9. Temporal Changes in Distribution of Walleye Pollock Eggs South of Hokkaido, Japan

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Abstract

We analyzed temporal changes in walleye pollock egg distribution and surface temperature in Funka Bay and adjacent areas, using data from repeated observations taken three to five times a year from January to March, 1989-1995. Maximum total egg number over the observational area at the fourth stage just before hatching was smaller than that at the first stage just after spawning, implying a decrease during egg development. The maximum decreased greatly in 1992 and 1993, when the number of fourth-stage eggs was low in the bay, whereas this was not the case in the other years when the eggs largely stayed in the bay. A large number of fourth-stage eggs stayed in the bay when the surface temperature around the mouth of the bay suddenly decreased during development. Each year class of pollock in 1992 and 1993 was caught in small numbers when they were one and two years old. It is suggested that the number of eggs hatched in the bay, which can be important in determining changes in the stock, depends primarily on the timing and penetration of inflow of Oyashio water into the area around the mouth of the bay.

Introduction

Walleye pollock is one of the most important commercial species for Hokkaido, only exceeded by salmon and scallops. The species is a benthopelagic fish found over the continental shelf and continental slope in areas of 30-400 m water depth (Cohen et al., 1990). In the Pacific, off Hokkaido, the pollock spawn in the coastal regions from Iturup (Etorohu) Island to around Funka Bay (Tsuji, 1979). Based on adult stock abundance and information on gonadal maturity, pollock appear to migrate from the Hokkaido coast to the adjacent waters of Funka Bay to spawn (Hamatsu and Yabuki, 1995). This region might be the most important spawning ground for pollook at least in the area south and east of Hokkaido.

Yoon (1981) concluded, based on examination of ovarian eggs, that spawning begins in November and continues into March, with a peak in January and February, in Funka Bay and adjacent areas. Cold and relatively fresh water influenced by the melting sea ice suddenly flows into the Funka Bay area at this time (Ohtani, 1971; Ogasawara, 1987). Since pollock eggs are pelagic, they can be carried away from the area by the flow, in addition to their response to the sudden change in ambient temperature. This environmental change is likely to seriously affect the population of the pollock south of Hokkaido.

We have made observations of Funka Bay and southeast off the bay since 1989 to obtain information on egg distributions at each developmental stage, along with ambient water temperature and salinity. These observations were repeated for fixed stations to allow analysis of temporal changes. In the present study, we clarified the changes in egg distribution with their development in relation to the influence of flow on the temporal changes. The total number of eggs in the observational area was compared with the catch of pollock to determine the influence of the egg abundance on the stock of the pollock.

Data and Methods

During January to March, 1989-1995, sampling was repeated three to five times at fixed stations located in Funka Bay and south off the bay. For each station, net tows were conducted from 100 m depth to the surface to catch walleye pollock eggs for quantification of each of the four developmental stages, from just after spawning to just before hatching. The observation and classification of these stages are described in Wakabayashi and Watanabe (1990). The time from spawning through the four stages are 27, 75, 80, and 160 hours.

Since the eggs are pelagic, we can assume the net was towed through the layer in which the eggs exist. The number of eggs per unit area was calculated for each of the four stages to form time series of egg-density distribution. The time series from January to March was used for analysis in relation to the simultaneously-observed sea surface temperature and salinity fields.

Results

Dominant Temporal Change from EOF Analysis

EOF analysis was carried out using all the time series for egg density per unit area and surface temperature and salinity, to illustrate their dominant pattern in time-dependent change. The EOF first mode shows that surface temperature changes with a similar phase throughout the observational area. The pattern of the mode is almost parallel to the bathymetry, showing the dominance in the area just east of Tsugaru Straits. This corresponds to a temporal change in inflow of warm water from Tsugaru Straits into the Pacific, implying a temporal change in inflow of the cold water of the Oyashio as well.

Egg density for the first and second stages changed strongly at the mouth of Funka Bay, over the continental shelf east of the bay, and just east of Oshima Peninsula. For the third and fourth stages, only the bay is dominant. This implies that many eggs were hatched in the bay.

Temporal Change in Total Egg Number and Surface Temperature Distribution

Total egg number for each stage was integrated over all the observational area to show its temporal change for each of the years 1989-1995. The total number of first-stage eggs immediately after spawning showed a maximum on February 6 and 11, 1989; January 22, 1990; February 10, 1991; January 24, 1992; January 22, 1993; January 30, 1994; and January 23, 1995. In each of the years, except for 1989 and 1991, the peak of the spawning was not identified since the number decreased monotonously. On the other hand, the total egg number for the fourth-stage eggs just before hatching had a maximum on February 15, 1989; February 19, 1990; February 4, 1991; January 24, 1992; February 4, 1993; January 30, 1994; and February 12, 1995.

In most years, the date of the maximum for fourth-stage eggs occurred at the same time as, or close to, the date of the maximum for the first-stage eggs. The time between the first and fourth stages is about seven days, which is shorter than, or similar to, intervals between the repeated observations. Thus, we can compare the rate of change in the maximum number for the fourth-stage egg to that for the first-stage to determine the annual variation in decrease of egg abundance during development. The rate was small in 1989, 1992, and 1993, and large in 1990, 1991, 1994, and 1995. The rate is greater than one in 1994 and 1995, possibly due to an overestimate of the fourth-stage egg number or underestimate of the first-stage egg number, or by both.

Alternately, the EOF score for the surface temperature tends to decrease for all years except 1989 and 1993, suggesting inflow of the Oyashio water and/or reduction of the Tsugaru Warm Current, as stated above. In years with the large egg-number rate for the period of the fourth stage to the first, the EOF score of the temperature decreased suddenly when the first-stage egg is the largest, but not during the small-rate years. It seems that the sudden change of the oceanic conditions in the observational area may correspond to the change in the egg abundance.

The majority of the fourth-stage eggs in the observational area existed in Funka Bay in all the large-rate years and in 1989, during which the egg number was extremely high. Funka Bay is important as a reservoir for the eggs. During most of the large-rate years, a significant temperature front was formed from the north to the south as a western boundary of the cold Oyashio water. The inflow velocity of the Oyashio seems to control the water exchange between the bay and the outside area, which in turn changes the number of the egg in the bay.

Discussion

Abundance of pollock eggs just prior to hatching changed annually, with a minimum in 1992 and 1993. However, we cannot have identified the peak of spawning from the repeated observations, in which the total egg number decreased monotonously. Catch of walleye pollock in the southeast of Honshu for each age class in 1990-1995 is compared with the total egg number obtained. We then discuss whether the annual change in egg abundance in Funka Bay and its adjacent area influenced the walleye pollock stock.

The fishery catch in the area northeast of Honshu was separated into catches for the age classes proportionally to the catch of each class using the observational vessel. The annual change in the catch of age 0 pollock shows a curve with a minimum in 1992 and 1993, in which the amount of the fourth-stage egg was the smallest in 1989-1995. The catch of age 1 pollock also shows a curve having a minimum in 1993 and 1994. The small number of eggs in Funka Bay might have produced a small stock of juveniles. Water exchange in Funka Bay in the spawning season could be important for the stock abundance of the pollock.

On the other hand, it is supposed that the sudden inflow of the Oyashio related to the water exchange of the bay. We examined temperature and salinity sections early in February along 41° 30'E observed by the Hakodate Marine Observatory in 1989-1995 (Japan Meteorological Agency, 1991-1997). Warm and saline water extended from Tsugaru Straits to the east in 1989, 1991, 1992, and 1993, years in which the eggs decreased significantly except for 1991. The extension of the warm water seems to correspond to the water exchange in Funka Bay as well as the Oyashio water inflow, with some exceptions. We need to study further the interaction between the Tsugaru Warm Current and the Oyashio.

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