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Oceanographic conditions of the Western Subarctic Gyre region based on oceanographic data during the JARPN 1994-1999

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ABSTRACT

The Oceanographic conditions of the Western Subarctic Gyre region of the North Pacific Ocean were analyzed for the JARPN 1994-1999. XBT, XCTD and CTD data obtained in the JARPN surveys were used for the analysis. In the offshore region, strong temperature front was observed along the 40-43N latitude from 148E to 170E. The front is the Subarctic Boundary, which is the southern boundary of the distribution of the subarctic cold and low-saline water mass. The position of the Subarctic Boundary changed on the year-to-year time scale. The northward shift of the Subarctic Boundary in 1994 brought the warm state in the front region and the southward shift in 1997 caused the cold state. The Subarctic Front exists around 43-45° N. The subsurface temperature minimum layer is formed in the area north of the Sunarctic Front. Using the sea surface temperature data, the preliminary analysis about the relationship between oceanographic conditions and distribution of Minke Whales in the offshore region was performed. The good correlation between sea surface temperature and northward migration of Minke Whales was found. Basic oceanographic structures of the research area in the Sea of Okhotsk and the area south of Hokkaido were also investigated.

INTRODUCTION

The research area of JARPN 1994-1999 was the Western Subarctic Gyre region in the North Pacific Ocean. Figure 1 shows the schematic view of the gyre. The Western Subarctic Gyre region is known as an area of high production capacity. The Oyashio, which is the Western Boundary Current of the gyre, flows into the sea area east of Honshu and sustains the high productivity there. Many species utilize the Western Subarctic Gyre region as a feeding ground in the summer season. From the Oceanographical viewpoints, the Subarctic Gyre region is the highly variable on decadal to inter-decadal time scales (Watanabe and Mizuno, 1994, Nakamura et. al., 1997) and is thought to play an important role in the climate system. So the detailed study of the Subarctic Gyre in the North Pacific is strongly required in the recent years.

In the JARPN 1994-1999, many oceanographic observations were carried out in the Western Subarctic Gyre region. The data are important not only for the investigation of the environment for the Minke Whale but for the investigation of the long-term variation of the oceanographic structure. The purpose of this report is to show the general oceanographic conditions of the JARPN area.

DATA

Subsurface thermal conditions were mainly observed by using the XBT (eXpendable Bathy Thermograpgh) from 1994 to 1997. 62 profiles were obtained for 1994, 57 for 1995, 66 for 1996 and 63 for 1997. In 1998 and 1999, XCTD (eXpendable Conductivity-Temperature-Depth) profilers were introduced to get both temperature and salinity profiles. 50 XCTD probed were launched in 1998 and 42 profiles in 1999. The CTD observation by SBE-19 also initiated by R/V Yushin-Maru and 22 observations were carried out in 1999. Figure 2 shows oceanographic observation points for the JARPN 1994-1999. The Western Subarctic Gyre region west of 170E was almost covered. We also used the sea surface temperature (SST) data in the Western North Pacific provided by Japan Meteorological Agency.

RESULTS

Oceanographic conditions in the offshore region

Figure 3 shows the meridional temperature and salinity sections along the 170° E observed in 1995. Two major front systems are found in the Subarctic Gyre region of the North Pacific Ocean. The northern one is called as the Subarctic Front and which is found around 45° N in the temperature section which is indicated by a drop of 4℃ contour in the temperature section (Favorite et al., 1976). The front shows the southern boundary of the region characterized by the near-surface temperature minimum and the strong halocline. The southern one is called as the Subarctic Boundary that marks the southern boundary of the subarctic low saline surface water. The Subarctic Boundary located around 42° 30'N indicated by 34.0 psu contour in the salinity section. The boundary is also indicated by 6-9C temperature contour at 300m (Zhang et al., 1993).

Figure 4 shows the horizontal temperature distribution at 100m and 300m constructed by using all the data from JARPN 1994-1999. The contour line of 4℃ in the 100m temperature indicates the position of the Subarctic Front. The front lies around 43-45° N. The averaged meridional temperature section of the area is also shown in Fig. 5. The near-surface temperature minimum layer is clearly formed in the area north of the front. The temperature value below 2℃ are detected. The summertime strong solar irradiation raises the sea surface temperature and brings the

strong stratification between the surface and the temperature minimum layers. In the southeastern part of the JARPN area, the Subarctic Boundary is clearly found around 40-43° N.

To observe the year-to-year variation of the oceanographic conditions in the JARPN area, the SST map for each year were made. Figure 6 shows the SST maps of June for 1994 and 1997. Oceanographic conditions in southern part of the JARPN area around 40° N changed from warm state in 1994 to cold state in 1997. The SST difference between 1994 and 1997 is reached to 3℃ in the southwestern part of the JARPN survey area. This cooling trend reflected the southward shift of the Subarctic Boundary.

Relationship between the SST and the sighting points of Minke Whale in the offshore region

To look the relationship between SST and distribution of Minke Whales, we plotted sighting points of Minke Whales on the SST map of each calendar month from May to August (Fig. 7). In the offshore region, sighting points show a concentration in the Subarctic Boundary region around 40° N from May to July. In July, another concentration is found around 45° N. Sighting points widely distribute in the Western Subarctic Gyre region north of 40° N in August. Figure 8 shows the relationship between sea surface temperature and meridional movement of sighting points in the sub-area 9. The averaged latitude of sighting points for each calendar month is plotted with error-bar. The close relationship between warming of the area in July and the start of the northward shift of sighting points is clearly seen.

The Sea of Okhotsk

The southwest region of the Sea of Okhotsk was observed in 1996 and 1999. The oceanographic observation points are shown in Fig. 9. In this region, the observation was carried out outside of the Soya Warm Current along the northeast coast of Hokkaido. As shown in the Fig.10, the hydrographic structure of the area is characterized by near surface temperature minimum reached to –1.0℃. The survey area covered both the continental shelf region and the deep Kuril Basin. The temperature minimum layer is thin in the shelf region and thick in the Kuril Basin (Fig. 11). In the shelf region west of 144° E, warm and saline water mass was found below the temperature minimum layer. As the density of the water mass was around 26.8 kg/m^3, the water mass could be a source of the North Pacific Intermediate Water.

The area south of Hokkaido

The area south of Hokkaido was observed in 1996 and 1999. The oceanographic observation points are shown in Fig. 12. Figure 13 shows zonal temperature section along the B line in Fig.12 observed in 1996. Meridional temperature and salinity sections along C and D lines in Fig.12 are shown in Fig.14 and Fig.15. C and D lines were observed by using XCTD in 1999. In 1996, warm

water mass from the Tsugaru Warm Current occupied the area west of 143° E. In the area east of the longitude, the cold and low-saline Oyashio water occupied in both 1996 and 1999. The temperature minimum layers with temperature below 1℃ was observed in the region. The Warm Core Ring was observed in 1999 southern part of the C-line. The strong front was formed around 42° N.

SUMMARY

Oceanographic conditions of the JARPN area were analyzed by using the oceanographic observation data obtained during the JARPN 1994-1999 and other related data set. Two major front systems observed in the offshore region of the JARPN region. The one is the Subarctic Front around 43-45N and the other is subarctic boundary around 40-43° N. The geographical position of the Subarctic Boundary shows strong year-to-year variability and which bring the large anomalies in the temperature field. The peak-to-peak value of the year-to-year variations of the SST in the front region reached to about 3℃. In the Sea of Okhotsk, the strong temperature minimum layer below 1℃ was found . In the sea area south of Hokkaido, there were three major components, the Tsugaru Warm Current, the Oyashio and the Warm Core Ring. The preliminary analysis of the relationship between the oeeanographic condition and the distribution of Minke Whale in the offshore region was performed. The good correlation between sea surface temperature and northward migration of Minke Whales was found.

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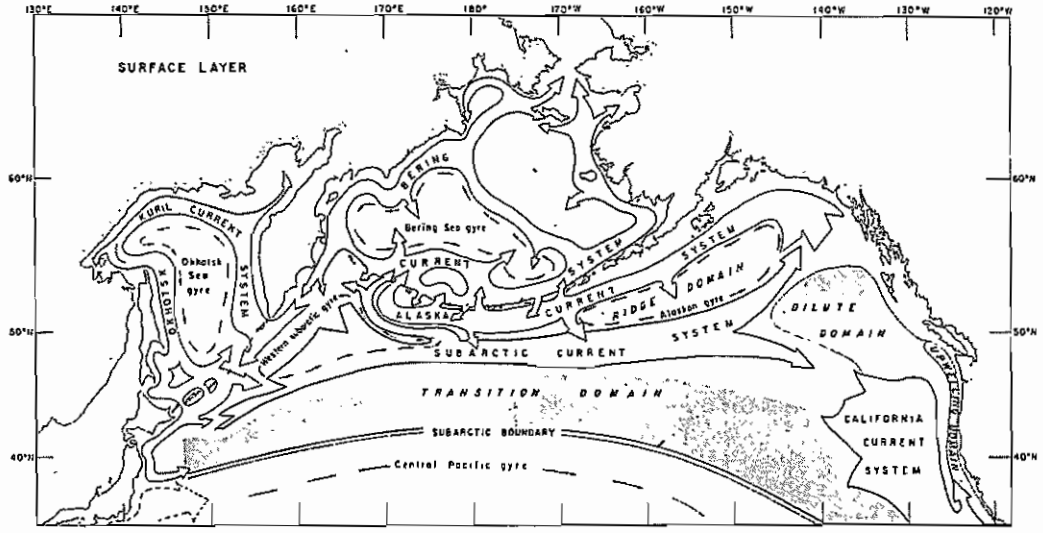

Figure 1. Schematic view of the subarctic gyre of the North Pacific cited from Favorite et al (1976).

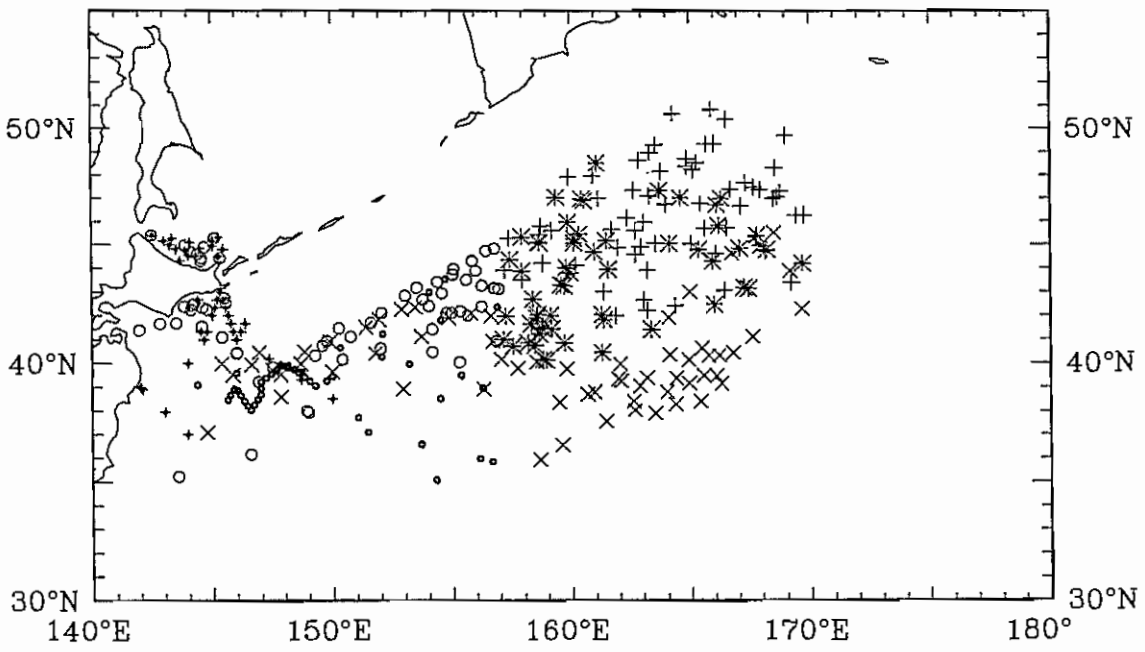

Figure 2. XBT and XCTD observation points in the JARPN survey 1994-1999

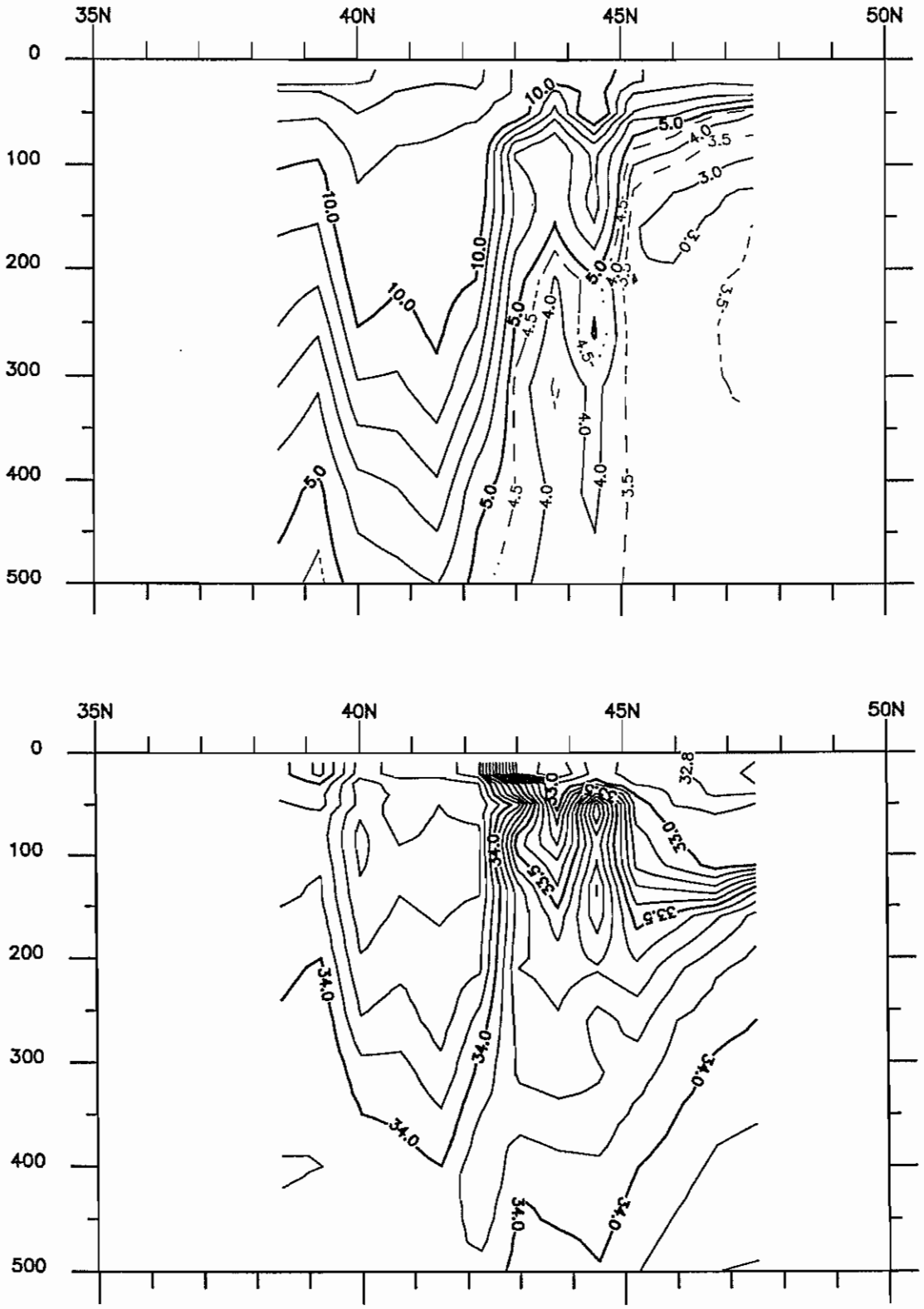

Figure 3. Temperature(Upper) and salinity(lower) distribution along the 170E meridian observed by Hokkaido University's R/V Hokusei-Maru in July 1995. Contour interval is 1℃ for temperature and 0.1 psu for salinity.

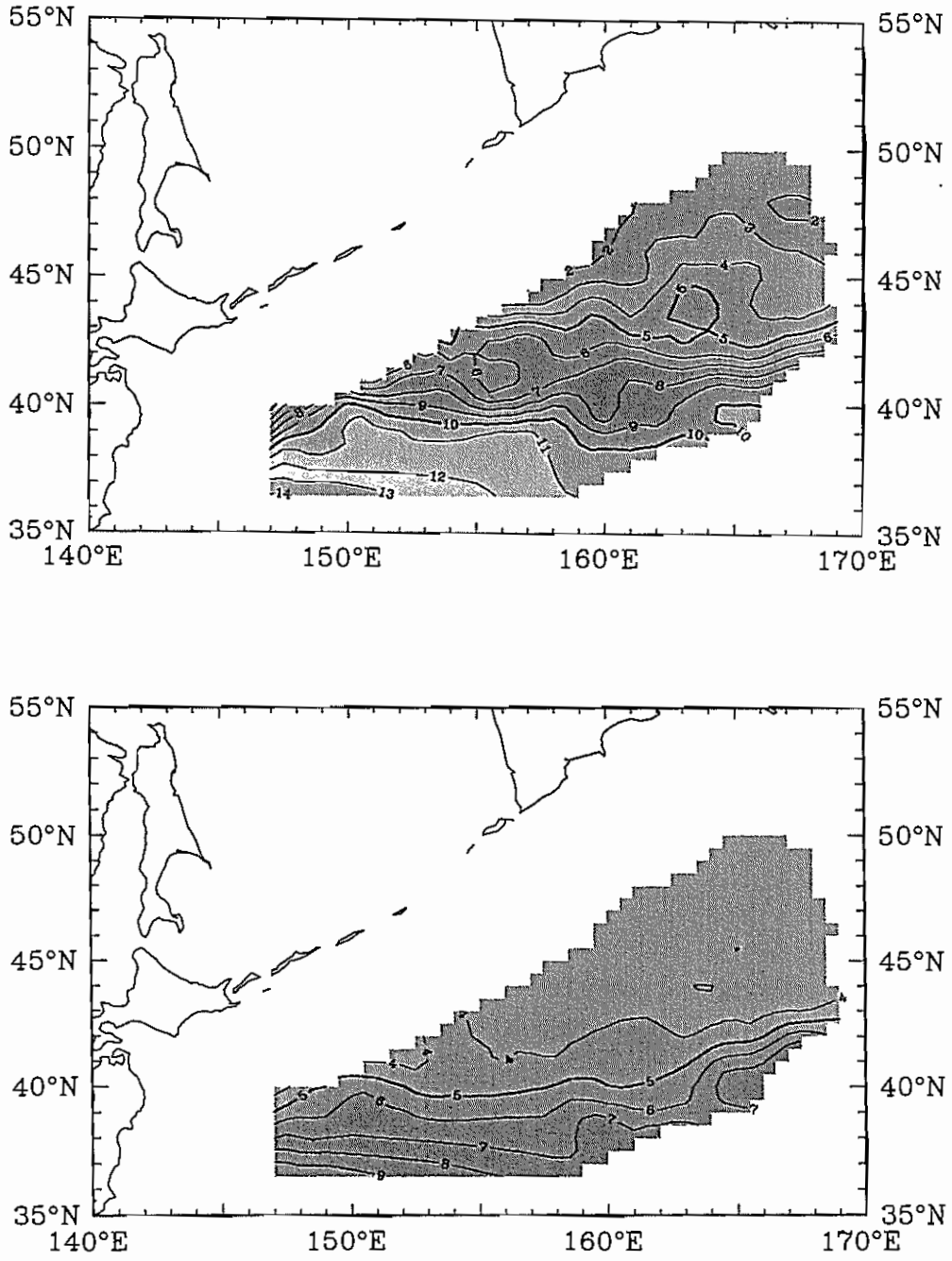

Figure 4. Horizontal distribution of the temperature at 100m depth (Upper) and at 300m (lower) constructed by using the JARPN XBT data set. Contour interval is 1℃.

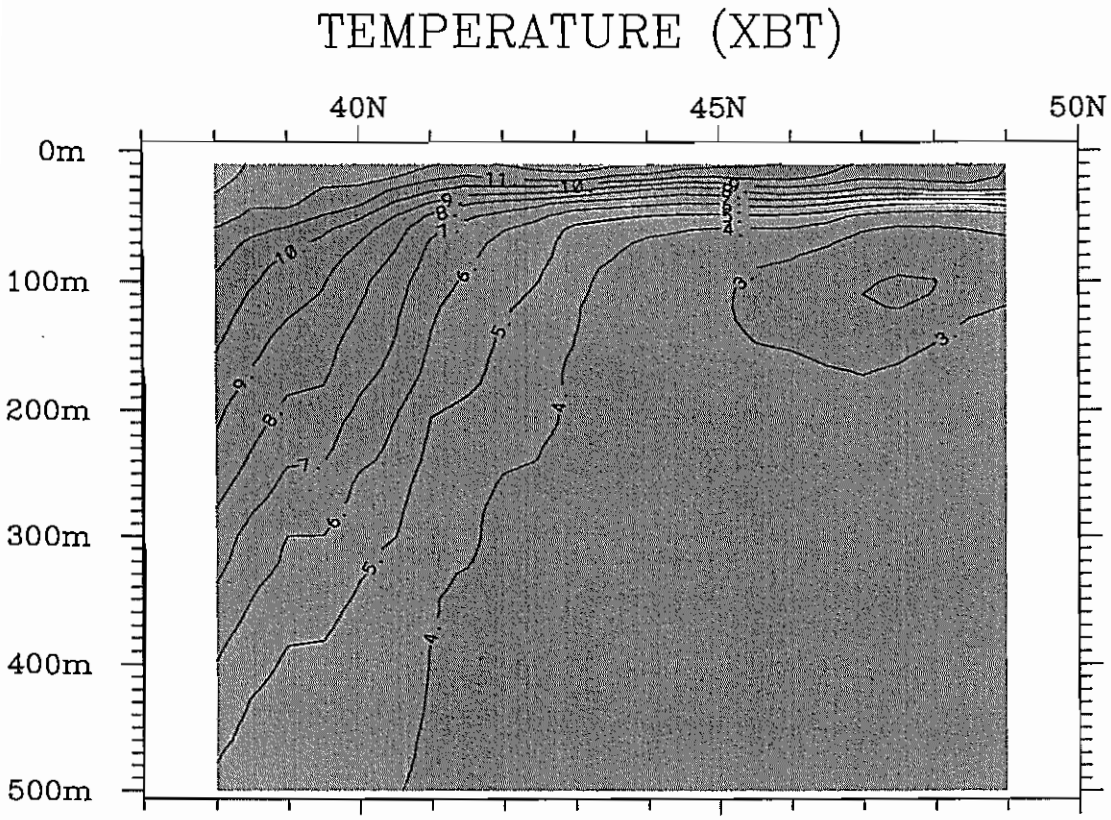

Figure 5. Meridional temperature section in the off-shore region of JARPN 1994-1999 constructed by using the JARPN XBT data set. Contour interval is 1℃.

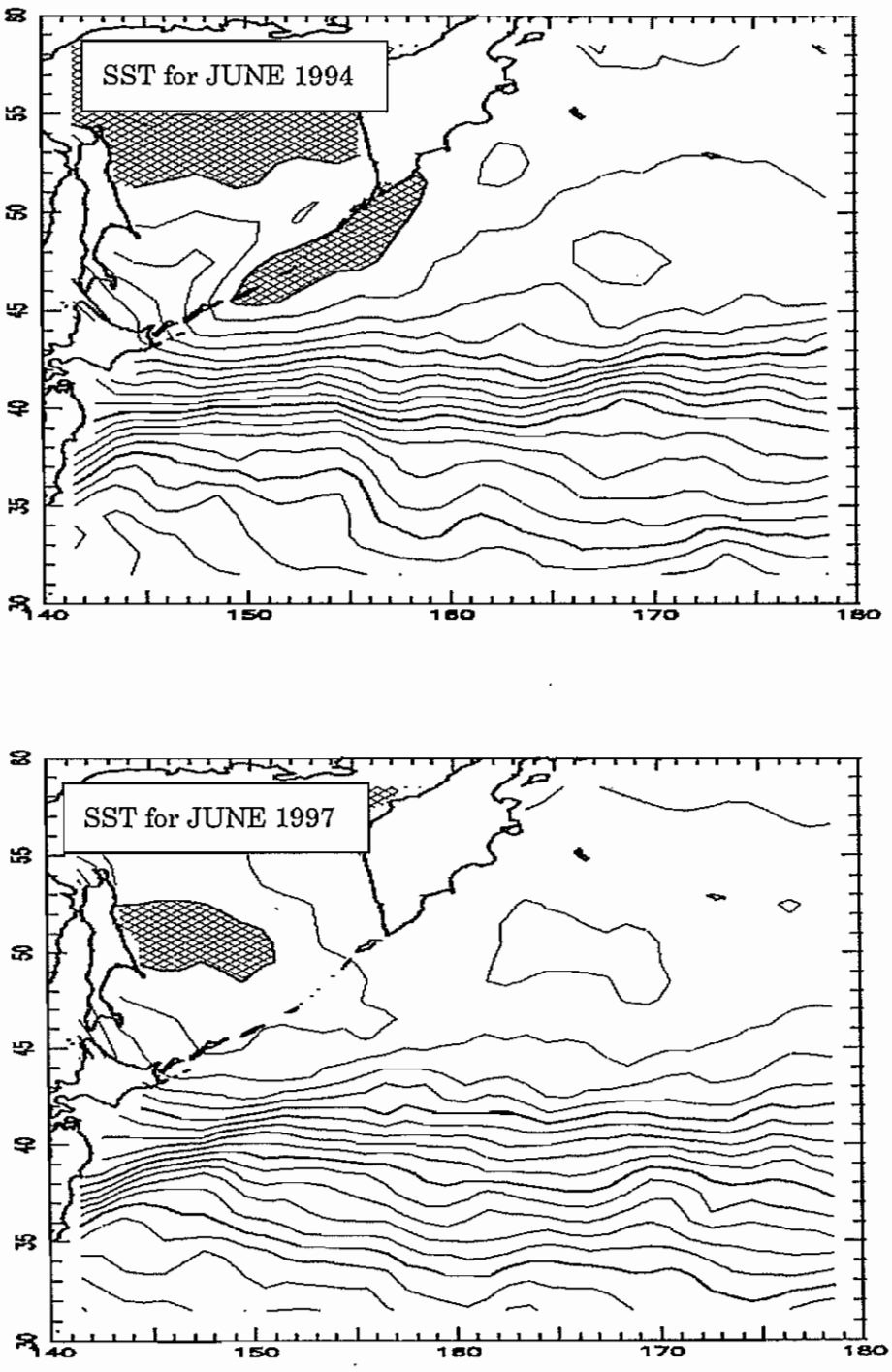

Figure 6 Monthly mean sea surface temperature distribution for the June of 1994 (upper) and of 1997(lower). Contour interval is 1℃ and the areas below 5℃ are hatched.

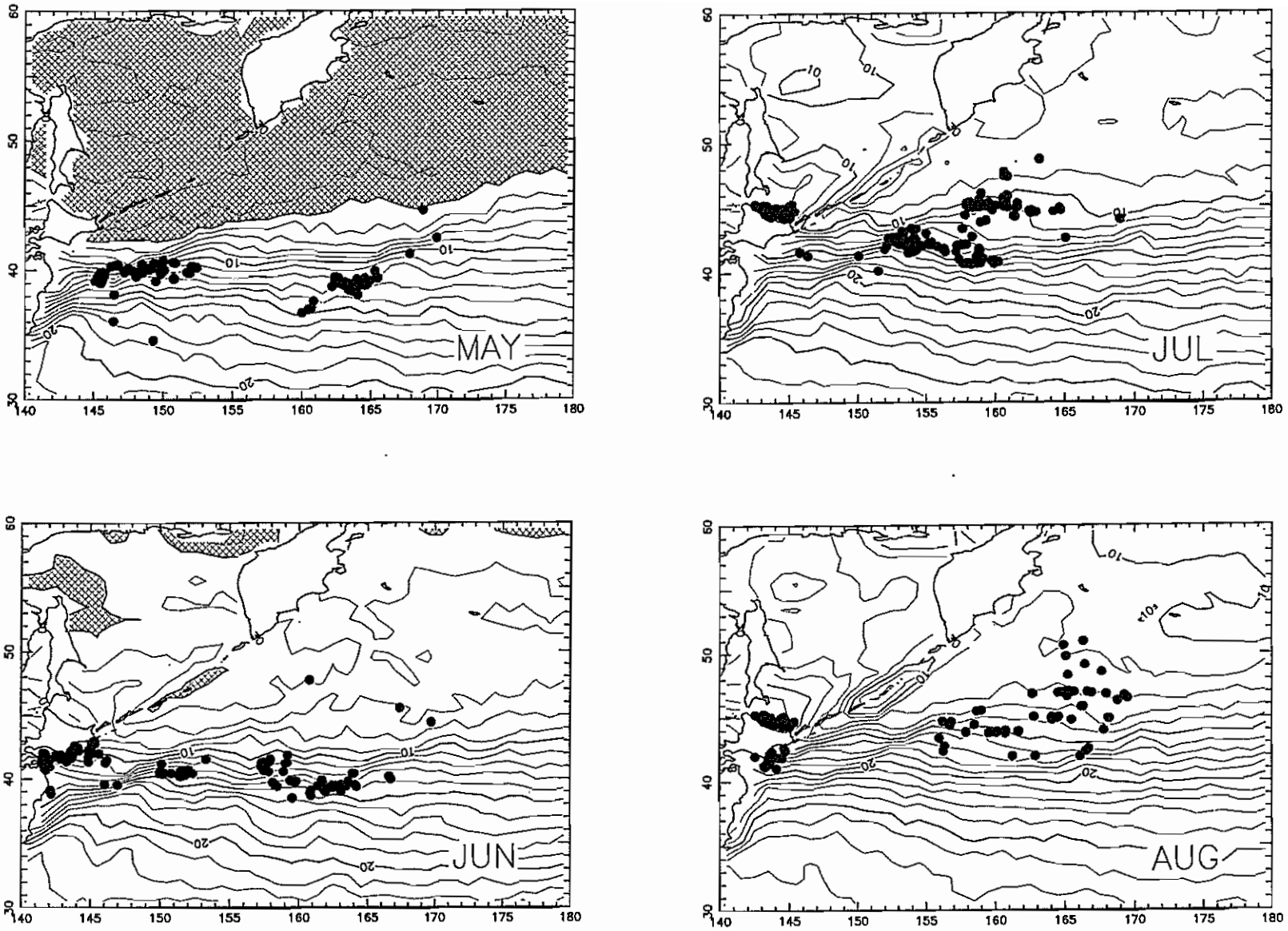

Figure 7. Monthly mean sea surface temperature distributions from May to August for the 4 years-period from 1994 to 1997. Contour interval is 1℃ and the area below 5℃ are cross-hatched. Full circles drawn on each map indicate the sighting positions of minke whales.

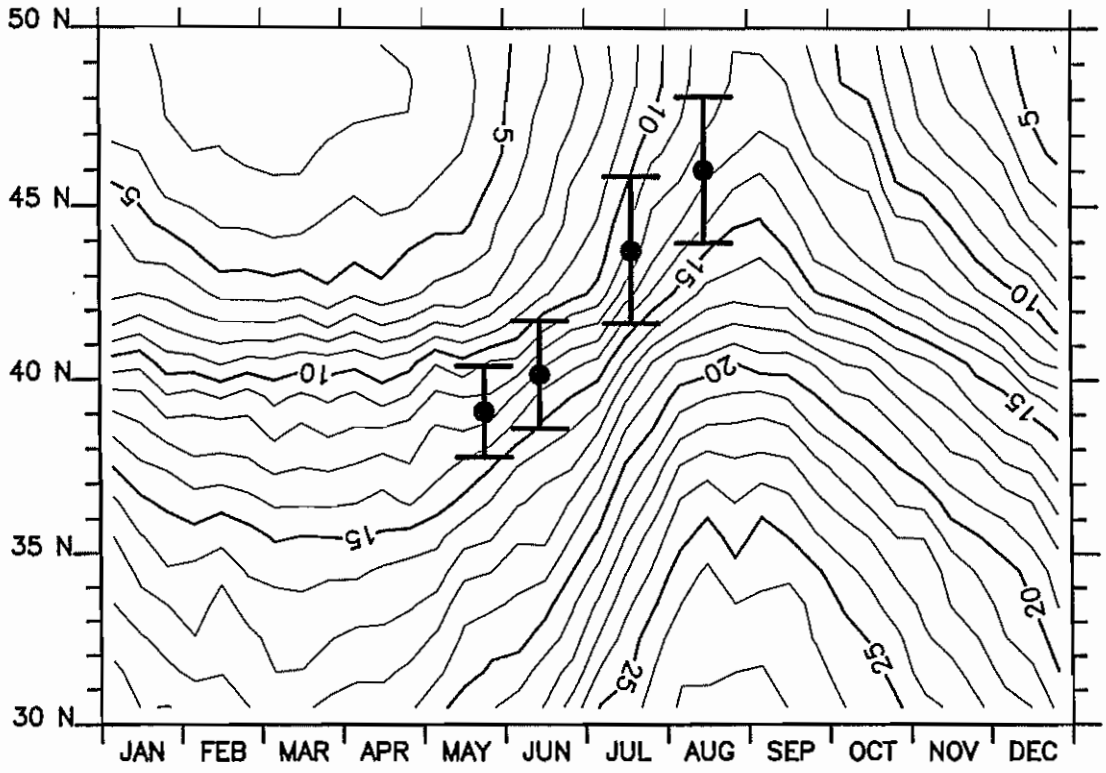

Figure 8. Time-Latitude diagram of seasonal variations of sea surface temperature in the sub-area No.9 (east of 157° E). Contour interval is 1℃. The full circle with error-bar shows the averaged latitude of the sighting position of the minke whales for each calendar month.

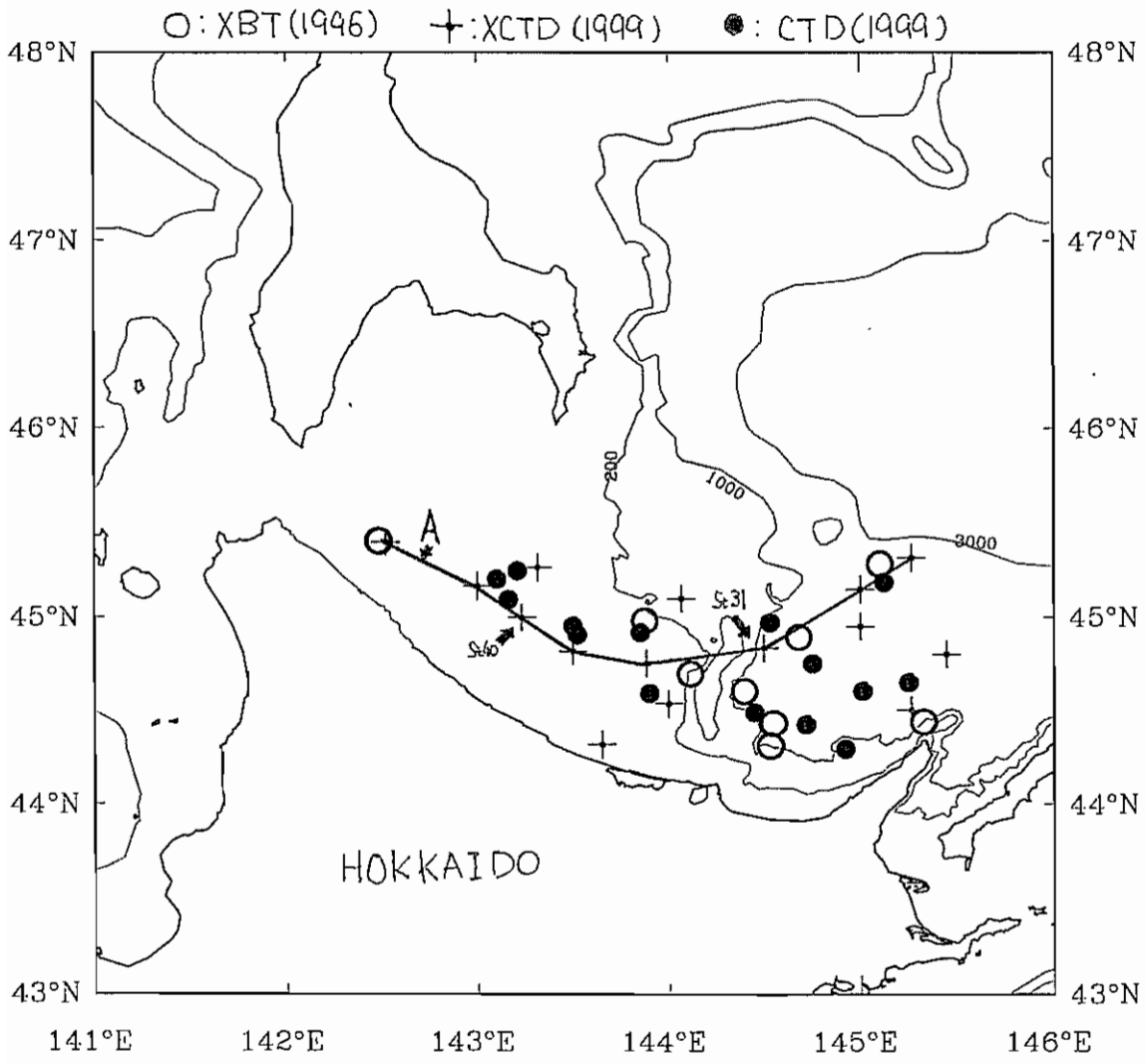

Figure 9. Oceanographic observation points in the Sea of Okhotsk.

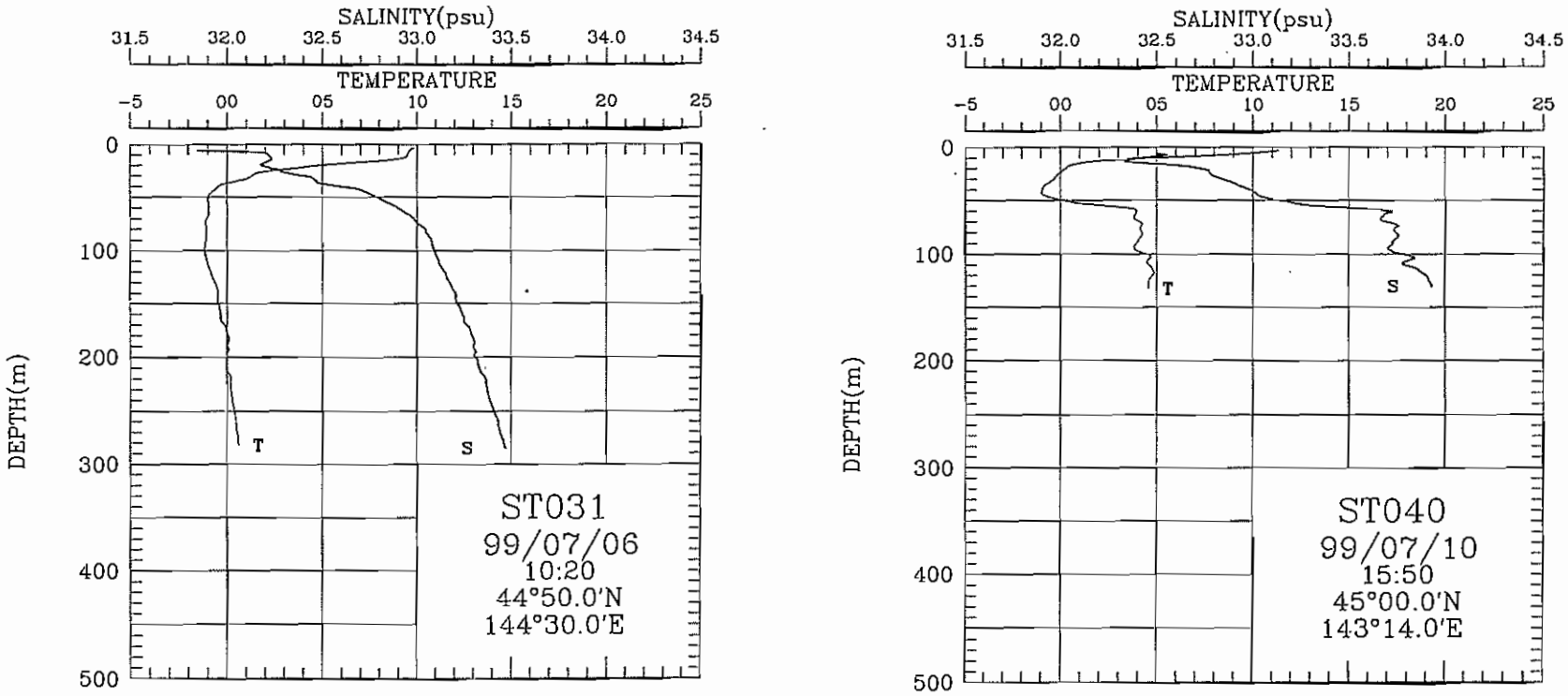

Figure 10. Temperature and Salinity profiles observed by XCTD in the Kuril Basin (left panel) and in the shelf region(right panel).

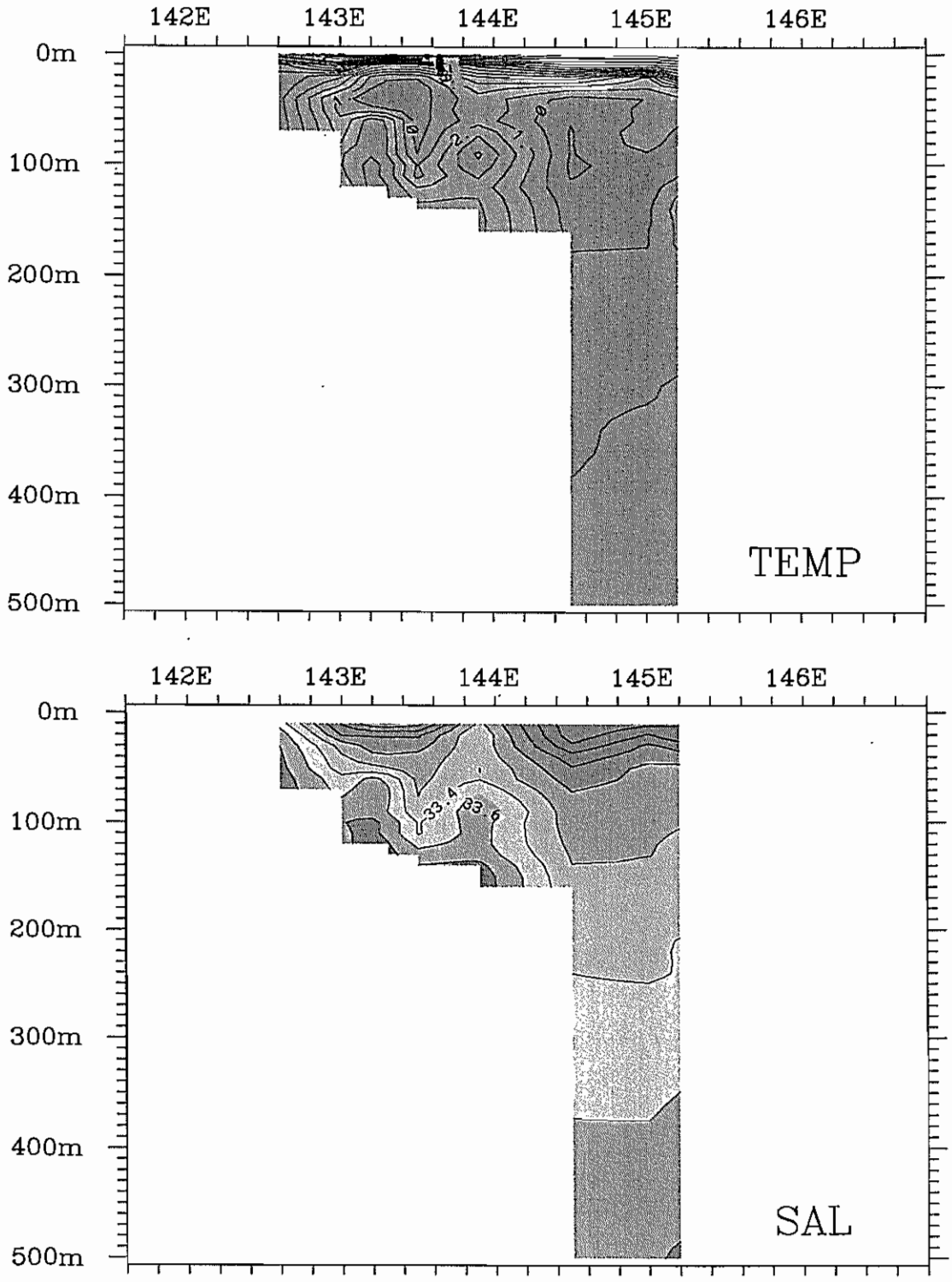

Figure 11. Temperature (upper) and Salinity (lower) zonal section along solid line A in the Figure 9. Data are obtained by XCTD in 1999. Contour interval is 1℃ for temperature and 0.2 psu for salinity.

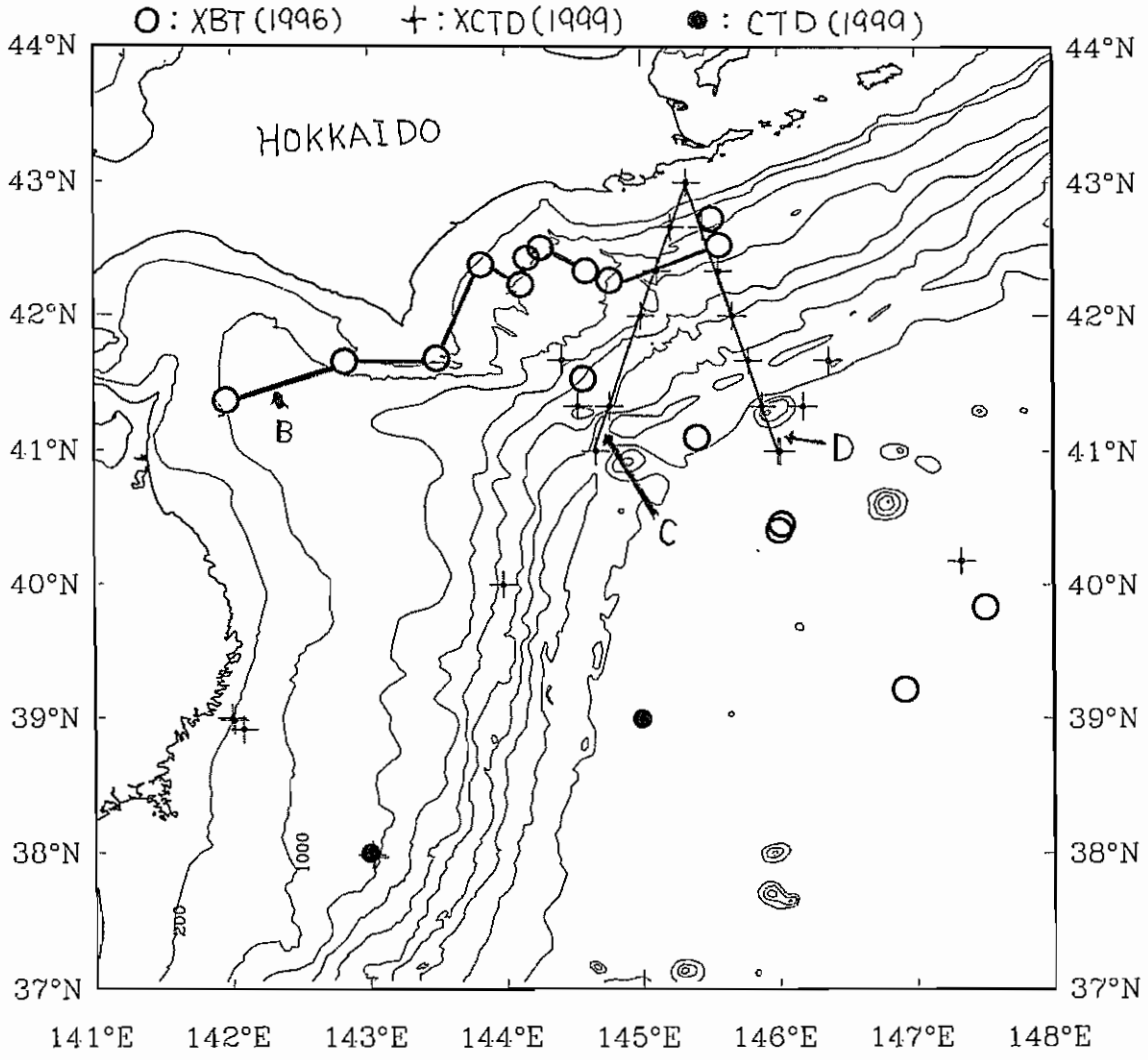

Figure 12. Oceanographic observation points in the area south of Hokkaido.

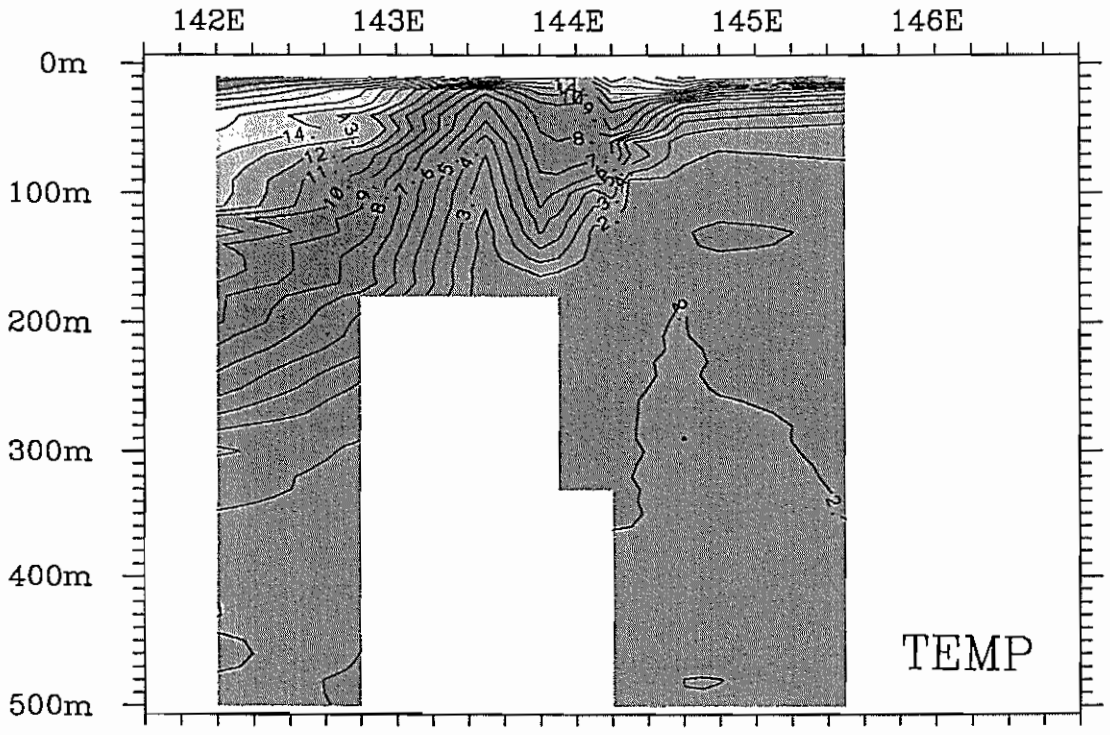

Figure 13. Zonal temperature section along the solid line B in the Figure 12. Data are obtained by XBT in 1996. Contour interval is 1℃.

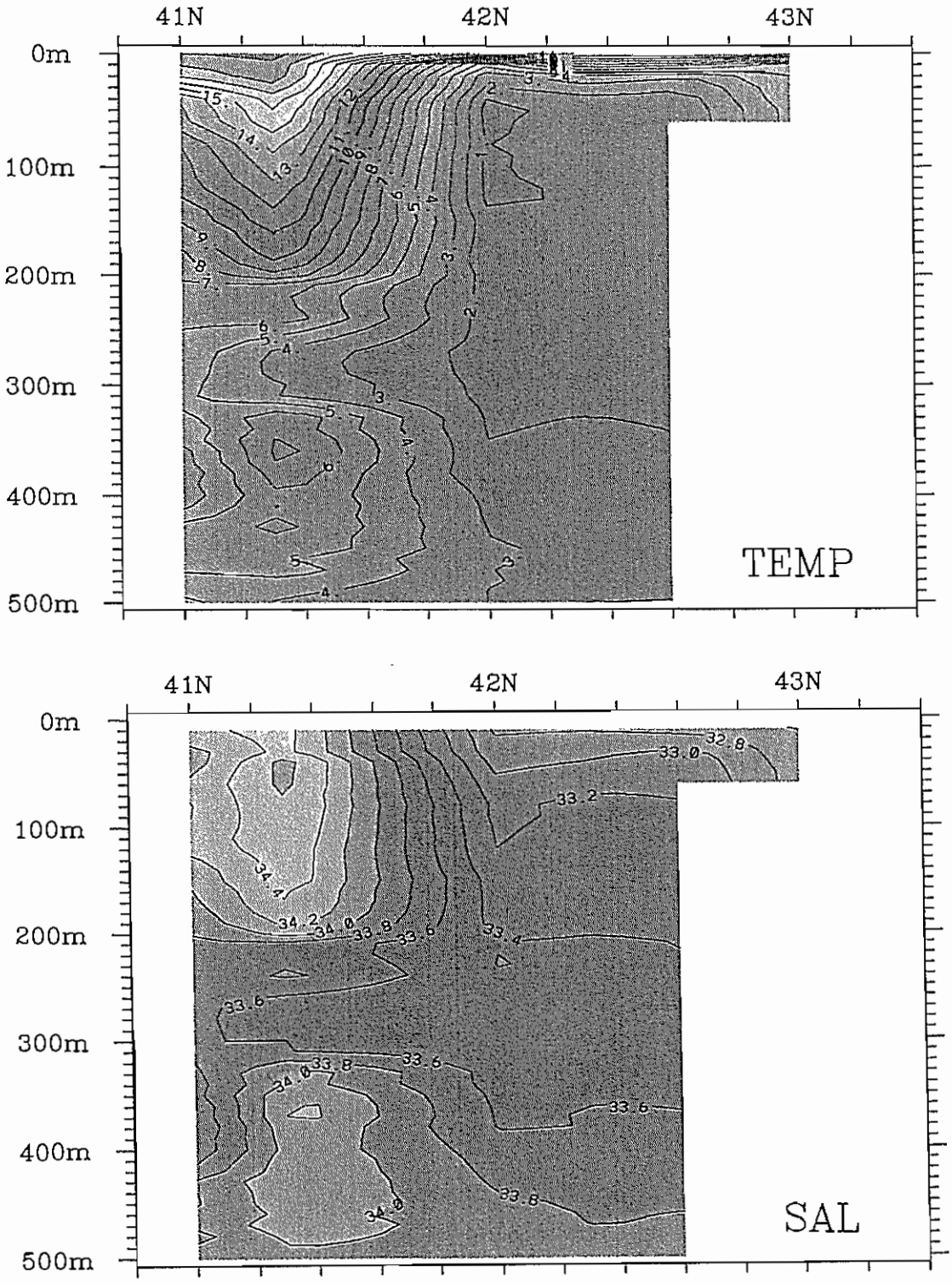

Figure 14. Meridional temperature (upper) and salinity (lower) sections along the solid line C in the Figure 12. Data are obtained by XCTD in 1999. Contour interval is 1℃ for temperature and 0.2 psu for salinity.

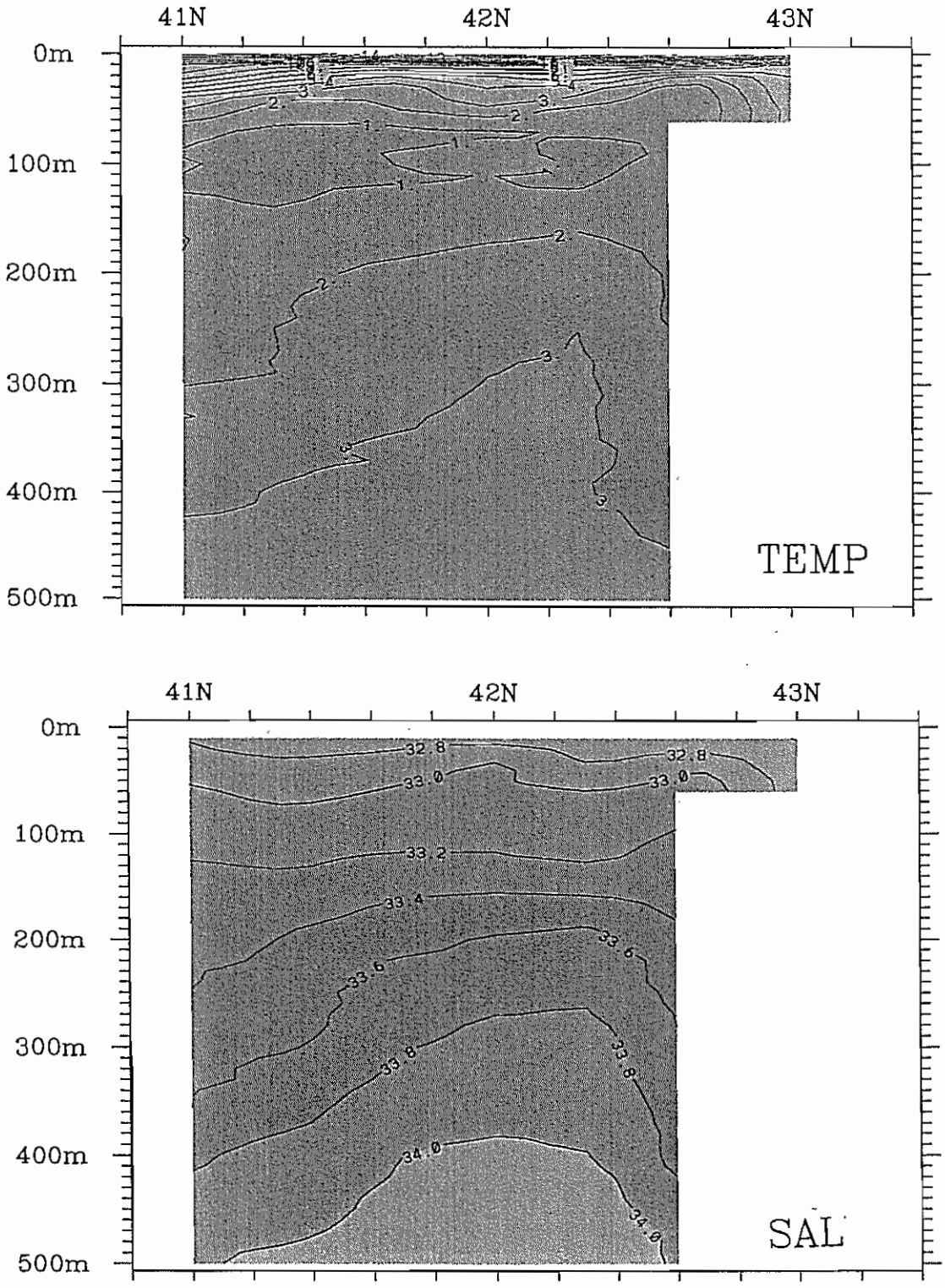

Figure 15. Meridional temperature (upper) and salinity (lower) sections along the solid line D in the Figure 12. Data are obtained by XCTD in 1999. Contour interval is 1℃ for temperature and 0.2 psu for salinity.