological productivity of the Northwest Atlantic area and at the same time, may strongly affect the abundance and distribution of the commercial fishes, particularly near the boundary of the area. Temperature is the most important factor of fishes life, as it determines the physical state of environment and appears to be the major ecological factor, affecting reproduction and survival at early stages (Rose, MS 1992; Myers *et al.*, MS 1992a and b; Drinkwater and Myers, 1987), as well as qualitative and quantitative composition of food items and other elements of fish life cycle. It should be noted, that water temperature variations in the Northwest Atlantic are mainly determined by advective processes, caused by the warm water northward transport by the Gulf Stream system and the cold water southward transport by the Labrador Current system, which differ both in physical characteristics and biotopes. Taking into account these peculiarities, an attempt was made here to compare interannual variations of some fish species year-classes abundance and interannual variations of the sea-surface temperature and some indices of warm and cold waters advection during 1977–91 in the Northwest Atlantic.

Materials and Methods

Temporal series of average annual sea-surface temperatures (SST) by longitude and latitude quadrants of 2.5 × 2.5° were obtained from average monthly data, archived by the Moscow Hydrometeocenter. Indices of hydrological front locations at sea surface, which were assumed to be the distance (in tens of miles) of hydrological fronts northward of 37°N at each longitude between 59° and 65°W, were used as water advection indices. Those indices were obtained by averaging the data of 3–4 day Canadian maps of hydrological fronts by a month and year over entire area from 59° to 65°W. Data on year-class abundance for the ages of 1–3 years of several fish species and different assessment methods, were obtained from different

sources, shown in Table 1. The assessment methods of year-class abundance included virtual population analysis, trawl and acoustic surveys.

The natural series of oceanographic indices and abundance of year-classes of the selected fish species utilized for the 15-year period from 1977 to 1991, were statistically treated by personal computer using the STATGRAPH software program.

Results and Discussion

Silver hake in Div. 4VWX. During the period of study the abundance of 1-year-old silver hake varied considerably. The lowest abundance amounting to 1.8×10^7 individuals was found in 1979, and the highest one of 55.2×10^7 individuals in 1985. Comparison of young silver hake abundance and temperature with the dynamic indices showed a direct relation to the latter (Fig. 1A–C). The years of the most strong silver hake year-classes corresponded to the years of the highest average annual SST and of the most northward shift of the cold shelf water boundary. A generally close relationship to SST was found at the Scotian Shelf Slope, where silver hake aggregations were distributed in the warm water of the slope during the major part of the year. The comparison of 1-year-old abundance to three hydrological predictors showed the most close correlation to the temperature of slope warm water (Fig. 1B). The figure shows a beginning of the increase in the SST in 1991, which allows us to expect an appearance of strong silver hake year-classes in near future.

Cod in Div. 5Z. The strong inverse relation of 1-year-old cod abundance in Div. 5Z and SST in the Labrador Current area (Fig. 1D) was observed. The highest cod abundance was found in the years of the lowest SST. The correlation coefficient value (0.48) showed the cold water advection impact on that stock reproduction. As is seen from Fig. 1D, the variability of cod abundance and SST had one peculiarity, i.e. before 1986 the inverse relation appeared every year, and variations of both parameters were rather sharp. Since 1986, the above-mentioned "response" of cod abundance to SST variations ceased, and in 1986-91 its values differed slightly from year-to-year and were close to minimum level. As Hunt and Buzeta (MS 1992) showed those years were characterized by the cod stock decrease in the area as a result of the appearance of several poor year-classes. The causes of these poor year-classes seemed to be related to some other conditions, not temperature, however as is shown in the Fig. 1D, a rise of the Labrador water temperature was found in those years. A preliminary conclusion could be made, that the decrease of the Labrador water temperature since 1990 permits us to expect an increase in abundance of cod year-classes in Div. 5Z. The first year of this indicator was that of 1991.

Pollock in Subareas 4–6. The interannual variations of 3-year-old pollock abundance showed an inverse relation to SST of Labrador water ($r = -0.40$), illustrated in Fig. 1E. The temporal series of abundance data was restricted with no data after 1988, although temperature patterns are shown to 1991. The plots suggest that 3-year-old pollock abundance was higher in 1989 than in 1988, decreased in 1990 and was considerably higher in 1991 than in 1990.

Haddock in Div. 4W. The 1-year-old haddock abundance variability was correlated both to SST on the Scotian Shelf area and to the advective index, i.e. to the cold shelf water boundary. Thus the years of the lowest abundance 1983–86 and 1989–91 corresponded to the most pronounced northward shifts of the boundary (Fig. 1F). The plots suggest that the haddock year-class abundance should remain at a relatively low level unless the cold water advection on the Scotian Shelf increased after 1991.

Herring in Div. 4T. Unlike cod, pollock and haddock, the abundance of 2-year-old herring showed no marked relation to the temperature conditions. However, comparison of the abundance and the warm water advection (variations of the Gulf Stream

TABLE 1. Methods of fish year-classes abundance assessment (1–3 years) in NAFO zone.

Species	Stock Unit	Age	Method of Assessment	Source
Silver hake	Scotian area	1	Trawl survey	Waldron *et al.*, MS 1992
Cod	Georges Bank	1	VPA	Hunt and Buzeta, MS 1992
Pollock	New Scotland Georges Bank	3	Trawl survey	Annand and Beanlands, MS 1992
Haddock	Scotian area	1	Trawl survey	Zwanenburg, MS 1992
Atlantic herring	Gulf of St. Lawrence	2	VPA	Claytor *et al.*, MS 1991
Capelin	Great Newfoundland Bank	3	Acoustic survey	Miller, MS 1991

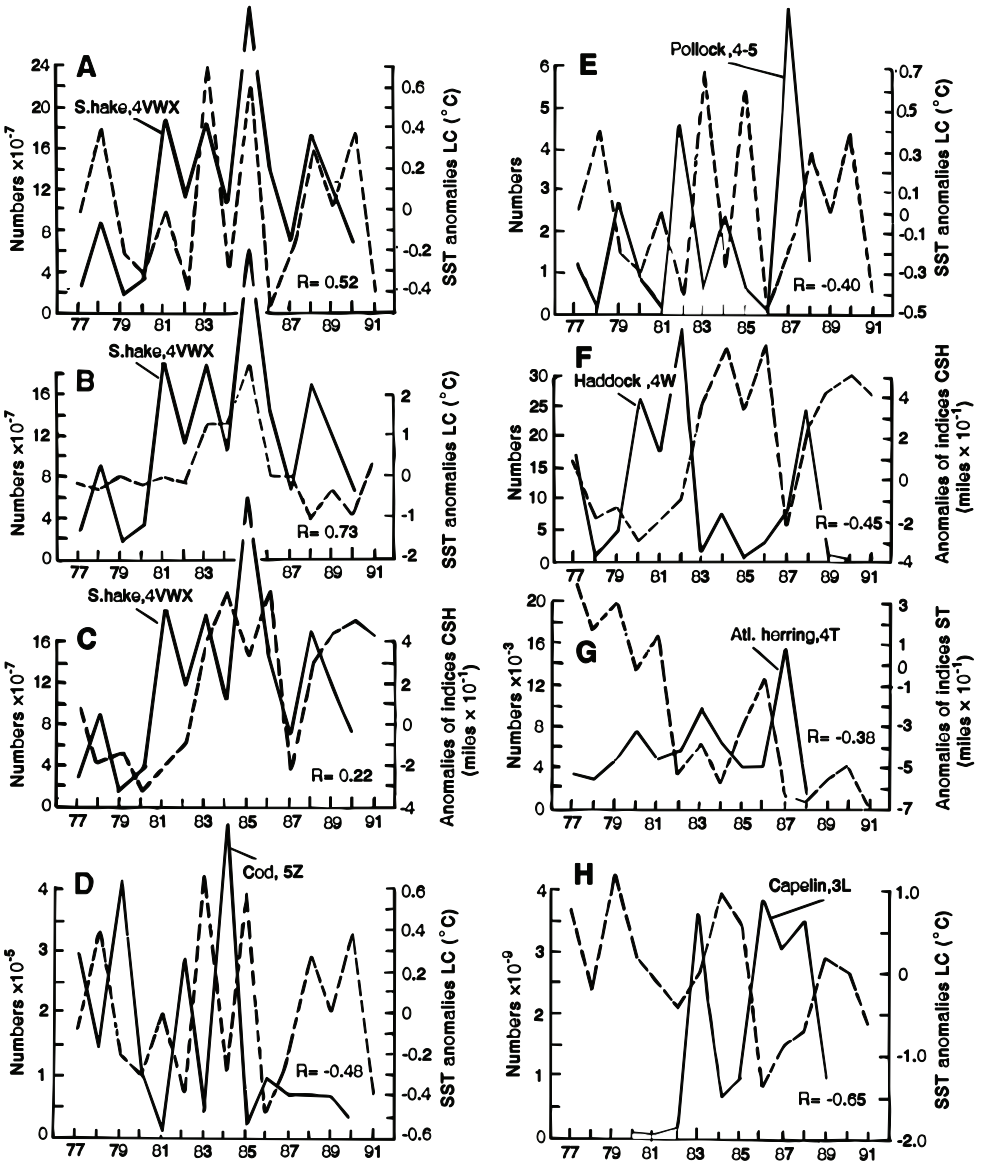

Fig. 1. Interannual variability of some fish species year-classes abundance and hydrological conditions in the Northwest Atlantic in 1976–91.

Comments: SST – sea-surface temperature
LC – waters of the Labrador Current
SL – slope waters
CSH – cold shelf waters
ST – water of the Gulf Stream

front boundary) at the trend level during the entire period, revealed a decrease of the warm water advection at the shelf and a slow growth of herring abundance (Fig. 1G).

Capelin in Div. 3L. The abundance of 2-year-old capelin showed the closest relation (r = -0.65) to the temperature of Labrador water (Fig. 1H), as compared to the above-mentioned cold water species. However, it should be noted that the temporal series is the shortest one available and the relationship obtained is not considered a reliable one.

Thus, the analysis mainly shows the qualitative relationships of year-class abundance of some commercial fish species in the Northwest Atlantic to the temperature and advective factors considered. The relationships revealed that there appears to be a

direct one for warm water species (silver hake) and an inverse one for cold water species (cod, haddock, pollock, herring and capelin). It seems that silver hake abundance variations are related rather to warm water temperature variations (slope water and the Gulf Stream) and its advection, than to Labrador water advection, while cod year-class abundance is more closely related to the Labrador Current system variability. Templeman (1972) showed that strong year-classes of cod and haddock appeared at moderately low temperatures in the area between Georges Bank at the West and the Barents Sea at the East, and the higher temperatures southwards should unfavourably affect the year-class abundance. This is illustrated by haddock in the southern Grand Bank area, the abundance of which greatly depends on the climatic variability. As for silver hake of the Scotian Shelf, it should be noted that the latter is a warm water species, as compared to cod and haddock, and distributes at the northern boundary of the area. Hence, we may suppose, that strong year-classes of the silver hake populations should appear mainly in the years of positive temperature anomalies. The results of the research carried out on these stocks do not contradict the above conclusions we have drawn from our analyses.

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