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The Effect of the Oceanic Condition on Variations of the Catches of Alaska Pollack in the East Sea (the Japan Sea)

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The effect of the oceanic condition on variations of the catches of Alaska pollack (*Theragra chalcogramma*) in the East Sea (the Japan Sea) is examined using monthly catches data of this fish and temperature data during 1972 to 1991. Since 1973 the catches of Alaska pollack have gradually increased, showing a peak in 1981, and then rapidly decreased after 1986. A significant negative correlation was found between variations of the catches and the temperature at 50 m depth offshore Mukho. In 1981, the year of the highest catches in the study period, the water mass in the Eastern Korean Coastal Sea of the East Sea was extremely cold, while the year of poor catch, 1979, was much warmer than the annual mean temperature. The results show that the temperature variations around the Eastern Korean Coastal Sea play an important role in the variations of the catches of Alaska pollack, implying that the effect of the Tsushima Warm Current is also very important.

Key words : Alaska pollack, temperature, negative correlation, 1981, 1979, Tsushima Warm Current

Introduction

The East Sea (the Japan Sea) is composed of a cold water called the Japan Sea Proper Water which occupies over 80% of total water volume of the East Sea (Yasui et al., 1967), covering the surface layer (about 300 m depth above) with the Tsushima Warm Current Water. Many water fronts, e.g., the Polar front, therefore, are frequently formed. Thus, the East Sea has been known as a main fishing ground which occupies about 13% of the total fish-catches of Korea (National Fisheries Research and Development Institute (NFRDI), 1993), and also as a good spawning and inhabitable place for many fish-species, for example, Alaska pollack (*Theragra chalcogramma*) (hereafter pollack), squid, or mackerels etc. According to NFRDI (1992), Alaska pollack has been caught by longlined, gill nets or purse-seines etc., and tends to be inhabitable in cold water. The migration path and the spawning place are supposed to be mainly located at the northern area of 38°N in the East Korean Coastal Sea (hereafter EKCS) in the East Sea as depicted in Fig. 1 (NFRDI, 1993).

In the past a fisheries-biological study of pollack was extensively carried out by Ogata (1956). In the Japanese coastal sea a tagging experiment was also attempted to examine the migration of pollack by Ogata et al. (1958, 1959). However, it seems that the oceanographical studies concerned with pollacks in the East Sea have hardly been carried out during past decades.

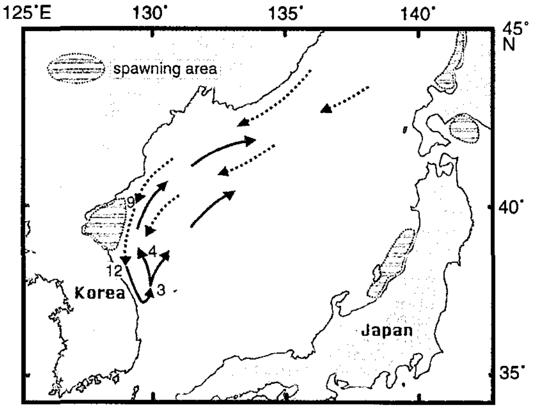

Fig. 1. Schematic map of the migration path and the spawning area of Alaska pollack by NFRDI (1993). Numerals represent months.

Figure 2 shows annual-mean variations of the total catches of pollack (black circles) obtained from NFRDI (1972~1991) and temperature (white circles) at 50 m depth of St. 7 on line 106 of routine-oceanographic observation of NFRDI (see Fig. 3). In general, since 1973 the total catches gradually increased, showing a peak in 1981, and then rapidly decreased after 1986. On the other hand, variations of temperature tend to be against to variations of the catches, i.e. they roughly show a negative correlation. This implies that the variation of

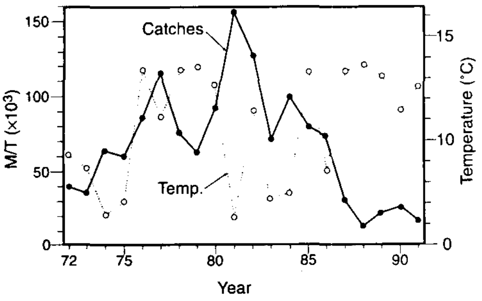

Fig. 2. Annual-mean variations of total catches of pollack (black circles) and temperature (white circles) at 50 m depth of St. 7 on line 106 during 1972 to 1991.

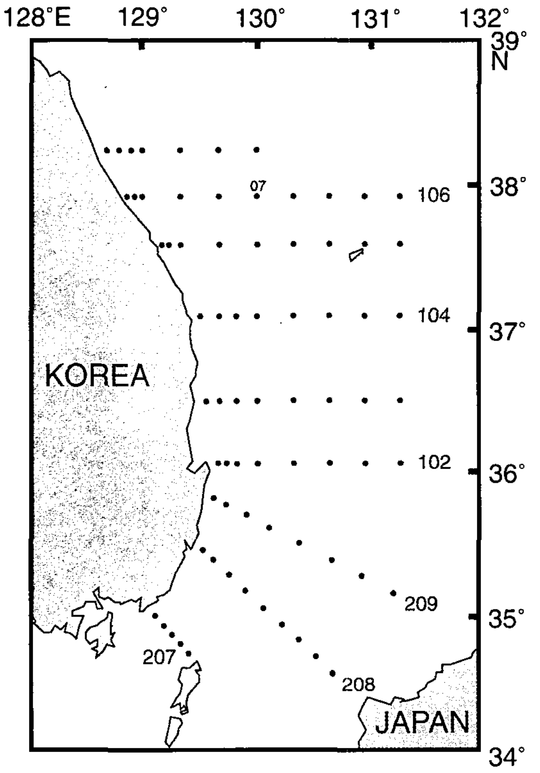

Fig. 3. Oceanographic stations of NFRDI in the East Sea. The vertical structures of temperature are analized on line 106.

the catches may be closely related to variations of oceanic condition in the East Sea. Note that the catches of pollack showed the maximum in 1981 when the EKCS was very abnormally cold in long term periods (Hong et al., 1984).

To examine an effect of oceanic condition on the variations of the catches of pollack in detail is the focus of this paper. A simple analysis of temperature field will be given and compared with interannual variations of the catches of pollack.

Data

The monthly mean data of the catches of pollack used in this paper are obtained from NFRDI during 1972 to 1991. These data, unfortunately, are not locally resolved in detail but for a wide region such as Kangwon or Kyungbuk. This makes the data analysis for the catches in this study very simple and us confine to discussion within the total catches data without detailed treatment about fishing grounds of pollack.

In order to examine an oceanic condition in the EKCS the temperature data obtained from NFRDI are used (NFRDI, 1972~1991). The vertical structures of temperature are analized on line 106 (Fig. 3) which is actually located in the most northern area of regular observation-lines of NFRDI because of irregular observation on line 107. Line 106 may also be appropriate for this study because it might be closer to the main fishing ground of pollack. Annual means of temperature on line 106 are obtained from an oceanographic handbook by NFRDI (1979).

Results

The catches of pollack are locally different as illustrated in Fig. 4. The annual mean catches at Kangwon (black circles) are roughly about three times larger (about 60,000 M/T) than that at Kyungbuk (open circles; about 20,000 M/T) during 1972 to 1991, although the variation patterns are almost the same each other. This result shows that the northern area of EKCS is the good fishing ground of pollack in this period.

Annual-monthly mean of the catches of pollack (1972~1991) (Fig. 5) generally shows the maximum in January (about 10,500 M/T), decreases until May when it reaches the minimum (about 3,600 M/T) and then increases untill December. Roughly, the rich catch season is during autumn to winter, while the poor catch season is during spring to summer. In November the catches temporarily decrease. The details about that will be discussed in the final section.

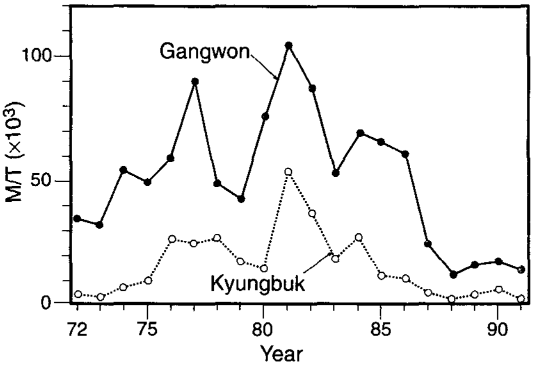

Fig. 4. The annual mean catches at Kangwon (black circles) and Kyungbuk (open circles) during 1972 to 1991.

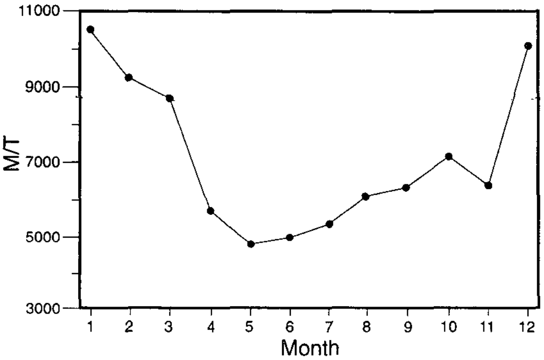

Fig. 5. Interannual monthly mean catches of pollack during 1972 to 1991.

Figure 6 gives varitions of anomalies for the catches of pollack (solid lines) and temperature (break lines) at 50 m of St. 7 on line 106 (see Fig. 3) during 1972 to 1991. Thick lines represent six-months running means for each one. The zero level indicates interannual mean values of each variable for the study period. Also seen in this figure is the negative correlation in the monthly variations between the catches and the temperature, as already mentioned in Fig. 2, and also the seasonal variations of the catches in Fig. 5 are shown, although the amplitudes vary largely year to year.

In order to examine the effect of the oceanic condition on the catches of pollack in detail, the comparison between two years is given, i.e., regarding 1981 and 1979 as a rich catch year and a poor catch year of pollack, respectively. The year 1981 will be appropriate for the rich catch year because the catches in this year was

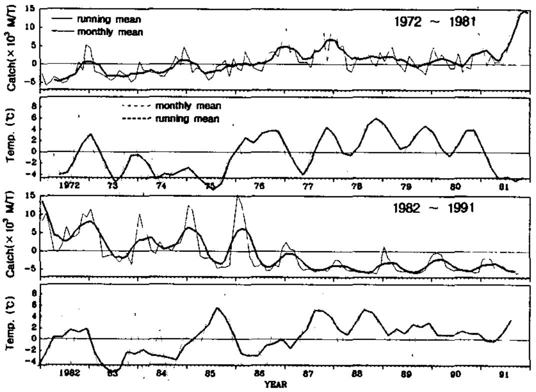

Fig. 6. Anomalies for the catches of pollack (solid lines) and temperature (break lines) at 50 m of St. 7 on line 106 during 1972 to 1991. Thick lines represent six-months running means for each one.

the maximum in the study period. The year 1979, however, can be arguable because there are also many other years for the poor catch in the study period, e.g., 1973 or 1988 etc. However, we note that in 1979 the catches have been temporarily decreased in the periods of totally being increased since 1973 (see Fig. 2 and Fig. 6), implying that it is possible for the year 1979 to have a different-oceanic condition from other rich-catch years in these periods.

On line 106 several vertical structures of temperature in October (the rich-catch season) are given in Fig. 7. Here we note 5℃ isotherm as a measure of temperature variation of water mass, and also it may indicate an optimum- inhabitable temperature of pollack in the East Sea (Ogata, 1956). Annual mean temperature (Fig. 7a) during 1961 to 1975 shows that 5℃ isotherm exists at about 50 m depth in the coastal area, and deepens down about 150 m depth offshore. In 1981 (Fig. 7b), however, the 5℃ isotherm exists between 50 m and 75 m depths and thus generally has risen 50 m to 100 m above than that in the annual mean, whereas in 1979 (Fig. 7c) it extends to 300 m depth below especially offshore. The anomalies of temperature in 1981 (Fig. 8a) from the annual mean at each station exhibit that negative values cover the whole area except a surface or a coastal area, having highly negative values (−5℃ to −10℃) in the range from about 20 m to 100 m depth. By contrast the year 1979 (Fig. 8b) occupies highly positive values especially offshore although the coastal area partly has negtive values. This shows that water mass on line 106 in 1981 was extremely colder than the annual mean and vice versa in 1979. (The similar examples on line 105 or line 103 etc., were given by Hong et al. (1984) although the4 study period was during 1966 to 1981 and the temperature at 100 m depth was used.)

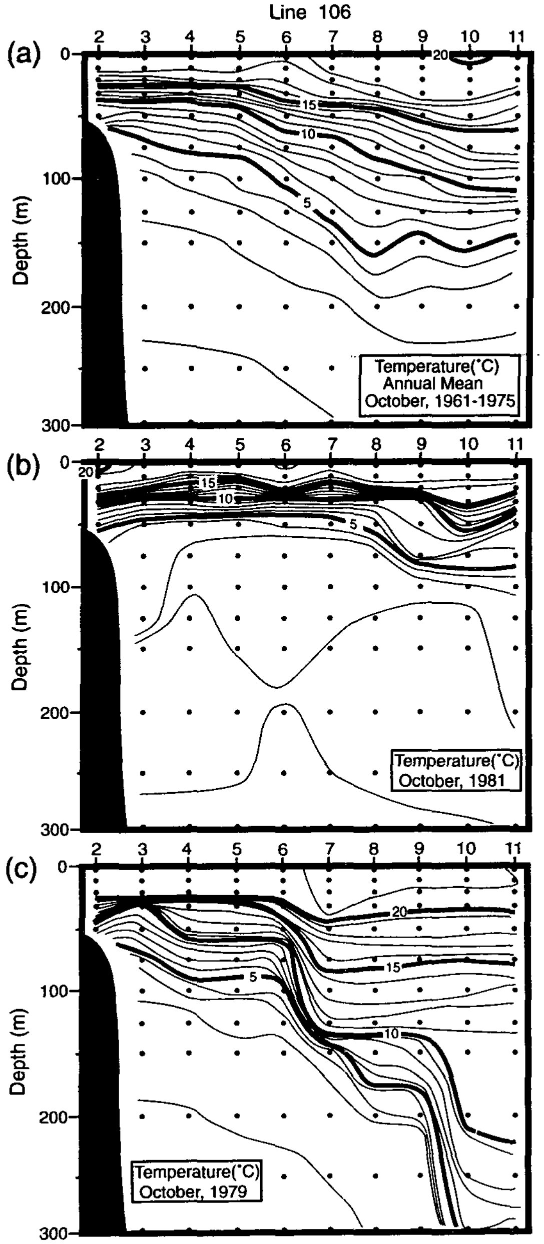

Fig. 7. The vertical structures of temperature in October on line 106 a) in the interannual mean during 1961 to 1975, b) in 1981, and c) in 1979.

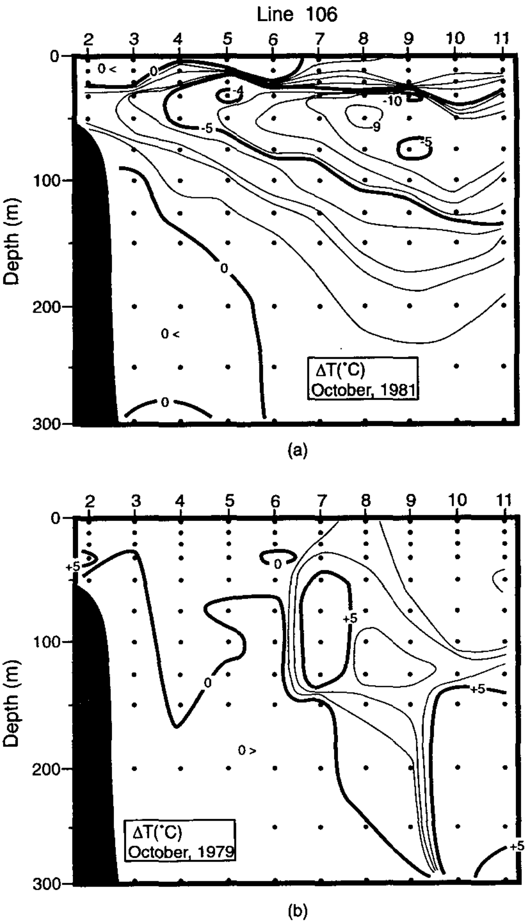

Fig. 8. Same as Fig. 7 except for the anomalies from the annual mean temperature a) in 1981 b) in 1979.

Seasonal variations of vertical structure of temperature at St. 7 on line 106 are illustrated in Fig. 9. The 5°C isotherm in the annual mean (Fig. 9a) is rising up to about 100 m depth due to stratification from spring to summer, and is falling down to about 150 m depth due to strong convection from autumn to winter. In 1981 (Fig. 9b), on the other hand, the 5°C isotherm exists in the ranges of 50 m to 75 m depth throughout the year except December so that it rose up to the surface with about 50 m to 100 m above than the annual mean. In 1979 (Fig. 9c), the poor-catch year, we find it at about 200 m depth (or below) except October. The anomalies in 1981

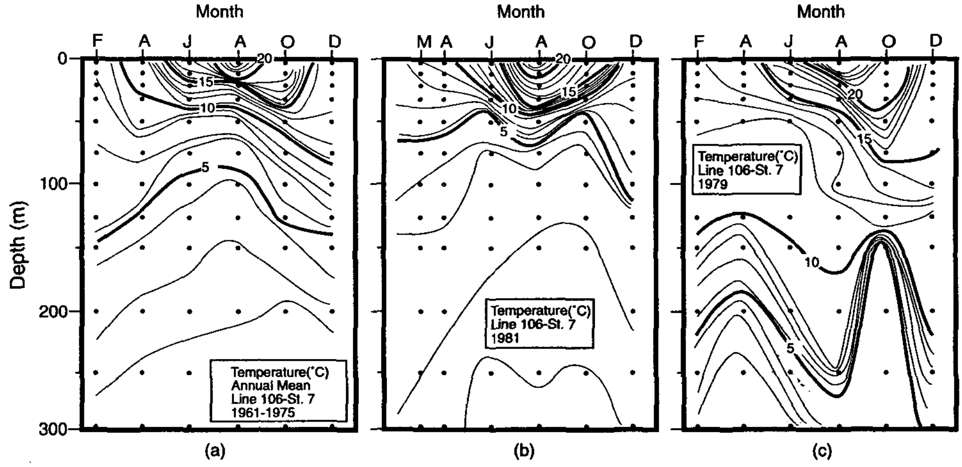

Fig. 9. Seasonal variations of vertical structure of temperature at St. 7 on line 106 a) in the annual mean, b) in 1981, and c) in 1979.

(Fig. 10a) from the annual mean give that negative values occupy the whole seasons except a surface layer in August. In particular they are very large in the rich catch season, October to December. In 1979 (Fig. 10b) they show the opposite situation to 1981, i.e., highly warm water mass almost occupies throughout the year. The above results present that variations of temperature in the EKCS are greatly effective on variations of the catches of pollack.

A comparison between horizontal distribution of temperatures in two years may also reveal a contrast for water masses. Usually, 10℃ isotherm at 100 m depth has been known as a measure for representing main path of the Tsushima Warm Current in the East Sea. Horizontal distribution of temperature in March, 1981 (Fig. 11a) (the observation by NFRDI in this year was carried

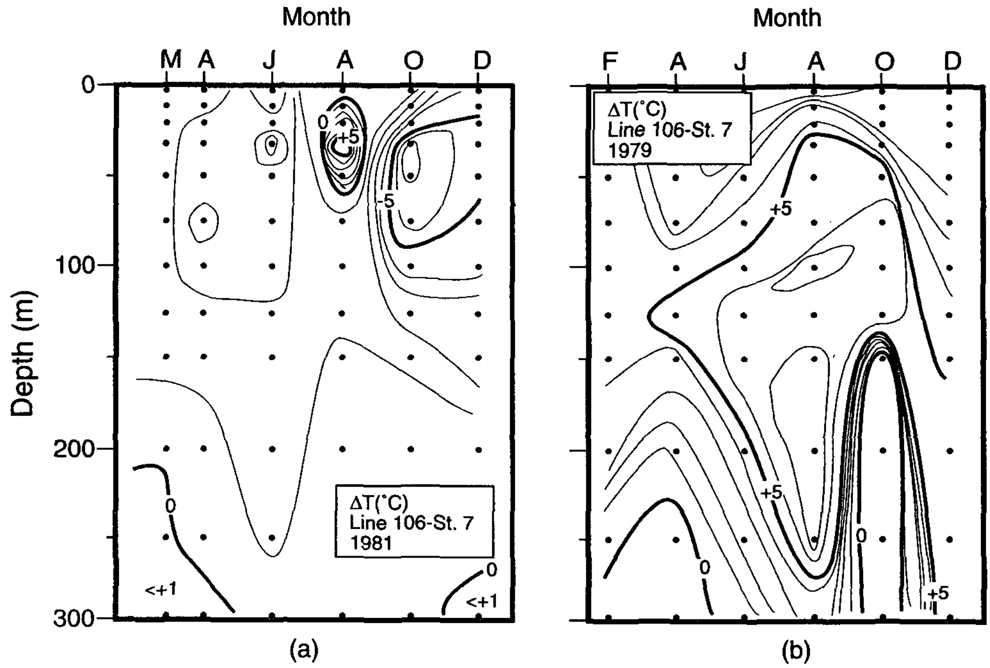

Fig. 10. Same as Fig. 9 except for the anomalies from annual mean temperature a) in 1981 b) in 1979.

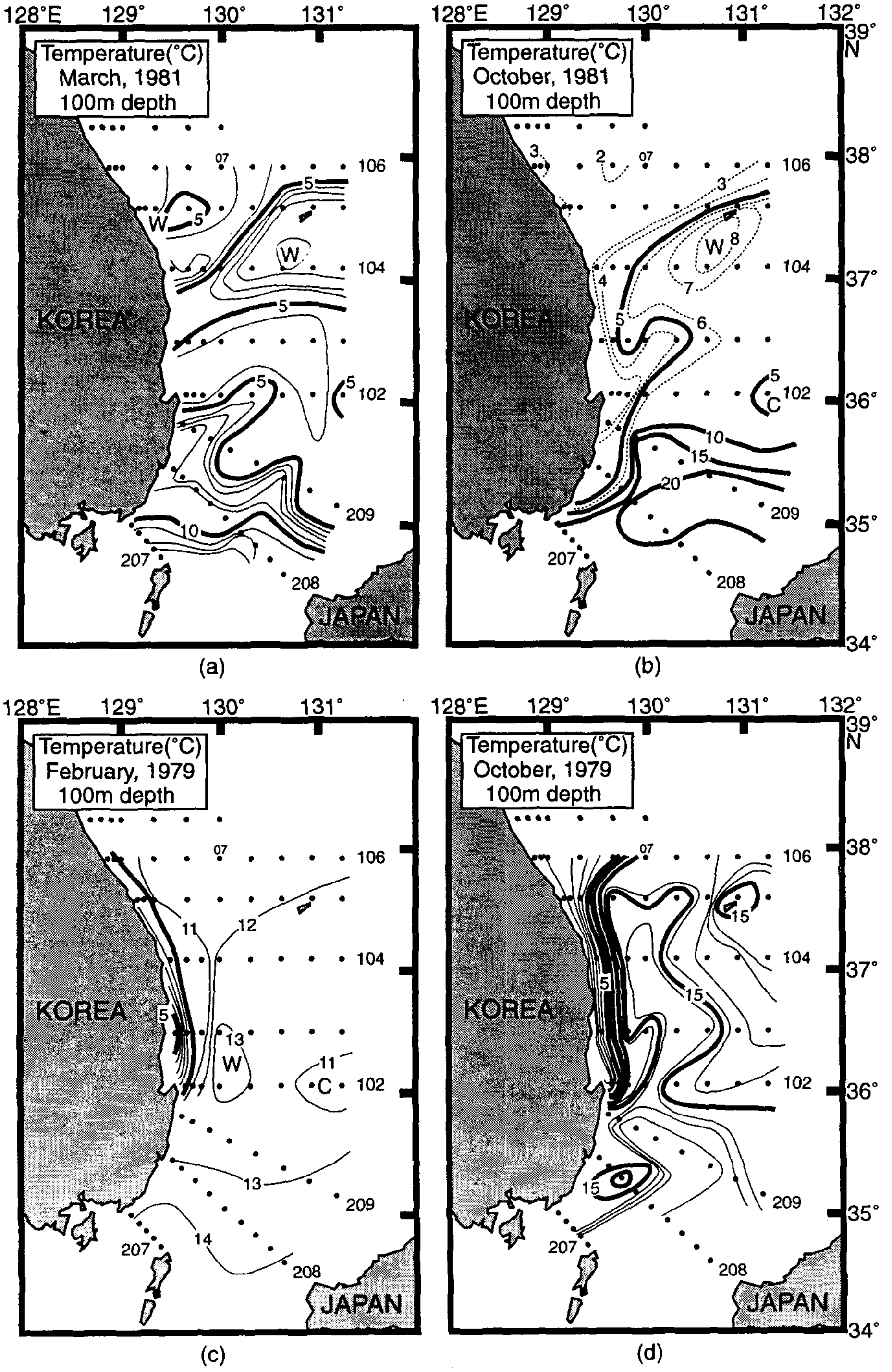

Fig. 11. **Horizontal distribution of temperature at 100 m depth a) in March and b) in October, 1981, c) in Febuary and d) in October, 1979.**

out in early March instead of February) gives 10℃ isotherm to exist in southern area of 35°N, implying that the main stream of the Tsushima Warm Current flowed towards the northern Japanese coast so that the EKCS was much colder. This situation maintains in October (Fig. 11b) although the cold water region along the east Korean coast more extended southward and 10℃ isotherm moved over somewhat northward to about 36°N.

Temperature field in February, 1979 (Fig. 11c), on the other hand, shows that there is a large contrast with 1981, i.e. 10℃ isotherm extended to far more northern area of 38°N, implying that the effect of the Tsushima Warm Current on EKCS was very large. In October 1979 (Fig. 11d) the pattern of temperature field was also maintained even if the strength of the warm current has been more powerful. Consequently, these above results indicate that the variations of the path of the Tsushima Warm Current can greatly influence on water mass in the EKCS and can result in variations of the catches of pollack in the East Sea.

Conclusions and Discussion

The effect of the oceanic condition on variations of the catches of Alaska Pollack in the East Sea (the Japan Sea) was examined using monthly catches data of Alaska pollack and temperature data, and the conclusions are as follows:

1) In general, since 1973 the catches of Alaska pollack has gradually increased, showing a peak in 1981 but rapidly decreased after 1986.

2) In this period a negative correlation between variations of the catches and temperature in the Eastern Korean Coastal Sea (EKCS) is significant.

3) In 1981, the rich catch year, when the catches showed the maximum in the study period, the water mass was extremely cold while in 1979, the poor catch year, it was much warmer than the annual mean of temperature.

4) The results show that the Tsushima Warm Current plays an important role in variations of the catches of Alaska pollack.

Alaska pollacks are preferable to cold water, and the inhabitable temperature has been known between 2~10 ℃ in the East Sea, especially with optimum- inhabitable temperature, 3~5℃ (Ogata, 1956). Variations of temperature field, therefore, may directly affect their migration paths, inhabitable layer, and/or the fishing grounds. We also showed that an increase of the catches of pollack in this study is closely related to cooling of the water mass in the EKCS and vice versa, e.g., as shown in Figs. 2 and 6, but we could not show 'the process' of the catches variations because we do not have detailed catches data for pollack in time and space, including the CPUE (catches per unit effort) data.

In November the catches temporarily decreased as shown in Fig. 5. It is very significant when we consider the averaged period (twenty years) although the difference between catches in October (about 6,200 M/T) and November (about 5,500) is not large. This may be caused by vertical variation of optimum-catching depth of pollack resulted from increased warm water layer due to strong convection in this season. Vertically seasonal variations of temperature as shown in Fig. 9 may give an evidence for that. Unfortunately, we could not study about that because the routine observation by NFRDI is usually excluded in November. Nevertheless, this point needs to study more in detail in the future, relating to seasonally vertical migration of pollack.

The population varitation of pollack in long-term period may also cause variations of the catches of pollack. Recently, fish population dynamics has been studied using a numerical model linking climate and fish population (Cowan et al., 1997), and a global change of long-term climate for variation of fish population has been also focused. In Fig. 6 the catches of pollack in the EKCS seem to fluctuate in long-term periods, above twenty-years, and the temperature also seems to fluctuate in the period above ten-years, even if the time series are very short to present the long-term variations. This may imply that the variation of the catches of pollack may be also caused by the population variation of pollack in the East Sea coupling the long-term climate change.

The Tsushima Warm Current basically flows northward along the east Korean coast as the East Korean Warm Current. However, sometimes the main path of the current is largely changed and flows towards northern Janpanse coast as indicated in Fig. 11. Kim et al. (1986) also pointed out that the East Korean Warm Current was not formed in some years, e.g., 1981. It is interesting that the year 1981 when the catches of pollack were the maximum in the study period was an abnormally cold year (Hong et al., 1984). The results in this study showed that the water mass in the EKCS may be fluctuated by variation of the main path of the Tsushima Warm Current, i.e., roughly speaking it causes variations of temperature field in the EKCS and thus variations of the catches of pollack. This conclusion, however, needs more complement in the future because we could not locally analyze the temperature variations in the fishing grounds of pollack due to lack of the catches data. In the future study it must be attempted using the catches data of pollack in time and space.

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