SEASONAL VARIATION OF THE EAST HOKKAIDO COASTAL CURRENT (THE COASTAL OYASHIO AND THE EAST HOKKAIDO WARM CURRENT)

Yutaka Nagata[1], Sachiko Oguma[2], Keiichi Nagase[3], Kimihiro Aikawa[3], Iori Tanaka[4], Akifumi Nakata[4], and Masashi Natsume[4]

[1] Marine Information Research Center, Japan Hydrographic Association (Tokyo); [2] Hokkaido National Fisheries Research Institute (Kushiro); [3] Nemuro City Fisheries Research Institute (Nemuro); [4] Hokkaido Central Fisheries Experiment Station (Yoichi)

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Fig. – 18, ref. – 9.

1. INTRODUCTION

The Okhotsk Sea Water flows out into the Pacific Ocean through Bussol Strait. It is believed that the Okhotsk Water is carried also through the gaps of the southern Kuril Islands, but the direct evidence is very few. Along the East Coast of the Hokkaido, a narrow coastal band of cold and less saline water is usually found in the first half of year and a narrow warm and saline water is found in the second half of year. The former water is referred as the Coastal Oyashio (e. g.: Ohtani 1989, Isoda et al. 2003, and Kono et al.), and the latter is called as the East Hokkaido Warm Current. Combining these two currents, Ogasawra (1990) gave the name of the East Hokkaido Coastal Current. The origin of the Coastal Oyashio Water has been thought to be the melted sea-ice water in Okhotsk Sea due to its very cold and less saline nature (e. g., Ohtani, 1989), and that of the East Hokkaido Warm Current would be the Soya Current Water due to its very warm and saline nature. However, pathway of the Okhotsk Water to the Pacific Ocean has not been identified yet. Okhotsk sea-ice flows out to the Pacific Ocean through the Nemuro Strait in the spring time. However, the sill depth of the strait is less than 20m, and no significant current has been observed.

On the other hand, the water transport of the East Hokkaido Coastal Current has not estimated yet, as almost no data of direct current measurement has been available in the flow region of the East Hokkaido Coastal Current. Recently, the Hokkaido Fisheries Research Institute set a moored current system in the flow region (the water depth of the measuring site is about 100m) in the period from May

2003 to May 2004 (Kusaka et al., 2009). The observation was conducted at four depths ranging from 16m to 76 m. The current records exhibit considerable short period variations, but variation patterns are very similar for all depths. The current has barotropic nature, though the magnitude of the current tends to decrease with depth a little. The current directions were stable and identical for all depths, and were southwestward (parallel to the coast line).

We analyzed seasonal variations of the oceanic state in the sea to the east of Hokkaido by using the observed data by the Hokkaido Kushiro Fisheries Experiment Station, in order to solve the questions above mentioned.

2. DATA USED

The Hokkaido Kushiro Fisheries Experiment Station keeps routine observation network in the sea to the east of Hokkaido. The distribution of the observation points is considerably improved after 1990, and the temperature and salinity profiles are observed six times per year (basically in February, April, June, August, October and December). The distribution of the observation points is shown in **fig. 1.** We analyze mainly the area north of 42°N, and investigate the cross-sectional distributions of temperature and salinity along 4 north-south observation lines: P1, PK0, P2, PK1, and P3 (from east to west). We used 7 years data from 1990 to 1996. The observations were conducted in May instead of June in 1990 through 1993 and in July instead of August in 1992. These are assumed that they are made in June or August in this analysis.

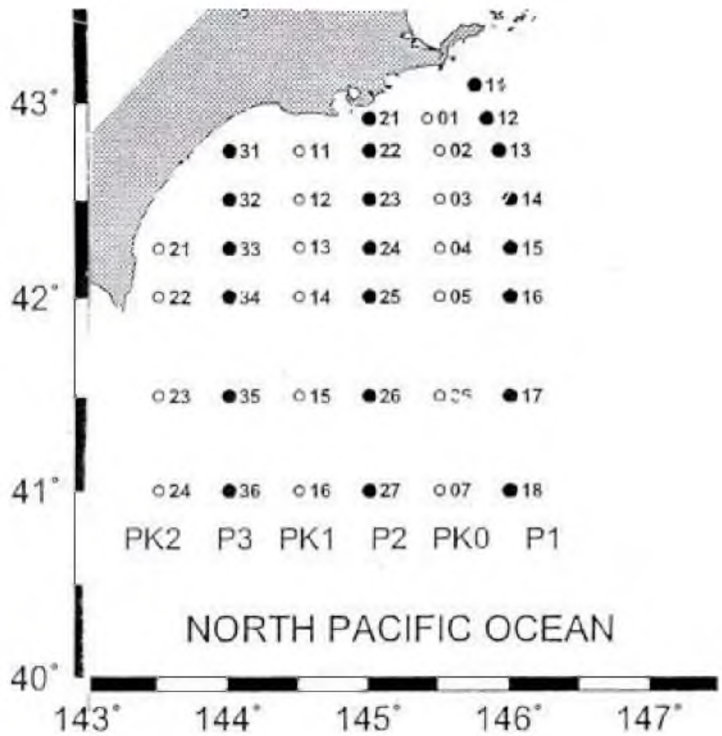

Fig. 1. Distribution of the routine observation points of the Hokkaido Kushiro Fisheries Experiment Station. P1, PK0, P2, PK1, P3, and PK2 are the names of north-south observation lines from east to west

3. TYPICAL EXAMPLES OF THE COASTAL OYASHIO AND THE EAST HOKKAIDO WARM CURRENT

The horizontal distributions of temperature (left: in °C) and of salinity (right) at 50m depth in February, 1994 are shown in **fig. 2.** This is one of the typical cases that the Coastal Oyashio is observed. A narrow band of the cold and less saline water can be seen just along the coast. The cross-sectional distributions of temperature (left: in °C) and of salinity (right) along P1 line in February, 1994 are shown in **fig. 3,** when the Coastal Oyashio was observed. The cold and less saline water can be seen just attached to the coastal slope. As seen in fig. 2 and fig. 3. The band structure is usually seen clearer in salinity field than in temperature field.

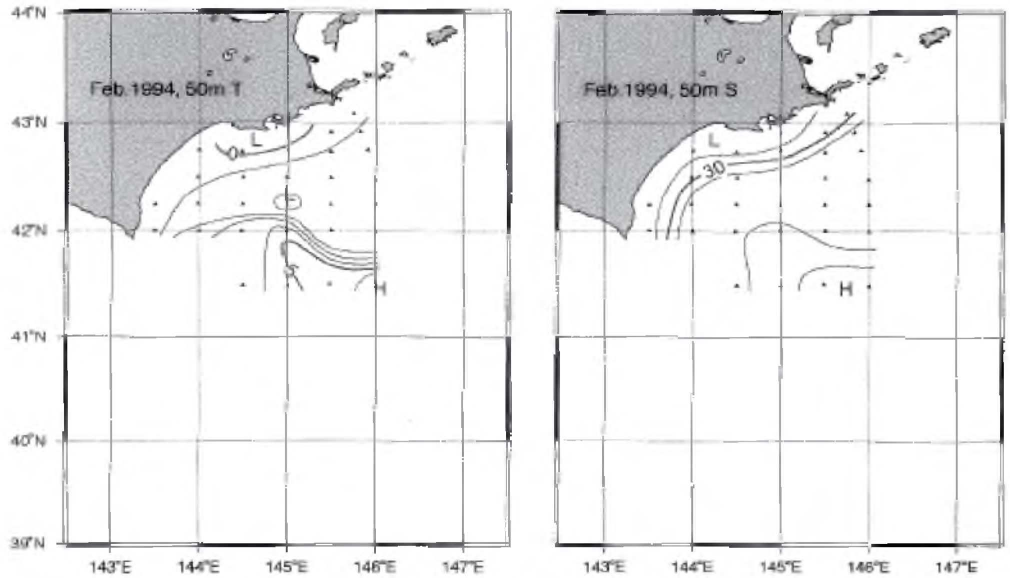

Fig. 2. Horizontal distributions of temperature (left in °C) and salinity (right) of the Coastal Oyashio at 50m depth in February, 1994

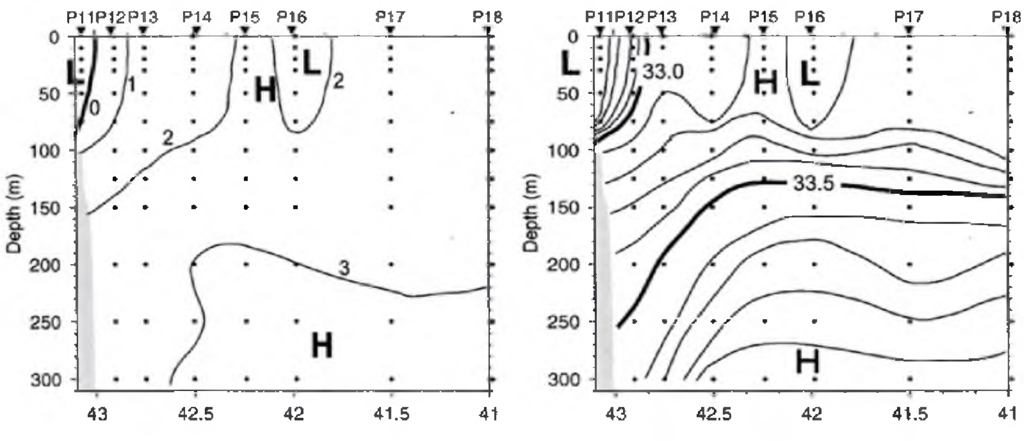

Fig. 3. Cross-sectional distributions of temperature (left in °C) and salinity (right) of the Coastal Oyashio along P1 line in February, 1996

The horizontal distributions of temperature (left: in °C) and of salinity (right) at 50m depth in October, 1993 are shown in **fig. 4,** when the East Hokkaido Warm Current was observed. The cross-sectional distributions of temperature (left: in °C) and of salinity (right) along PK1 line in December, 1996 are shown in **fig. 5.** A narrow band of the warm and saline water can be seen in these figures. It is not so clear in the case in December, but the band structure is usually seen clearer in temperature field than in salinity field in August and in October as seen in fig. 4.

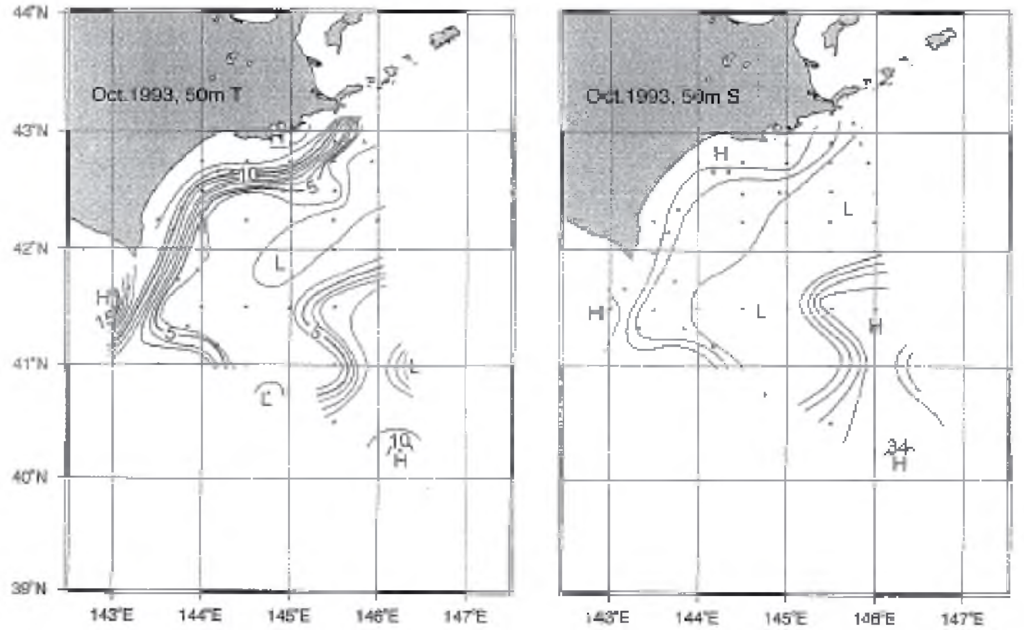

Fig. 4. *Horizontal distributions of temperature (left in °C) and salinity (right) of the East Hokkaido Warm Current at 50m depth in October, 1993*

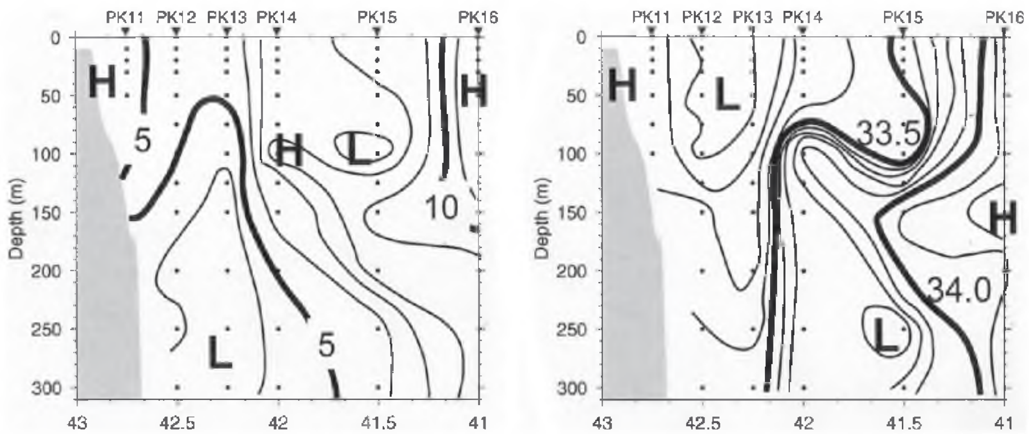

Fig. 5. *Cross-sectional distributions of temperature (left in °C) and salinity (right) of the East Hokkaido Warm Current along PK1 line in December, 1996*

Temperature and salinity values exhibit large seasonal variation. For example, the Coastal Oyashio is strongest in February, but it is often observed also in June. The temperature and salinity in June are much higher than those in February. The water type of the East Hokkaido Coastal Current is hard to be defined generally. So, at first, we shall confine our attention only on configuration of the isopleths. As the patterns of the horizontal distributions are very changeable with depth, we shall examine temperature and salinity distributions in the cross-sectional field along each observation line.

4. APPEARANCE STATUS OF THE EAST HOKKAIDO COASTAL CURRENT

All of the observed temperature and salinity cross-sectional distributions were examined for the period from 1990 to 1996, and grade of appearance is determined for each observation month, for each observation line and for each standard depth. The results are shown in **fig. 6** for Period I (February, April, and June) and in **fig. 7** for Period II (August, October, and December). In each column, left side symbol is for temperature field and right side symbol is for salinity field. As shown in the lower column of fig. 2 and fig 3, the East Hokkaido Coastal current (the Coastal Oyashio and the East Hokkaido Warm Current) appears as isotherms or isohalines surrounding isolated water which is attached to coastal slope. The grades of appearance are determined as follows. The grade is 5 if the East Hokkaido Warm Current is seen very clearly with well closed isotherms or isohalines, and is shown with open circle ○ in fig. 6 and fig. 7. The grade is 3 if the isotherms or isohalines are not so well closed, and is shown with open square □. The grade is 1 if the warmer or more saline water exists very near the coast, but doubtful as isotherms or isohalines are not closed or have irregular forms, and is shown in figures with open triangle △. In the similar way, we determined the grades for the Coastal Oyashio: –5 (closed circle ●) for very clear case, –3 (closed square ■) for clear case, and –1 (closed triangle ▲) for ambiguous case. If no coastal current is seen, the grade is 0, and is shown in figures with x mark. The value of the grade is used for statistical analysis in the next section.

Difference between fig. 6 and fig. 7 would be easily recognized. Fig. 6 is much darker than fig.7 as black marks are dominant in fig. 6, while fig. 7 is more whitish as white marks are dominant. Namely, the coastal band of cold and less saline water appears frequently in Period I, while that of the warm and saline water appears frequently in Period II. Period I is the season of the Coastal Oyashio and Period II is the season of the East Hokkaido Warm Current.

Darkness in fig. 6 decreases from February through June, and the grade of appearance is highest in February. Similar monthly changes can be seen also in Period II. The appearance nature appears almost identical for August and October, but for December it is considerably darker especially in 1996: the Coastal Oyashio appears to exist especially along eastern observation lines, P1 and PK0.

Fig. 6 and fig. 7 show that the Coastal Oyashio is seen clearer in salinity field than in the temperature field, while the East Hokkaido Warm Current seen clearer in temperature field than in salinity field. In order to see this nature more clearly, we shall try to make statistical analysis by using grade numbers

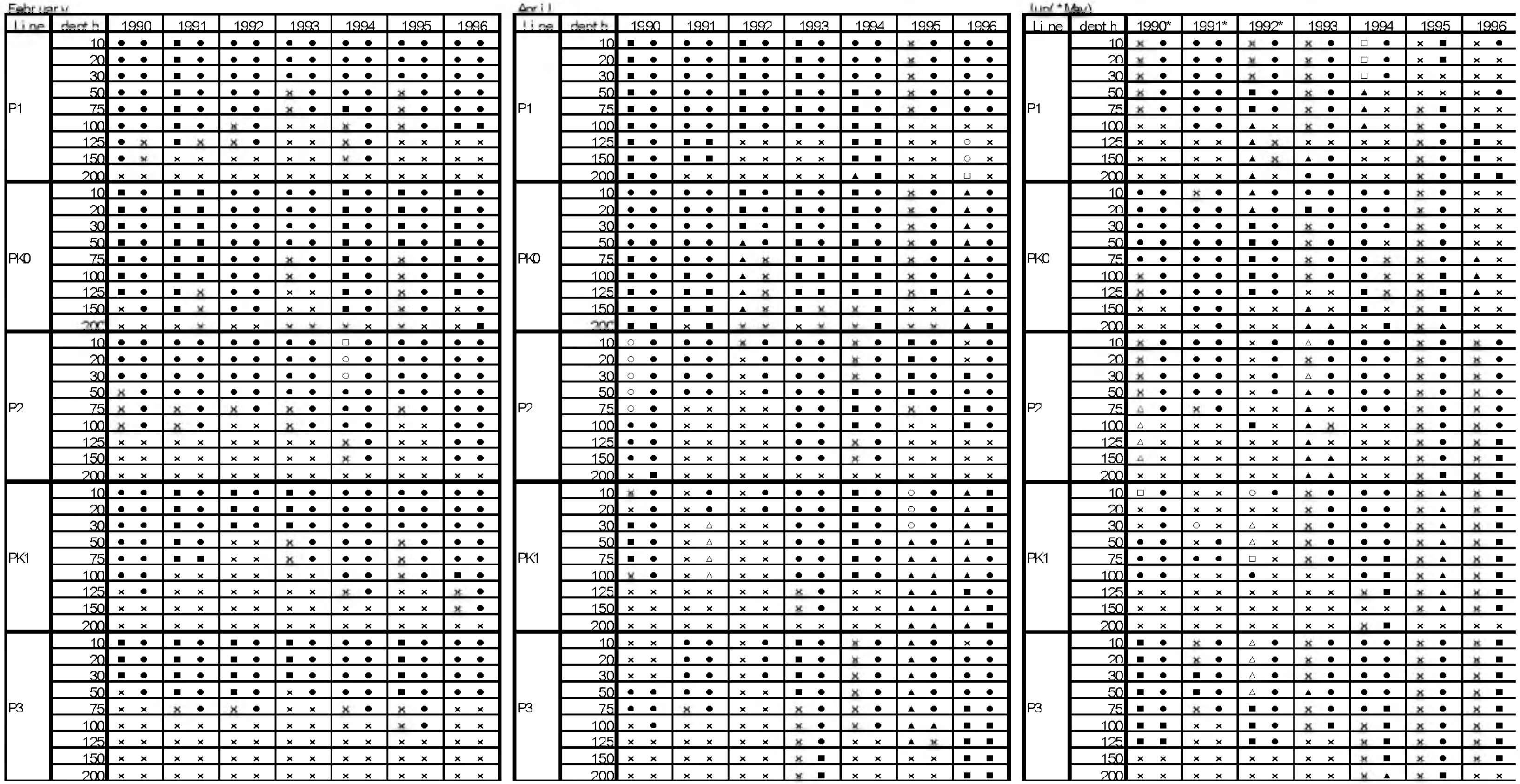

Fig. 6. *Appearance state of the East Hokkaido Coastal Current for period I (February: left, April: center and June: right). Left side and right side in each column show for temperature field and for salinity field, respectively. Black marks indicate that cold or less saline water was observed at stations nearest to the coast. White marks indicate that warm or saline water at stations just near to the coast. Circles indicate "very clear" case, squares "clear" case, and triangles "ambiguous case, respectively. If no isolated water is found, cross mark is shown. The month with * indicates that the data of the former month was used*

Aug(* Jul.)

Line	depth	1990	1991	1992*	1993	1994	1995	1996
P1	10		× ○	× ○	● ×	× ○	× ○	× □
	20		× ○	× ○	× ○	× ○	× ○	× ○
	30		× ○	× ○	○ ○	× ○	× ○	○ ○
	50		○ ○	○ ○	○ ○	○ ○	○ ○	○ ○
	75		○ ×	○ ○	○ ○	○ ○	○ ○	○ ○
	100		× ×	○ ○	□ ×	○ ○	× ○	× ○
	125		× ×	■ ×	× ×	× ×	× ×	× ×
	150		× ×	■ ×	× ×	× ×	× ×	× ×
	200		× ×	■ ×	× ×	× ×	× ×	× ●
PK0	10		× ●	○ ○	× △	× ○	× ○	○ ×
	20		● ●	○ ○	× □	× ○	× ○	○ ×
	30		● ●	○ ○	□ ○	× ○	× ○	○ ×
	50		× ●	○ ○	○ ○	○ ○	× ○	○ ×
	75		○ ×	○ ○	○ ○	○ ○	× ○	× ○
	100		○ ×	○ ○	○ ○	○ ○	× ○	× ○
	125		× ×	○ ○	○ □	○ ○	× □	× ×
	150		× ×	□ □	○ ×	× ×	× ×	× ×
	200		× ×	■ △	× ×	× ×	× ×	× ●
P2	10	○ ○	× ○	○ ●	○ □	□ ○	× ○	○ ○
	20	○ ○	× ○	○ ●	○ □	○ ○	○ ○	○ ×
	30	○ ○	○ ○	○ ●	○ ×	○ ○	○ ○	○ ×
	50	○ ○	○ ○	○ ●	○ ○	○ □	○ ○	○ ×
	75	○ ○	○ ×	○ ×	○ ○	□ □	○ ○	× □
	100	○ ×	○ ×	○ ×	○ ○	○ ○	○ ×	× ○
	125	○ △	× ×	○ ×	× ×	○ ○	○ ○	× ○
	150	△ △	× ×	○ ×	× ×	○ ○	× ○	× ○
	200	△ △	× ×	× ×	× ×	× ×	× ○	× ○
PK1	10	○ ○	× ●	○ ■	× ■	■ □	× ●	○ ●
	20	○ ○	× ×	○ ■	□ ○	× ×	× ●	○ ×
	30	○ ○	× ×	○ ■	○ ○	× ×	○ ●	○ ×
	50	○ ○	× ×	○ ■	○ ○	○ ■	○ ●	○ ○
	75	○ ○	○ □	○ ×	○ ○	□ ●	× ●	○ ×
	100	○ ○	○ □	○ ×	○ ○	□ ●	× ●	○ ●
	125	× ×	× ×	○ ×	○ ○	□ ●	× ●	× ×
	150	× ×	× ×	○ ×	△ ×	× ●	× ●	× ×
	200	× ×	× ×	× ×	△ ×	× ■	× ■	× ×
P3	10	○ ○	× ×	× ■	× ■	× ×	× ○	● ×
	20	○ ○	× ×	× ■	○ ×	× ×	× ○	× ×
	30	○ ○	× ×	× ■	○ ●	× ×	○ ○	○ ×
	50	○ ○	○ ×	○ ■	○ ●	○ ×	○ ○	○ ×
	75	○ ×	○ ×	○ ×	○ ●	○ ×	○ ○	□ ■
	100	○ ×	○ ×	○ ×	○ ●	○ ×	○ ○	□ □
	125	○ ×	○ □	○ ×	○ ×	○ ×	○ ×	□ □
	150	× ×	○ □	× ×	× ×	○ ×	× ×	× ×
	200	× ×	× □	× ×	× ×	× □	× ×	× ×

October

Line	depth	1990	1991	1992	1993	1994	1995	1996
P1	10	× ○	× ○	○ ○	○ ○	× ○	○ ○	× ○
	20	× ○	□ ○	○ ○	○ ○	× ○	○ ○	× ○
	30	× ○	○ ○	○ ○	○ ○	○ ○	○ ○	□ ○
	50	○ ○	○ ○	○ ○	○ □	○ ○	○ ○	○ ○
	75	○ ○	○ ○	○ □	○ ○	○ ○	○ ○	○ ○
	100	× ○	○ □	× ×	○ ▲	○ ○	× ○	○ ○
	125	● ○	□ □	× ×	○ ●	□ ×	× □	× ○
	150	● ○	□ ×	× ×	× ●	× ×	× ×	× ×
	200	× ×	× ×	× ×	× ■	× ×	× ×	× ●
PK0	10	× ○	× ○	× ○	○ ○	× ●	□ ●	× ■
	20	× ○	× ○	× ○	○ ○	× ●	□ ●	× ■
	30	× ○	× ○	× ○	○ ○	× ●	□ ×	○ ×
	50	○ ○	● ○	○ ○	○ ○	× ●	□ ×	○ ○
	75	○ ○	○ ▲	○ ■	○ ○	× ●	△ ○	○ ×
	100	○ ○	○ ●	○ ×	○ ○	▲ ●	× ■	○ □
	125	○ ○	○ ■	× ×	○ □	▲ ●	× ×	□ ×
	150	× ×	× ▲	× ×	○ ×	× ×	× ×	× ×
	200	× ×	× ×	× ×	× ●	× ×	× ×	× ○
P2	10	× ■	○ ○	○ ■	○ ■	× ▲	● ○	□ ○
	20	× ×	○ ○	○ ●	○ ×	× ▲	○ ○	○ ○
	30	○ ○	○ ○	○ ●	○ ○	× ▲	○ ○	○ ○
	50	○ ○	○ ○	○ ×	○ ○	□ ×	○ ○	○ ○
	75	○ □	○ □	○ ×	○ ○	□ △	○ ○	□ ○
	100	○ □	○ □	○ ×	○ ○	× △	○ ○	× ×
	125	□ △	× ×	○ ×	○ ○	× △	○ □	× ■
	150	□ ×	× ×	× ×	○ ○	× △	○ ■	× ■
	200	× ×	× ×	× ×	× ×	× ×	× ×	× ■
PK1	10	□ ×	× ○	△ ●	○ ○	○ ●	○ ○	× ×
	20	□ ×	× ○	△ ●	○ ○	○ ■	○ ○	○ ×
	30	□ ×	× ○	△ ●	○ ○	○ ×	○ ○	○ ×
	50	□ ×	○ ○	△ ■	○ ○	○ ×	○ ○	○ ×
	75	× ○	○ ○	△ ×	○ ○	○ ×	○ ○	○ ×
	100	× ○	○ ○	△ ×	○ ○	■ ×	○ □	○ ×
	125	× ×	× ×	× ×	□ ○	× ×	□ ×	× ×
	150	× ×	× ×	× ×	× ×	× ×	□ ×	× ×
	200	× ×	× ×	× ×	× ×	× ×	× ×	× ●
P3	10	○ ×	× ■	× ●	○ ○	× ×	× ●	× ×
	20	○ ×	× ■	× ●	○ ○	× ×	× ●	× ×
	30	○ ×	× ×	× ●	○ ○	○ ×	× ●	× ×
	50	○ ×	○ ×	× ×	○ ○	○ ×	× ■	○ ×
	75	○ ○	○ ○	○ ×	○ ○	× ×	○ ○	○ ×
	100	○ ×	○ □	○ ×	△ ○	× ×	○ ○	○ ×
	125	× ×	○ ×	○ ×	× ×	× ×	○ ○	○ ×
	150	× ×	× ×	□ ×	△ △	× ×	× □	○ ×
	200	× ×	× ×	× ×	△ △	× ×	× □	× ×

December

Line	depth	1990	1991	1992	1993	1994	1995	1996
P1	10	○ □	○ ○	○ ■	○ ■	△ ▲	○ ●	● ●
	20	○ □	○ ○	○ ■	○ ■	△ ▲	○ ●	● ●
	30	○ □	○ ○	○ ■	○ ■	△ ▲	○ ●	● ●
	50	○ □	○ ○	○ ■	○ ■	× ×	○ ●	● ●
	75	○ □	○ □	○ ■	○ ×	□ ○	○ ●	× ●
	100	○ ■	○ ■	○ ×	○ ×	○ ○	□ ●	× ●
	125	○ □	○ ●	○ ×	○ ×	○ ○	□ ■	□ □
	150	○ □	□ ●	□ □	□ ■	○ ○	□ ■	○ ○
	200	□ □	× ●	× □	× ■	□ ×	× ■	□ ○
PK0	10	△ ○	□ ○	□ ●	○ ▲	▲ ■	○ ●	● ●
	20	△ ○	□ ○	□ ●	○ ▲	▲ ■	○ ●	● ●
	30	× ○	□ ○	□ ●	○ ▲	▲ ■	○ ●	● ●
	50	× ×	□ ○	□ ●	○ ▲	▲ ■	○ ●	● ●
	75	○ ■	○ ■	○ ●	○ ×	○ ●	○ ●	○ ●
	100	○ ■	○ ■	○ ●	○ ×	○ ●	○ ●	× ●
	125	○ ■	○ ●	× ×	○ ×	○ ●	○ ●	× ●
	150	× ×	□ ●	× ×	× ×	× ●	○ ×	× ●
	200	× ×	○ ●	× ×	× ×	× ●	○ ×	× ○
P2	10	○ □	□ □	○ ○	○ □	× ×	○ ■	○ ○
	20	○ □	□ □	○ ○	○ □	× ×	○ □	□ ○
	30	○ □	□ □	○ ○	○ □	× ×	○ □	□ ○
	50	○ □	○ □	○ ○	○ □	○ ×	○ ○	□ ○
	75	○ □	○ ×	○ ×	○ □	○ ×	○ ×	□ □
	100	○ □	○ ×	○ ×	○ △	× □	○ ■	□ ×
	125	○ □	○ ×	○ ×	○ ×	× □	○ ■	□ ×
	150	○ □	○ ●	○ △	○ □	× □	○ ■	○ ●
	200	× ×	× ×	× △	× ×	× ×	○ ■	× ×
PK1	10	△ ▲	○ ○	○ ●	△ △	× ×	○ ×	○ ○
	20	△ ▲	○ ○	○ ●	△ △	× ×	○ ×	○ ○
	30	△ ▲	○ ○	○ ●	△ △	× ×	○ ×	○ ○
	50	△ ▲	○ ○	○ ●	△ △	× ×	○ ×	○ ○
	75	× ▲	○ ○	○ ●	△ △	× ×	○ ●	○ ○
	100	△ ▲	○ ×	○ ●	○ △	○ ×	○ ●	○ ○
	125	× ×	□ ×	○ ▲	× △	× ■	□ ■	○ ×
	150	× ×	□ ×	○ ▲	× ×	× ●	□ ■	○ ×
	200	× ×	○ ●	○ ▲	× ×	× ●	□ ■	× ×
P3	10	○ ●	○ ×	□ □	△ ▲	× ×	○ ×	× ■
	20	○ ●	○ ×	□ □	△ ▲	× ×	○ ×	× ■
	30	○ ●	○ ×	□ □	△ ▲	× ×	○ ×	□ ■
	50	○ ●	○ ×	□ □	△ ▲	× ×	○ ×	□ ■
	75	○ ×	○ ×	□ ×	△ ×	× ×	○ ×	○ △
	100	○ ×	○ ×	□ ×	× ×	× ×	○ ×	○ ×
	125	○ ×	○ ×	□ □	× ×	× ×	○ ×	○ ×
	150	○ ×	○ ×	□ △	× ×	○ ×	○ ×	○ ×
	200	× ×	× ■	× ■	× ×	○ ×	○ ×	○ ×

Fig. 7. *Same as in fig. 6 except for the period II (August, October and December)*

5. NUMERICAL REPRESENTATION

By using the numerical values of the grade of appearance, we calculated the appearance indices averages over 7 years (over 6 years for P1 and PK0 lines), for each depth and for each month Then, we averaged over observation lines to know how the appearance index is changed if the observation depth is changed. The results for period I (February, April and June) are shown in upper row in **fig. 8** and those for Period II (August, October and December) in lower row in fig. 8. The full lines indicate the variations of temperature index, and the dotted lines indicate those of salinity index.

All of the indices for Period I lie only in negative domain (except for near 200m), indicating that Period I is the season of the Coastal Oyashio. The indices for Period II lie in positive domain (except for near 200m, and for salinity in December), indicating that Period II is the season of the East Hokkaido Warm Current. Magnitude of the salinity indices are always larger than that the temperature indices in Period I, showing that the Coastal Oyashio appears clearer in salinity distributions. While, magnitude of the temperature indices is larger than that of the salinity indices except for near surface layers in August, showing that the East Hokkaido Warm Current appears clearer in the temperature distributions. The curve of the salinity index is smoother than that of temperature index I Period I, while that of the temperature index is smoother than salinity index. So, we may focus our attention on salinity index for Period I, and on temperature index for Period II.

The magnitudes of the salinity indices in Period I decrease monotonically with depth. It crosses –4 line about at 50m, and –3 line about at 100m. The index value –3 is set as the limit that the "clear" Coastal Oyashio can be recognized according to our definition. This would mean that the thickness of the Coastal Oyashio is about 100m.

As to the East Hokkaido Warm Current in Period II, the situation in December is very special, and both of the distribution patterns of the Coastal Oyashio and of the East Hokkaido Warm Current can be recognized. The salinity index is almost zero for all depths. If we consider that the Coastal Oyashio is seen clearer in salinity index, it does not conflict the former conclusion that December is included into the season of the Warm East Hokkaido Warm Current. However, the situation in December cannot be discussed in the present index analysis. Here, we shall confine our attention to the graphs in August and in October.

Temperature indices in August and October decrease with depth below 75m、 and cross 3 line at the depth about 100m. This would mean that the thickness of the East Hokkaido Warm Current is also about 100m. The variation curves of temperature indices in Period I show a maximum at 50–75m depth. The indices decrease towards surface in the layers shallower than 50m depth. The temperature and salinity cross-sections along PK0 line averaged over 7 years from 1990 to 1996 are shown in **fig. 9.** As seen in this figure, the warm and less saline surface layer covers the area under consideration in the summer season from June to October. This surface layer would be generated by the heat and water exchange through ocean surface. This surface layer often masks the structure of the East Hokkaido Warm Current, and the East Hokkaido Warm Current is sometimes hard to be recognized. Thus, the indices tend to decrease in the surface layer. So, if we try to investigate the seasonal variations of the East Hokkaido Coastal Current, reference level should be taken near at 50m depth.

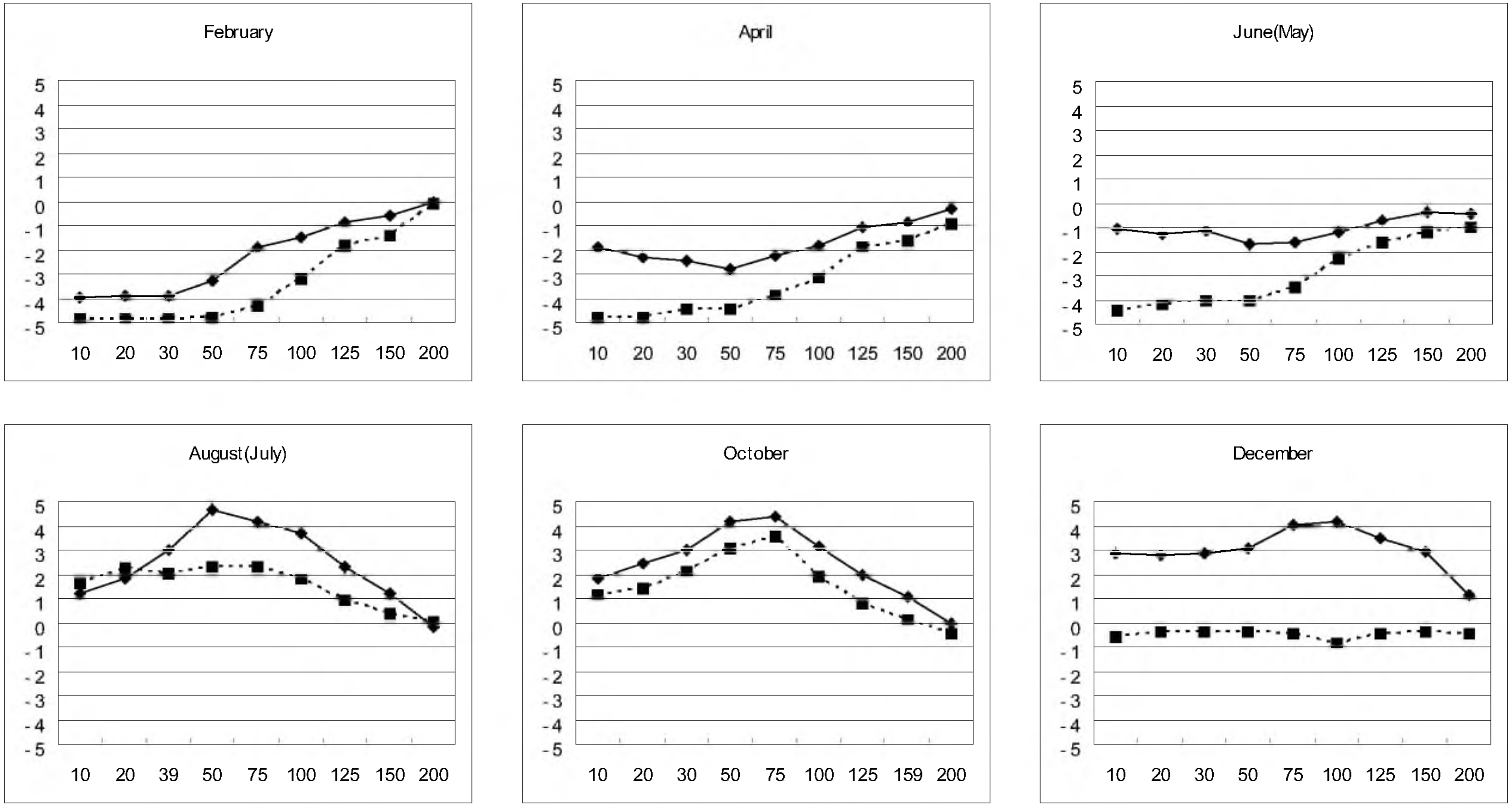

Fig. 8. *Changes of the appearance indices of temperature (full lines) and of salinity (dotted line) against observation depth. Period I is shown in upper row, and Period II in lower row*

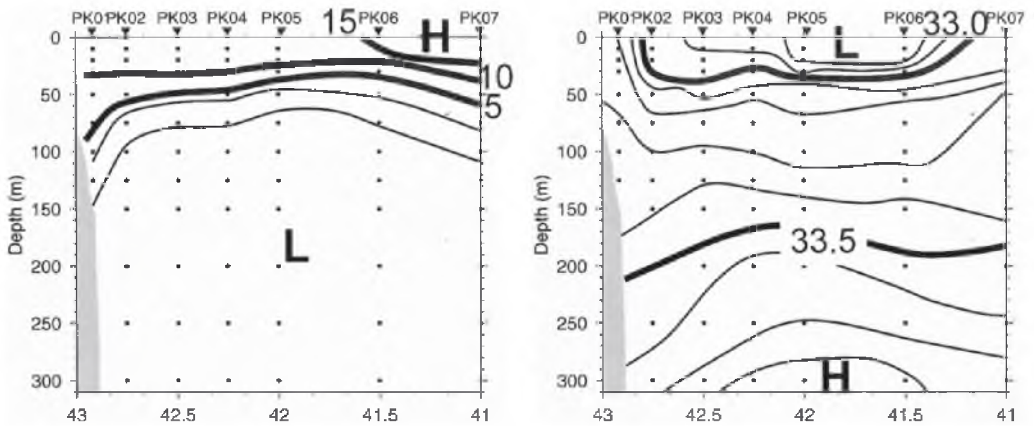

Fig. 9. *Temperature (left) and salinity (right) cross-sections along PK0 line in August averaged over 7 years from 1990 to 1996*

The changes of the temperature and salinity indices against observation lines were also calculated in similar way. The results are shown in **fig. 10.** The negative indices in February and in April tend to increase when the observation line moves from east to west, indicating that the structure of the Coastal Oyashio is weakened from east to west. The positive indices in October tend to decrease from east to west, indicating that the structure of the East Hokkaido Warm Current is weakened also from east to west. These results support the assumption that the water of the East Hokkaido Coastal Current originates from northeastward seas, and carried along the coast. The results of the direct current measurement conducted by the Hokkaido Regional Fisheries Research Institute (Kusaka et al., 2009) are very consistent to our results.

The significant trends cannot be recognized in the index curves in June, in August and December. The Coastal Oyashio is clear and strong in February and in April, but is considerably weakened in June. The results of the configuration of isopleths suggest that the structure of the East Hokkaido Warm Current in August is clear just as same as that in October. However, the water mass analysis in the next section suggests that the East Hokkaido Warm Current is strongest in October. The weakness of the current in June, in August, and in December may explain that the dependency of the indices against observation lines is not seen in these months.

The changes of the indices against the year are also investigated, but no significant result can be found.

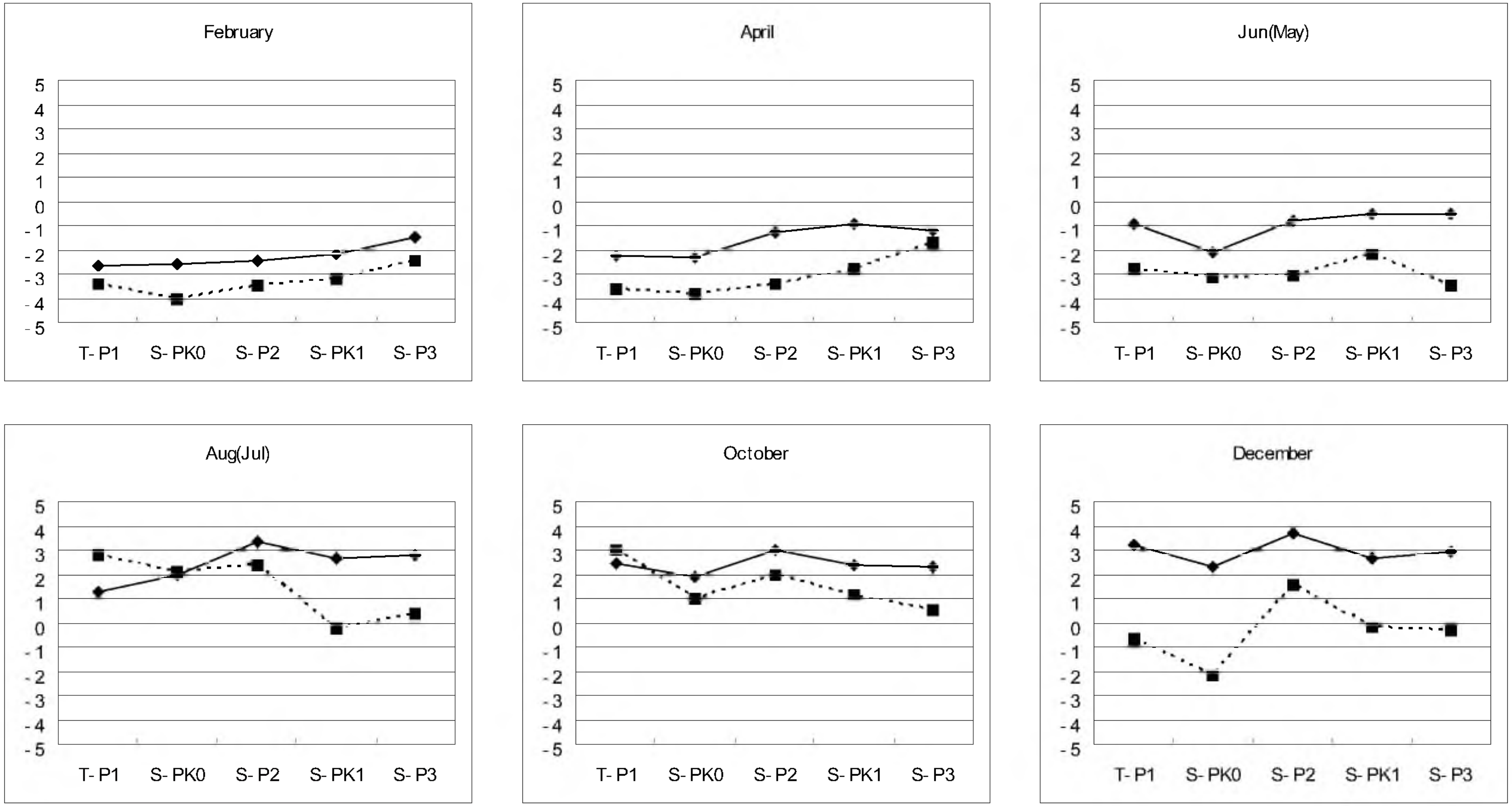

Fig. 10. *Same as in fig. 8 except for against observation line*

6. SEASONAL CHANGES OF THE WATER MASS OF THE EAST HOKKAIDO COASTAL CURRENT

Ogasawara (1990) discussed about the seasonal changes of water type of the East Hokkaido Coastal Current, and showed schematically its migration on T-S diagram. However, he did not mention about the definition of the water of the East Hokkaido Coastal Current. As discussed in the previous section, the thicknesses of the Coastal Oyashio and of the East Hokkaido Warm current are about 100m. The structure of the East Hokkaido Warm Current is not clear being masked by warm and less saline surface layer which appears in the summer season. So, the 50m depth is recommended to be chosen as the reference level to analyze the seasonal variation of the water mass of the East Hokkaido Coastal Current. We chose 2 stations nearest to the coast along 5 observation lines from P1 through P3, and the temperature and salinity values at the depth of 50m are used in the following analysis.

The data are classified into three groups: (1) the structure of the East Hokkaido Coastal Current is recognized both in temperature and salinity fields, (2) the structure is recognized either in temperature and salinity fields, and (3) the structure is not recognized both in temperature and salinity fields.

At first, the data are plotted on a TS surface for each month, with different marks for three cases. The data clusters for three cases, are overlapped one another, and the difference among three cases are hard to be seen. This indicates that the water type at 50m depth near the coast is very similar for each month, and not so much influenced whether the East Hokkaido Coast Current exists or not. This suggests that the origin of the water is not originated directly from the Okhotsk Sea. Even if the water is originated from Okhotsk Sea, it should have been modified by heat and water exchange through sea surface or by outflow of land waters.

The water inside of the Coastal Oyashio should have lower temperature and lower salinity than the environmental water, and that of the East Hokkaido Warm Current should have higher temperature and higher salinity than the environmental water, according to their definition. Some differences would be found between the case that the East Hokkaido Coastal Current is recognized and the case that no such current is recognized. The two extreme cases (1) and (3) are plotted on TS-diagram, and compared for each month from February through October in **fig. 11** through **fig. 15.** In these figures, the case (1) is shown with ● and the case (3) with ○. The plot for December (**fig. 16**) is made a little different way. The structure similar to the Coastal Oyashio appears sometimes in December. So, the case that the structure of the Coastal Oyashio is found at least in the salinity field is additionally considered, and is shown with ○. In fig. 16, the case (1) is shown with ■, and the case (3) is shown with ▲.

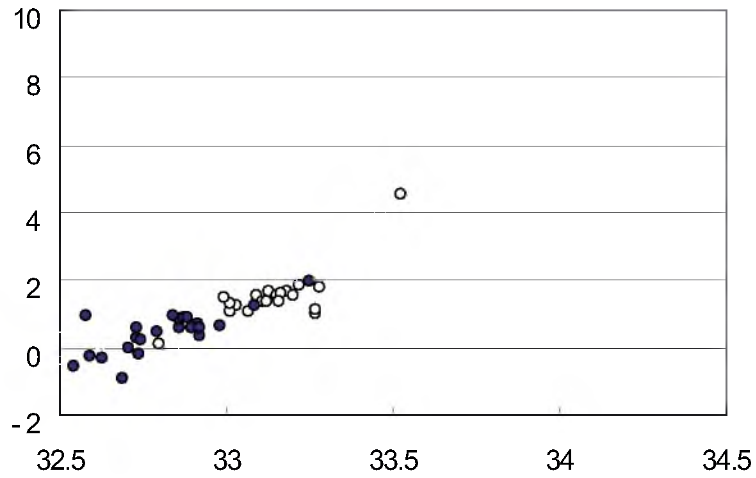

Fig. 11. *Scattering diagram of the water types in February. Closed circles indicate the case that the signature of the Coastal Oyashio is recognized in cross-section (case 1) and open circles the case that no signature of the Coastal Oyashio is recognized in the cross-section (case 3)*

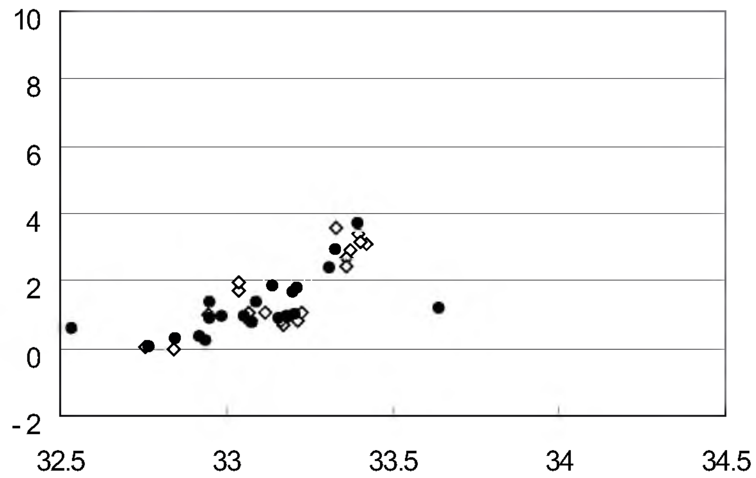

Fig. 12. *Same as in fig. 11 except in April*

In Period I (fig. 11 through **fig. 13**), the data points of the case (1) distribute a little colder and less saline side, but the area of the data cluster is overlapped each other. It would be noted that the overlapping area is the smallest in February when the Coastal Oyashio is strongest. In June, the distribution of data points of Case (3) extends towards higher temperature and higher salinity side. It may indicate that signal of the structure of the East Hokkaido Warm Current may be seen sometimes in June. Ohtani (1971) defined the water mass of the Coastal Oyashio as the water that its temperature is below 2°C and its salinity is below 33.0. This seems to correspond to the domain of the case (1) data cluster in February (fig. 11).

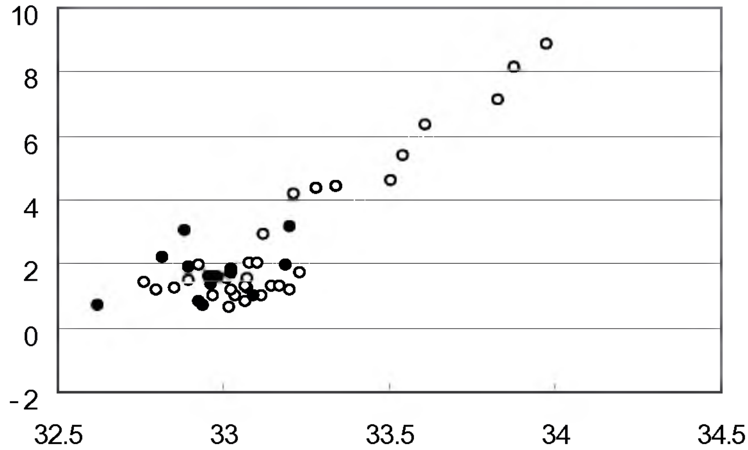

Fig. 13. *Same as in fig. 11 except in June*

In Period II (**fig. 14** through fig. 16), the data points of the case (1) distribute a little higher temperature and higher salinity than the case (3), but the area of the data cluster is overlapped each other. The overlapping area of the data clusters is smallest in October, and the data points of the case (1) distribute much warmer and more saline side than those of the case (3). This indicates that the East Hokkaido Warm Current is strongest in October, though the significant difference cannot be recognized in cross-sectional structures. The overlapping is largest in December (see the distributions of ■ and ▲). The data points (○) of the case that the structure of the Coastal Oyashio can be seen at least in salinity distribution distribute much colder side than those of the cases (1) and (3). This structure might be considered as the for-runner of the Coastal Oyashio is seen. However, it should be reminded that their temperature is considerably higher than the temperature of the Coastal Oyashio in February.

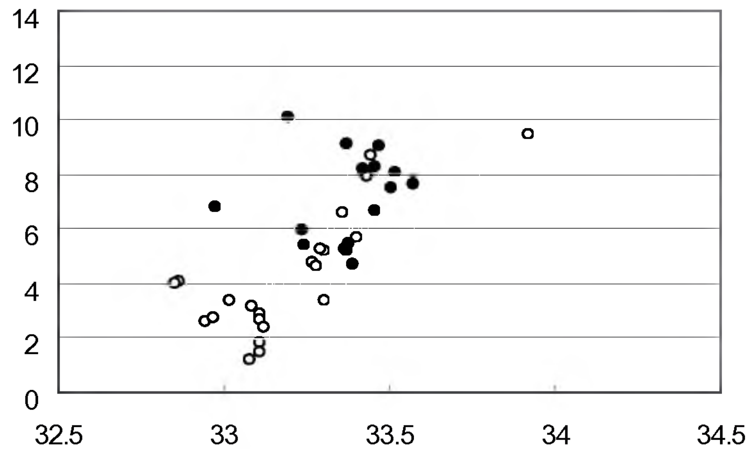

Fig. 14. *Scattering diagram of the water types in August. Closed circles indicate the case that the signature of the East Hokkaido Warm Current is recognized in cross-section (case 1) and open circles the case that no signature of East Hokkaido Warm Current is recognized in the cross-section (case 3)*

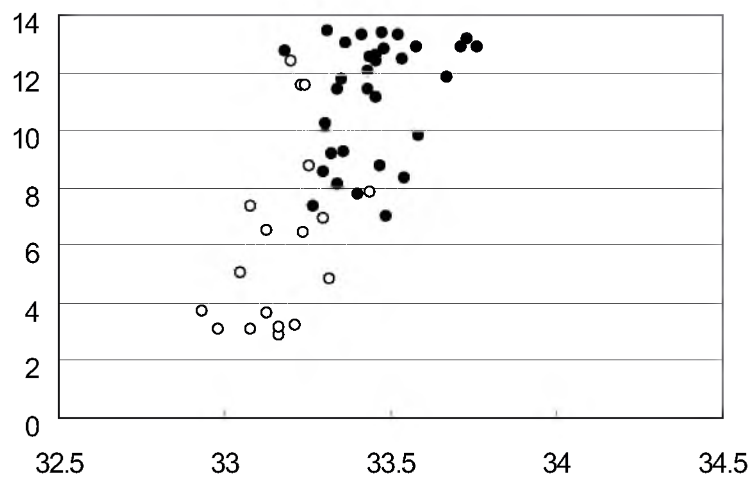

Fig. 15. Same as in fig. 14 except in October

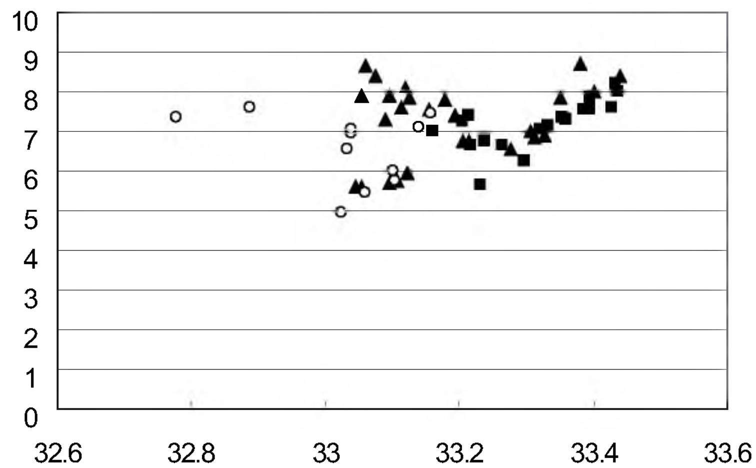

Fig. 16. Scattering diagram of the water types in December In December, the structure of the Coastal Oyashio sometimes appears. So, three marks are used in this figure. Closed squares indicate the case that the signature of the East Hokkaido Warm Current is recognized in cross-section (case 1), closed triangles the case that no signature of East Hokkaido Warm Current is recognized in the cross-section (case 3), and white circles the case that signature of the Coastal Oyashio is recognized at least in the salinity field

The seasonal variations of the water type of the East Hokkaido Coastal Current are shown in **fig. 17,** by using the data of the case (1). It is very interesting that the data points of Period I and those of Period II is clearly separated by the 4°C line. The temperature and salinity values in fig. 17 were averaged for each month, and the seasonal variation of the averaged water type is shown in **fig. 18.** The water type of the East Hokkaido Coastal Current migrates goes and returns along a specific curve. Physical meaning of this fact would be clarified in the future analysis.

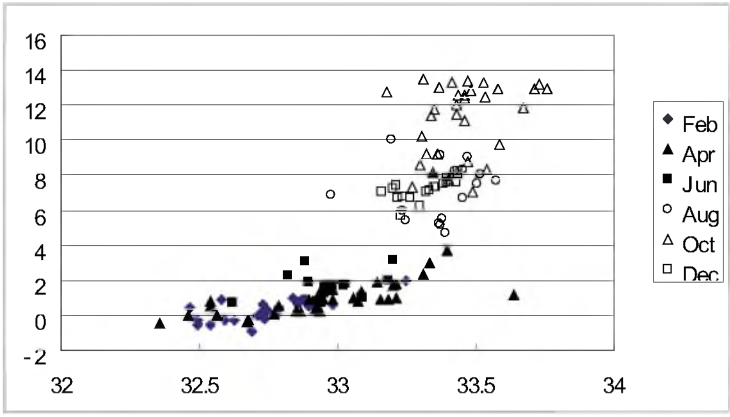

Fig. 17. Seasonal variation of the water type of the East Hokkaido Coastal Current Water

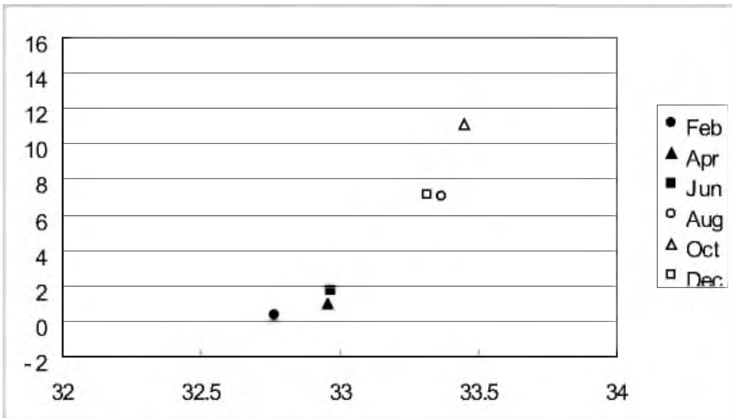

Fig. 18. Seasonal variation of the averaged temperature and salinity of the East Hokkaido Coastal Current Water

7. CONCLUDING REMARKS

The analyses are based on the observations conducted by the Hokkaido Kushiro Fisheries Experiment Station, which is made at two months interval. However, we can clarify several specific and unique characteristics of the seasonal variations as follow:

(1) From the analysis of the cross-sectional structure of the temperature and salinity fields, it is concluded that the Coastal Oyashio is strong in February and in April, and the East Hokkaido Warm Current is strong in August and in October. The water mass analysis indicates that the Coastal Oyashio is strongest in February, and that the East Hokkaido Warm Current is strongest in October.

(2) The first half of the year is the season of the Coastal Oyashio and the second half of the year is the season of the East Hokkaido Warm Current. Occurrence frequency of the Coastal Oyashio in February is almost 100%. While, the East Hokkaido Warm Current cannot be recognized in some years even in October, when the Current is usually strongest.

(3) The structure of the Coastal Oyashio is clearer in salinity field than in temperature field. While, the structure of the East Hokkaido Warm Current is clearer in temperature field than in salinity field.

(4) The thicknesses of the Coastal Oyashio and of the East Hokkaido Warm Current are about 100m.

(5) The structure of the East Hokkaido Warm Current is hard to be recognized, in surface layers, as the warm and less saline surface layer in summer season often masks it.

(6) December is thought to be included in the East Hokkaido Warm Water season in general. However, the structure similar to the Coastal Oyashio is recognized in some year. This might be thought as a fore-runner of the Coastal Oyashio.

(7) The temperature and salinity of the East Hokkaido Coastal Current exhibit very large seasonal variation. The water type tends to migrate along a specific curve in TS-diagram.

(8) Area of the cluster of the data points on TS-diagram is almost identical whether the East Hokkaido Coastal Current is recognized or not. This indicates that the origin of the water of the East Hokkaido coastal Current cannot be sought directly to the water which flows out from the Okhotsk Sea. Even if it originates from the Okhotsk Water, the water has been completely modified on the way to reach the seas to the east of Hokkaido.

The results obtained in this report are very consistent to the results of the DNA analysis made by M. Ikeda in this program that DNA property of the group of the Hanasaki crab to the east of the Shiretoko Peninsula is quite different from that of the group to the east of the Shiretoko Peninsula. These two groups was separated about several ten thousands years ago, and is isolated each other thereafter.

ACKNOWLEGEMENTS

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