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HYDROGRAPHIC CONDITIONS IN THE CHUKCHI SEA AND ST. LAWRENCE ISLAND POLYNYA REGION IN MIDSUMMERS OF 1990, 1991 AND 1992

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Abstract: Oceanographic observations and fish exploratory surveys were carried out in the Chukchi Sea and St. Lawrence Island Polynya regions in midsummers of 1990, 1991 and 1992. We report here the hydrographic conditions in these regions and consider their implications for marine ecology.

In the surveyed area off St. Lawrence Island the bottom water showed temperature below 0°C in all three years in late July. Near St. Lawrence Island the bottom waters were colder and more saline than those in the offshore region every year. This suggests that coastal upwelling occurred near the island.

In the Chukchi Sea, hydrographic conditions near the pack ice showed remarkable two-layer structure consisting of the warmer, fresher upper water and colder, saline lower water. The highest static stability of 40×10^{-5} m^{-1} existed between the two layers near the pack ice. The strong stratification disappeared in the ice free sea.

1. Introduction

Coastal polynyas play important roles not only in air-sea interaction in climatic changes but also in marine ecology in the Arctic Ocean. Fish communities are strongly related to the regional oceanography; particularly near the sea-ice, the primary production is greatly affected by the oceanographic structure. Oceanography and resources on the Eastern Bering Sea Shelf have been studied comprehensively (HOOD and CALDER, 1981). SCHUMACHER *et al.* (1983) studied the effects of a polynya on flow and water properties, and PAQUETTE and BOURKE (1981) investigated fronts near the pack ice in the Chukchi Sea. However, hydrographies near the polnyna region in summer, and the bottom conditions and the vertical water mass structures near the pack ice have yet to be surveyed fully.

In order to clarify the effects of hydrographic conditions near the polynya and the pack ice on the biological productivity and resources, we carried out CTD casts in the St. Lawrence Island Polynya region and the southeastern Chukchi Sea in midsummers of 1990, 1991 and 1992. We briefly describe here the hydrographies in relation to the formation mechanism of the polynya in winter, and the bottom conditions and the water mass structures near the ice margin. These structures and conditions are thought to control significantly the fish communities and the primary production.

2. Observations and Data

The CTD observations and the bottom trawl net samplings were carried out in late July of 1990, 1991 and 1992 by the training ship OSHORO MARU of Hokkaido University. The CTD stations are shown in Figs. 1 and 3 (HOKKAIDO UNIVERSITY, 1991, 1992, 1993). Static stability E is calculated from $E=1/\rho_0 \cdot d\rho/dz$, where E is static stability in 10^{-5} m^{-1}, ρ_0 is a reference density (1.026 g/cm^3), and $d\rho/dz$ is vertical density gradient.

3. Hydrographic Conditions in St. Lawrence Island Polynya Region

3.1. *Temperature and salinity distributions near the sea bottom*

Station positions in 1990, 1991 and 1992 are shown in Fig. 1. In 1992 the surveyed area was wider than those in other years. We show the horizontal distributions of temperature and salinity near the sea bottom in Figs. 1 and 3, because benthic fishes were most controlled by them and also their contrasts were most remarkable near the bottom layer in this season.

In Fig. 1 the bottom hydrographic conditions in the St. Lawrence Island polynya region are shown. The temperature contrast in 1991 was most remarkable among the three years (Fig. 1b). Salinity distribution near the bottom was correlated with that of temperature. In the northwestern part of the surveyed region the bottom water was saltier than 33.0 psu and colder than -1.5°C, on the other hand, the water was less saline and warmer on the southeastern shelf. The salinity contrast between the two regions was about 1.5 psu. In general the bottom temperature tended to increase from northwest to southeast, and the bottom salinity showed the reverse tendency.

Among these three years the water was coldest in the midsummer of 1990. Though the horizontal extent of the survey was smallest, most regions showed bottom temperature below 0°C. Particularly near St. Lawrence Island, the coldest bottom water, lower than -1.5°C, occupied a wide area. The bottom temperatures in 1991 and 1992 were a bit warmer. The waters on the northwestern shelf were colder than those on the southeastern shelf. This is due to the effect of warm Alaskan Coastal Water, which flows northward along the Alaskan coast (COACHMAN *et al.*, 1975).

3.2. *Cross sections of temperature, salinity and sigma-*t *off St. Lawrence Island*

The St. Lawrence Island polynya occurs frequently south of the island (SCHUMACHER *et al.*, 1983). Cross sections of temperature, salinity and sigma-*t* are shown in Fig. 2. Observation lines are shown in Fig. 1.

In general the bottom temperature near the island was lower than that in the offshore region, and the bottom salinity and density (sigma-*t*) near the island were higher than those in the offshore region. On July 21 and 22, 1991, the hydrographic structure was typical. That is, both the seasonal thermocline and

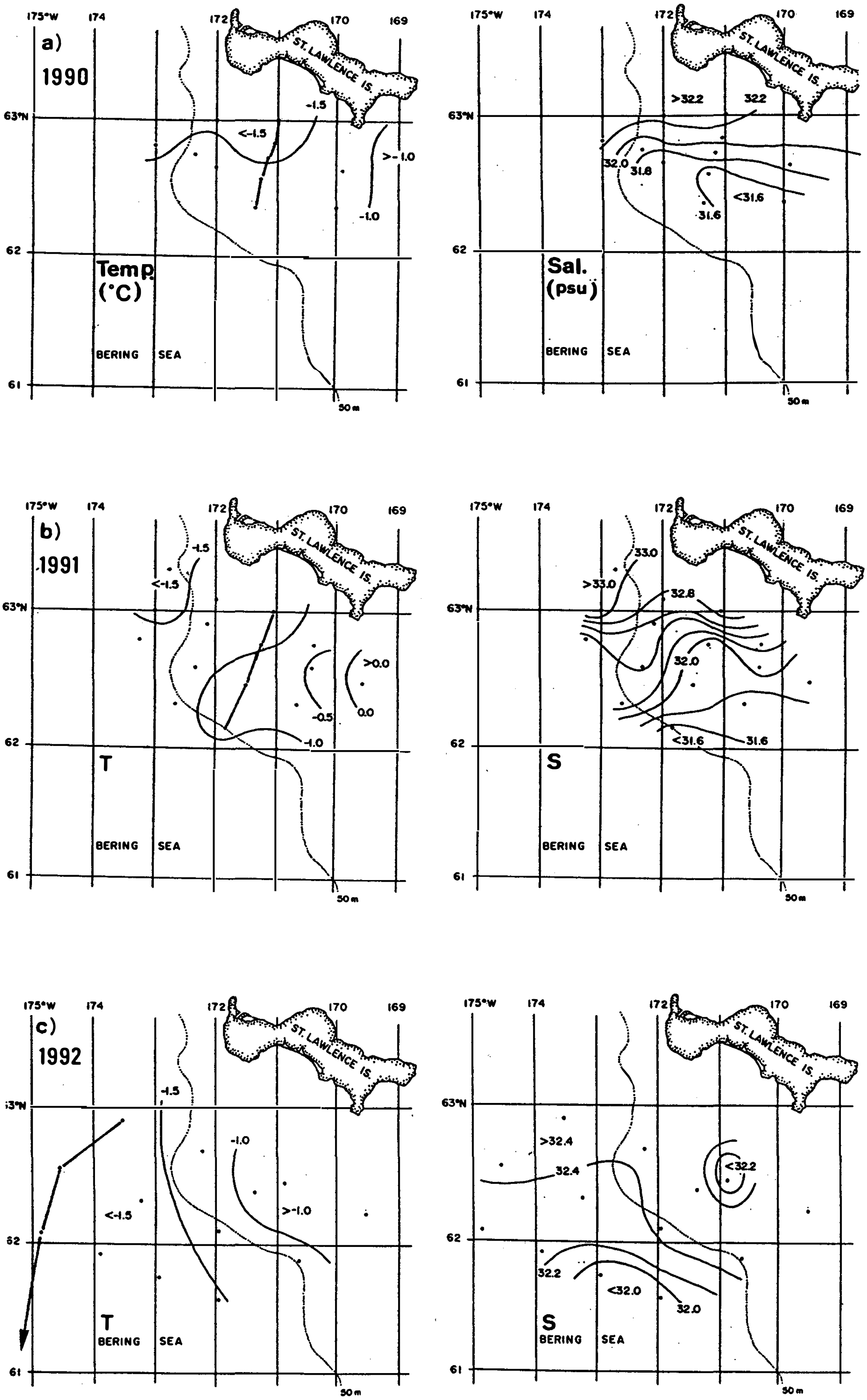

Fig. 1. Temperature and salinity distribution near the bottom in St. Lawrence Island Polynya region in midsummers of 1990 (a), 1991 (b) and 1992 (c).

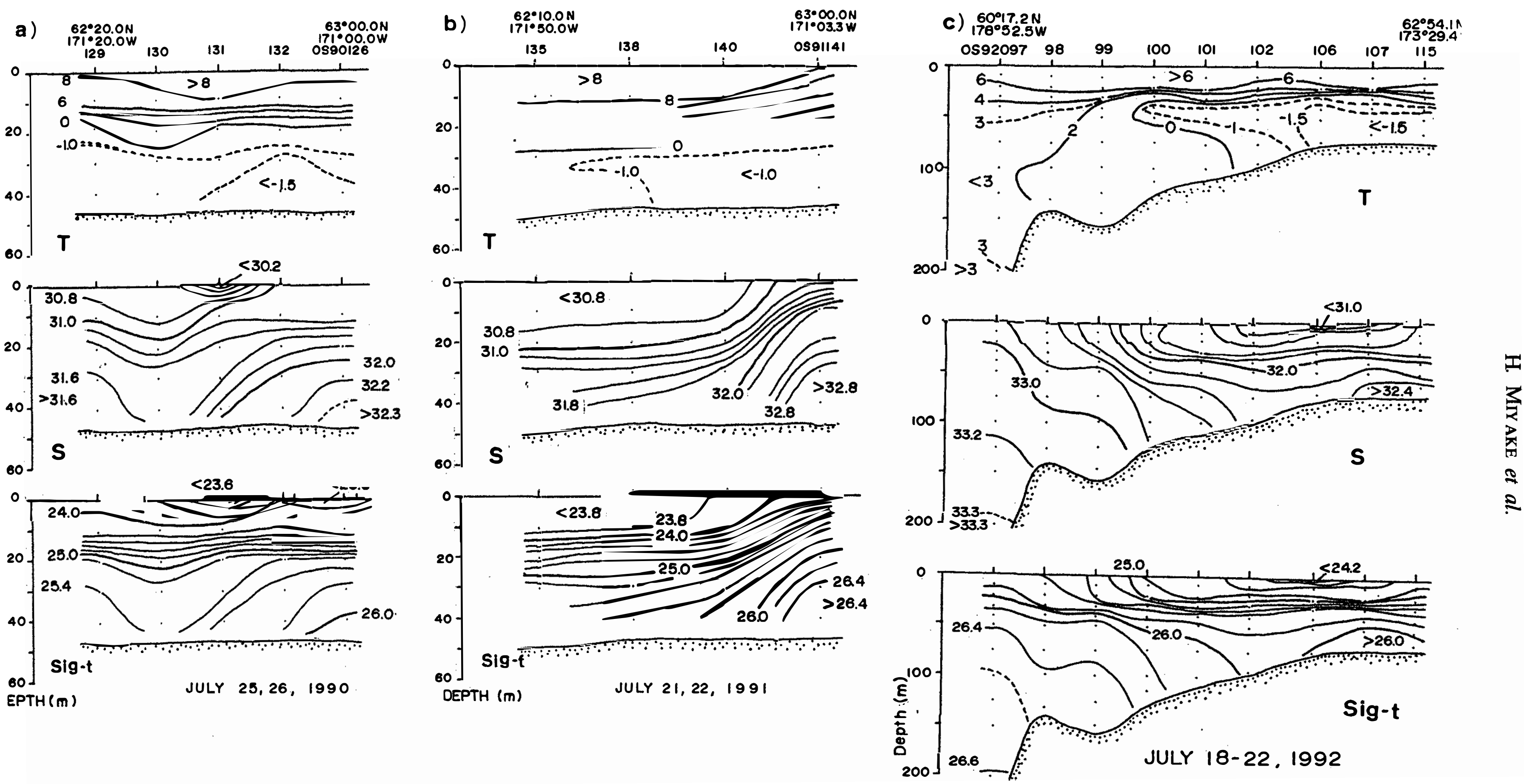

Fig. 2. *Cross sections of temperature, salinity and sigma-*t *south of St. Lawrence Island in 1990 (a), 1991 (b) and 1992 (c). Observation lines are shown in Fig. 1.*

halocline sloped upward toward the island, hence the pycnocline did too. The contours of 30.8 and 31.0 psu, and 23.8 and 24.0 sigma-*t* intercepted the sea surface near the island. These structures suggest that the surface water was blown away from the island by the northerly wind, and the bottom water upwelled near the island.

Figure 2c shows cross sections of temperature, salinity and sigma-*t* along 175°W longitude. This typically shows a structure of three domains from the shelf region to the continental slope. Cold and salty bottom water existed near the island, where the polynya had been in winter. This cold, salty and dense water might have flowed in along the bottom from the Gulf of Anadyr to compensate for the upwelled water even in midsummer.

On the middle shelf, a two-layer structure developed strongly because of the surface minimum salinity water. There was a strong pycnocline several tens of meters deep. A cold water tongue extended isopycnically out of the shelf and diffussed in to the intermediate layer over the shelf break.

The strong stratification of the water column disappeared over the shelf break. The distribution of the sigma-*t* suggests westward flow along the shelf break, which consists of a part of the Bering Sea subgyre. The structure of the three domains was somewhat different from those previously reported (SCHUMACHER *et al.*, 1979). SCHUMACHER *et al.* (1979) reported a well mixed coastal domain, but our observations show rather a strongly stratified coastal domain.

SCHUMACHER *et al.* (1983) reported that the northerly winds in midwinter coincided with increasing salinity and reversal of the ocean current. Even in midsummer the northerly winds seem to cause coastal upwelling and to supply nutrient rich water into the surface layer.

4. Hydrographic Conditions in the Southeastern Chukchi Sea

4.1. Temperature and salinity distributions near the bottom

We compare hydrographic conditions in midsummers of 1991 and 1992 in the southeastern Chukchi Sea. Figure 3 shows the temperature and salinity distributions near the bottom. In 1991 the sea-ice melted back toward the northeast and the southwest, but in 1992 it melted back only toward the southwest. The warm water flowed into northern Ledyard Bay and the bottom water was relatively warm in 1991. However, there was a strong horizontal gradient in the bottom layer salinity. The warm water had lower salinity than 32.0 psu but the bottom salinity increased to more than 33.0 psu near the pack ice.

The warm water stayed near Cape Lisburne in 1992 and a sharp thermal front occurred as a relatively narrow belt north of Cape Lisburne. North of the thermal front the bottom temperature was lower than 0°C. The bottom salinity also showed a sharp haline front north of Cape Lisburne; beyond it there was little horizontal gradient near the bottom. The bottom salinity was about 32.5 psu near the pack ice in 1992; this was about 1 psu lower than that in 1991.

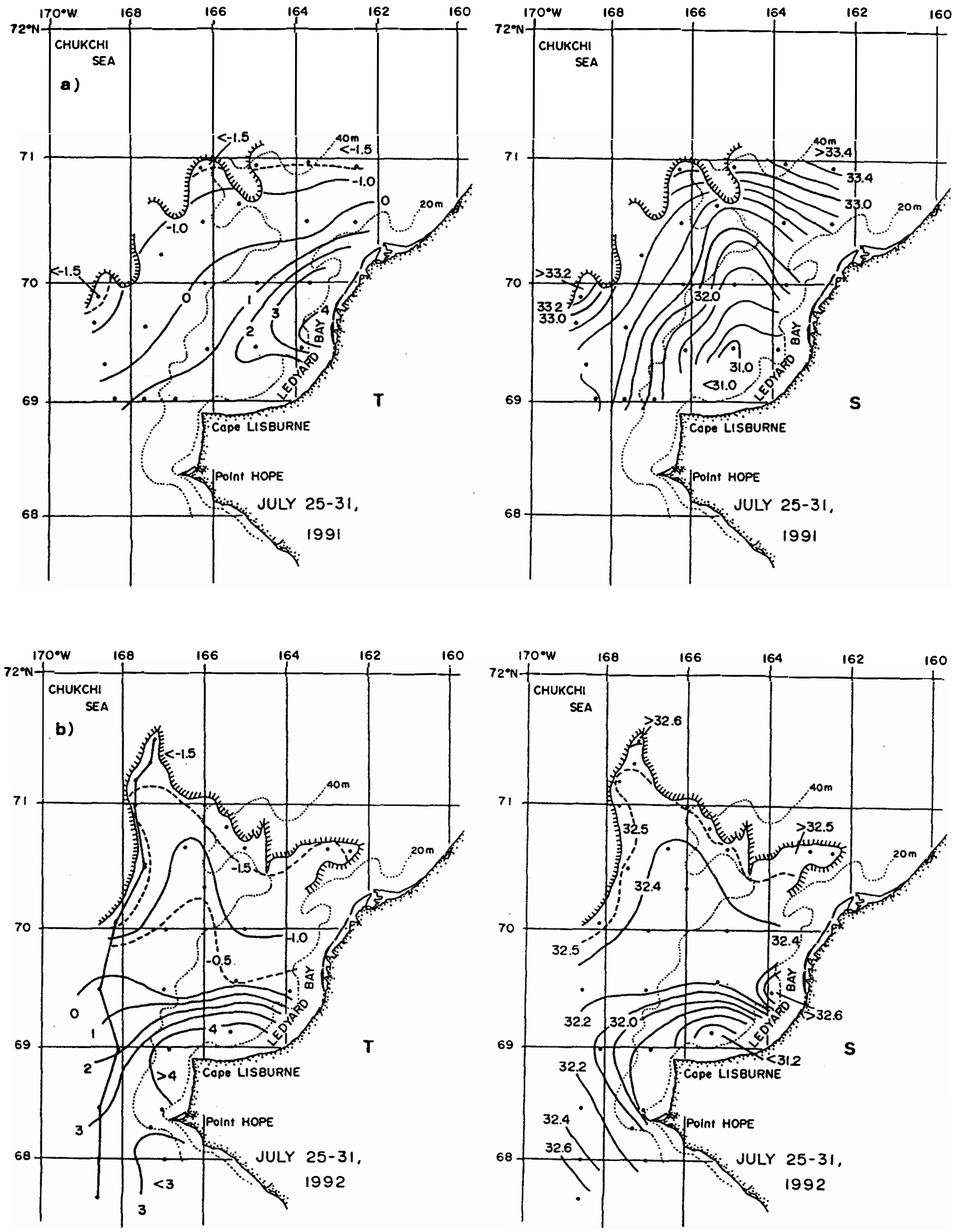

Fig. 3. Temperature and salinity distributions near the bottom in the Chukchi Sea in 1991 (a) and 1992 (b).

4.2. *Cross sections from the pack ice to the open sea*

We examine the vertical structure from the pack ice to the open sea in 1992. From Fig. 4 we can easily find that the water had two-layer structure near the pack ice and that the water was relatively homogeneous in the open sea. That is,

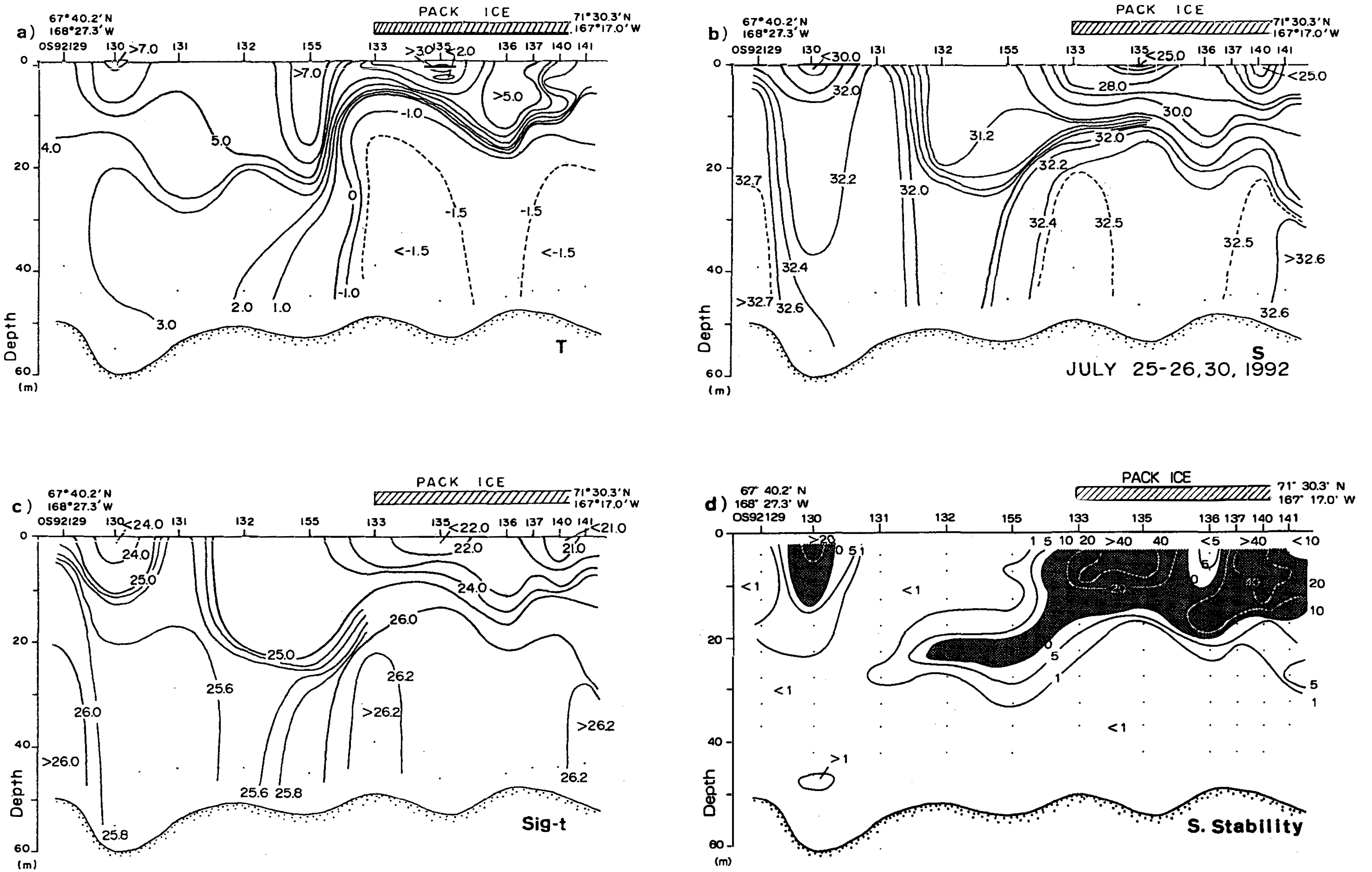

*Fig. 4. Cross sections of temperature (a), salinity(b), sigma-*t *(c) and static stability in* $10^{-5}\ m^{-1}$ *(d) from the pack ice to open sea regions in the Chukchi Sea of 1992. Observation lines are shown in Fig. 3b.*

near the pack ice the upper water of extremely low salinity overlay the colder and saltier lower water. At a depth of about 10 m, a strong pycnocline existed separating the two layers. PAQUETTE and BOURKE (1981) reported that the surface water temperature was below 0°C in the pack ice even in midsummer. In the marginal region of the pack ice, many fine structures were reported by PAQUETTE and BOURKE (1979).

Far away from the pack ice both the upper fresher water and the lower cold saltier water disappeared. A surface haline front and a bottom thermal front existed between Stns. 133 and 132. South of Stn. 132 the water had very week stratification.

4.3. Distributions of static stability

Static stabilities are shown in Fig. 4d. They were calculated between points at 5-m depth intervals in each water column except for the top and bottom layers. The top layer stability was calculated between 3 and 5 m depths, and the bottom layer stability was calculated using the deepest data available. Highest static stabilities (higher than 40×10^{-5} m^{-1}) occurred beneath the pack ice and a tongue of higher stability (10×10^{-5} m^{-1}) intruded to a depth of 25 m at Stn. 132. This distribution suggests that the pack ice prevents the forcing of kinetic energy into the water from the overlying air. As soon as the sea-ice melts back, the wind stresses penetrate into the water and then stir the surface stratified layer; finally, the two-layer structure disappears.

We are now analyzing the distributions and abundance of benthic fishes in the region. Hence the relationships between fish communities and the hydrographic environment will be one of the major studies in the future. Moreover, in order to clarify the effects of the hydrographic environment on the biological productivity, we need to take time series observations including meteorological data and chemical properties.

5. Concluding Remarks

We examined the oceanographic conditions of the coastal polynya region in the Bering Sea and of the sea-ice margin in the Chukchi Sea as a part of the survey of biological resources.

In the region where the polynya occurred in winter, the water structure suggested coastal upwelling. The upwelling, as well as tital mixing, seems to enhance primary production by supplying nutrients. The oceanographic structure near the pack ice was quite different from that in the ice free sea. The pack ice prevented the water from mixing vertically and caused the water column to maintaine a two-layer structure. In the ice free sea, the water properties were relatively homogeneous. Thus, the biological conditions for production seem also to be quite different in the two regions.

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