OCEANOGRAPHY AND WHALING GROUND IN THE SUBARCTIC REGION OF THE PACIFIC OCEAN

KEIJI NASU

INTRODUCTION

Oceanographic observation in the whaling grounds have been conducted for some years past on board the whaling factory ship "Kyokuyō-maru" and whale marking research boats. The work is carried out in the Chukchi Sea, Bering Sea and northern part of North Pacific Ocean with temperature by bathy thermograph and some serial observations.

Some aspects of the data obtained by these surveys were discussed in previous papers (Nasu 1957, 1958). Uda and Nasu (1956) discussed the whaling grounds in relation to meteorological and oceanographic conditions. Nemoto (1957, 1959) also had reported in detail on the subject from the point of the food of baleen whales and the ecology of plankton. The present paper gives the oceanograhpic structure in the whaling grounds and on the physical and chemical environment connected with the distribution of whales, using data obtained by whaling expedition cruises as well as sources.*

In this paper the vertical and horizontal distribution of water mass in the whaling grounds were examined.

The author is of the opinion that the vertical stability of sea water is also an important element for the formation of the whaling grounds.

ACKNOWLEDGEMENT

Grateful acknowledgement is made to the Japanese whaling inspectors and the staff of the whaling company who co-operated in the observations.

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DISTRIBUTION OF WHALES

As already reported by several scientists (Townsend 1935, Matsuura and Maeda 1942, Nikulin 1946, Sleptsov 1955) the larger whales in the northern part of North Pacific, Bering Sea and Chukchi Sea are blue, fin, humpback, sei, right,

* Other data were collected by Oshoro-maru and H.M.C.S. Ste Therese in the summer of 1955.

greenland, grey and sperm whale.

Blue whale (*Balaenoptera musculus*)

In general, blue whales are found in the northern part of North Pacific except the Bering Sea. According to Sleptsov (1955), blue whales are found in the south off Cape Olyutorski, the east off Cape Navarin and the Chukchi Sea. The result of Japanese whaling operations indicate that blue whales in the Bering Sea are scarce and are found mainly in the southern water of the Aleutian Islands. It appears, therefore, blue whales in the southern hemisphere have migrated to comparatively high latitude (Mackintosh and Wheeler 1929), but those in the Pacific sector of the northern hemisphere are found in relatively lower latitude. The blue whales seem to be found dominantly of about 50°N, 170°W.

Fin whale (*Balaenoptera physalus*)

Fin whales in the Sub-arctic Pacific sector are the most prevalent species for the stock of whale as is ture for Antarctic whaling and its distribution ranges from the North Pacific to Bering Sea and Chukchi Sea. In the Chukchi Sea (a part of the Arctic Ocean), Japanese research vessel, Yūki-maru found many fin whales (number of whales are unknown) near 66°40′N, 170°W. on August, 22, 1937 and a Japanese pelagic expedition caught 74 fin whales there in 1940. According to Nikulin (1946), in C. Serdzekamen and the Bering Sea, 177 fin whales (July:70, September: 57, October: 50 respectively) were found in 1937. Consequently, as already stated (Nasu 1960), many fin whales seem to migrate into the Siberian waters of the Chukchi Sea at least from the early summer to October.

During the summer season, fin whales in the Bering Sea have been observed in all areas except the central part about 58°N, 177°E and the east of 200 m depth contour line (extending north-west from Unalaska I). Moreover, fin whales were abundant to the north of Unalaska I., (center about 54°39′N, 160°W), near 59°30′N, 170°–00′W and Cape Navarin. Especially, to the north of Unalaska I. as already shown by Kawakami and Nasu (1956), fin whales were most concentrated. Many fin whales were captured in the waters of Cape Navarin and from some previous reports, it is considered that the fin whales migrate to the Chukchi Sea. Some whales were also captured to the west of St. Mathew Island, near 60°N, 178°W.

To the south of the Aleutian Islands, many fin whales are distributed in a belt situation centering around 50°N, 170°W, where blue, sei, and humpback whales have been caught, too. Therefore, this sea region is important for whaling operations, but the annual whaling condition there is unstable.

As already shown by Nemoto (1959), many fin whales are found in the waters around the Komandorski Islands, to the east of Kamchatka Peninsula. In the northern region of the Komandorski Islands, many fin whales were caught in 1956 and 1959.

In the area south-east of Kamchatka, it is considered that the fin whales already had migrated in the middle ten days of May. Fin whales were also captured in the waters off Cape Olyutorski, near 60°N, 170°E, but the whaling area and catch are both small.

Sei whale (*Balaenoptera borealis*)

In general, sei whales have been caught in the south region of the Aleutian Islands, but some whales were observed in the mouth of Anadyr Gulf in August of 1958. Sei whales are distributed mainly in the waters from the east of Kamchatka Peninsula to the south of Komandorsky Is. and from 180° to 170°W along the 51°N line.

Humpback whale (*Megaptera novae-angliae*)

Humpback whales are most prevalent in the waters south of the Aleutian Islands (especially, east of 170°W) and are also found in the area north of Unalaska Island. Form the record of operations of the Japanese expedition in 1940 (101 humpback whales were captured) and data obtained by the reserch vessel " Yuki-maru " in 1937 (many humpback whales were found, but total number is unknown), as Tomilin (1935) stated, it is clear that the humpback whales migrated to the Chikchi Sea. Humpback whales of the Ryūkyō waters have close relation to those of the eastern Aleutian sea area. (Kawakami and Ichihara 1958). Kellogg (1929) advanced the opinion that humpback whales in the west coast of Canada move as for north as Alaska. However, this has never been substantiated.

Sperm whale (*Physter catodon*)

Many sperm whales were captured along the Aleutian Islands, and the most dense area is situated near longitude 180°. Sperm whales were also captured in the region centered at 56°N, 170°W. According to data obtained by Japanese expeditions, few sperm whales have migrated as far as 61°–62°N latitude. Tomilin (1935) stated that the sperm whales did not migrate to the region north of Cape Navarin. Matsuura and Maeda (1942) determined that the northern limit of the distributional region of sperm whale had existed from 50°N to 60°N latitude by analyzing where whales were sighted and caught.

In general, sperm whales in the Bering sea are considered to migrate as far north as 60°N latitude. In addition, sperm whales have also migrated to the Kuril Is., the west of Kamchatka peninsula, and the central area of Okhotsk sea (Sleptov 1955).

WHALING GROUND OF BLUE AND FIN WHALE

1) Blue whale

The author can not discuss in detail the blue whaling grounds because the catch number have been restricted to 70 whales since 1955; however, the whaling grounds may be roughly divided into east and west longitude areas. Moreover, as stated by Nemoto (1959), blue whales have not been captured in the Bering sea. The whaling ground in east longitude is located in the vicinity of latitude 52°N and a narrow area along 51°N. In general, the center of whaling grounds existed in the vicinity of 52°N, 166°E. Catch in the west longitude was dominant in the area between 50°N and 49°N and its bound roughly covered from 178°W to 160°W (its center may be considered to locate near 50°N, 170°W). The densest area of catch was in the Aleutian waters from 170°W to 166°W, centered at 53°N, 165°W. A few blue whales were captured near 55°N, 157°W in 1960. Moreover, the rate of catch on east and west longitude was about 3:7 respectively.

2) Fin whale

Number of fin whales caught in the Subarctic Pacific area consist of more than 80 per cent of all whales caught.

Whaling ground of fin whale covered the greater part of the Bering Sea and the North Pacific Ocean north of 48°N, 12,998 fin whales were captured in the year 1952 to 1962, and prior to World War II 221 were caught in 1940 and 370 in 1941, respectively (catch in 1940 included 74 fin whales captured in Chukchi sea). Number of catch in the vicinity of 54°–30′N, 167°W, north of Unalaska I. was more than 500 whales in every one degree area for latitude and longitude. Number captured in one degree square area shows fin whales captured since 1952, and area more than 100 whales present the favorable ground for convenience and those named as follows.

1) Off Kamchatka Peninsula
2) Off Unalaska Island
3) Off Cape Navarin
4) Southern region of the Aleutian Island

GENERAL BATHYMETRY

Pelagic whaling in the Subarctic Pacific operates around north of latitude 48°N, in the Bering sea, and the Aleutian Is. The Aleutian Islands form a perfect arc of a circle, and divide the Bering Sea and the North Pacific. The Bering Sea forms roughly a scalene and its area is about 878,000 square miles (Barnes and Thompson 1938).

Fig. 1 is drawn by use of a bathymetric chart published by U.S. Navy Hydrographic office.

In general, the depth of Pacific side is deeper than that of the Bering sea, and the deepest area lies parallel to the Aleutian Islands at latitude 52°N, longitude 173°E, where it attains a maximum depth of more than 4,000 fathoms.

The 3,000 fathom contour line lies 60 sea miles off the south of Aleutian Islands and extends from 170°E to longitude 157°W. Consequently, there are steep continental slope lies in the area from 170°E to 157°W, the south of Aleutian Islands.

The 2,000 fathoms contour line lies to the north of the 3,000 fathoms lies and it extends from the central part of Kamchatka Peninsula to the Alaskan Continent, a distance of About 2,000 sea miles east and west. Therefore, the southern continental shelf of Aleutian Islands is very narrow. The maximum depth of the Aleutian Rigde lies to the northwest of Attu Island and its depth attains about 1,000 fathoms.

The deeper areas, those exceeding 2,000 fathoms, lie in the southwest part of the Bering Sea and the maximum depth is more than 2,200 fathoms at 54°N 175°W. The Bowers bank is located at the central part of Aleutian Islands, near long. 180° and extends to the north and northwest. The north edge of the 500 fathoms contour line lies along 55°N, and is 12 fathoms at the shallowest point 54°16′N, 179°30′E. The topography in the eastern and northern part of Bering Sea has a depth of at least 1,000 fathoms, and an extensive continental shelf exists. The 100 fathoms contour line extends from the Unimak Pass in the northwest direction to the south of Cape Navarin.

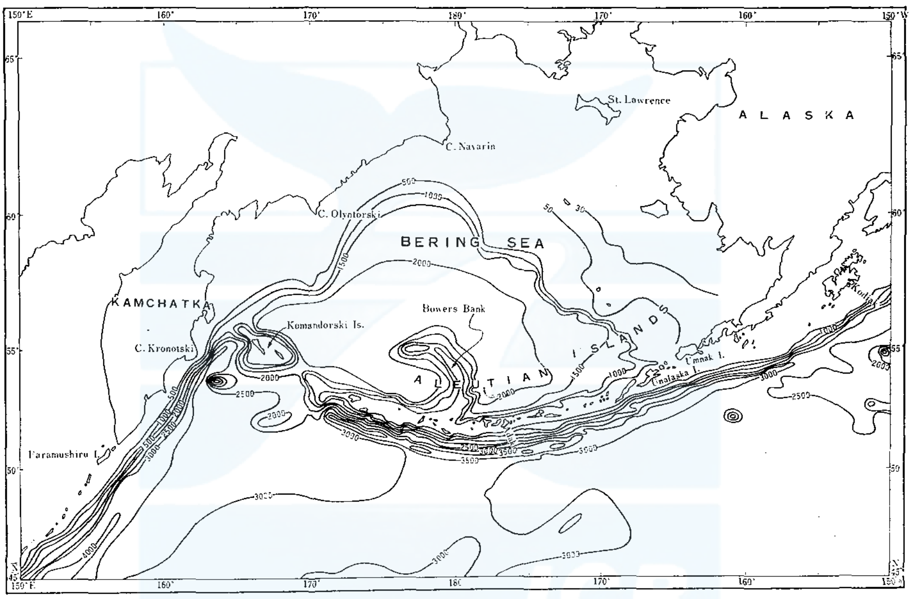

Fig. 1. Bathymetric chart, based on chart published by the U.S. Navy Hydrographic Office. (Soundings in fathoms)

Bering Strait is less than 50 sea miles wide at its narrow point and is from 20 to 30 fathoms deep. The depth in the Chukchi Sea is almost entirely less than 30 fathoms and has a minimum depth of 8 fathoms in 66°–30′N, 168°–30′W.

TEMPERATURE STRUCTURE

Horizontal distribution

Fig. 2–6 show monthly mean distribution of surface temperature during 1955–1959 every 1 degree latitude and longitude.

May:

In the east off Kamchatka, as already stated by Taguchi (1956), we can recognize cold current (coastal water) which is southerly flowing along the Kamchatka coastal line and warm current (offshore water) which is flowing from the southeast off Kamchatka Peninsula to the northwest. Taguchi (1956) divided coastal and offshore water in May and June by surface temperature as follows.

coastal water $> \theta$ 4.0°C
offshore water $< \theta$ 3.0°C

Fig. 2 shows the distribution of mean surface temperature in May.

Whaling ground in this season, in the off Kamchatka Peninsula is in general isotherms 1.0° to 3.5°C distributed from NNE to SSW. The isotherm of 1.0°C extends to the east of Onekotan Island (49°–30′N, 155°E) near the 158°E longitude, and isotherms of 2.0°, 2.5° and 3.0°C lie parallel to the isotherms of 1.0°C and the 3.0°C line reach to 161°E longitude. Moreover the distribution of these isotherms must be influenced by the cold water mass which is transported from Okhotsk Sea.

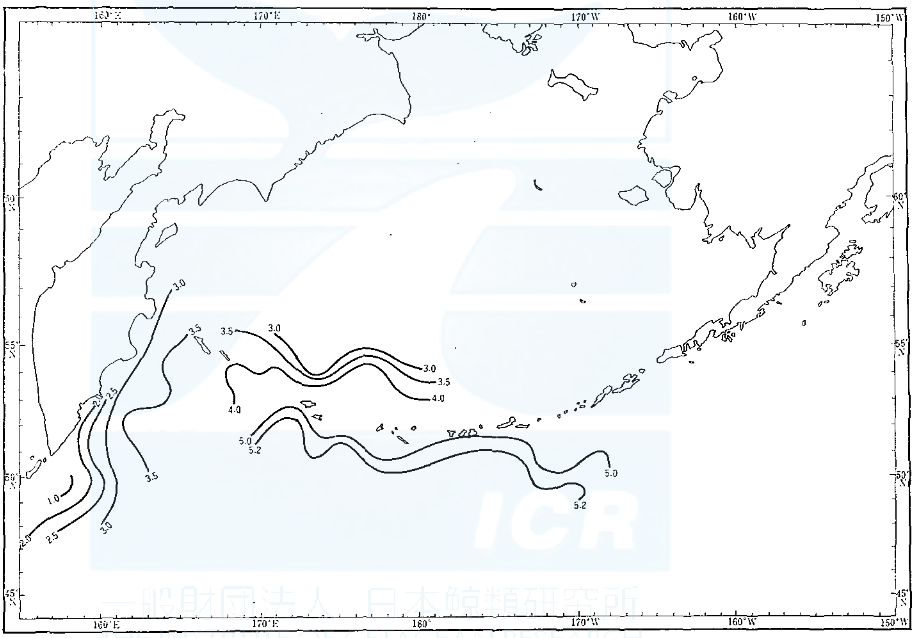

Fig. 2. Distribution of average sea surface temperature (°C) in May.

The coastal water which is characterized by less than 3.0°C approaching to the Kamchatka in the northern area and the coastal water at near Cape Africa reaches to only 15 sea miles off the shore.

To the east of the 3.0°C line, the 3.5°C line meanders from the Komandorski Islands to the southwest nearly parallel to the Kamchatka Peninsula and the water mass is characterized by 3.0° to 4.0°C at surface temperature covers on extensive area. From the determination of coastal water mass by Tagauchi (1956), mixing area consisted of coastal and off shore water must be extensive.

Oceanographic variation to the east off Kamchatka Peninsula, as stated by

Taguchi (1956), may be considered as due to the influence of those two water masses. Near 52°N, 162°E the 3.5°C isotherm extends to the west. This is a consequence of the returning flow (Kitano 1958) which is flowing to the west along the south of the Aleutian Islands.

On the southern side of the Aleutian Islands, isotherms (5.0° and 5.2°C) run towards the east and west nearly parallel to each other and the distrubution of sea temperature is characterized by a decrease from the west to the east. In the northern side of the Aleutian Islands, the 4.0°C-isotherm extended to the east of the Komandorski Islands with meandering.

The 3.5° and 3.0°C isotherms lie to the north of 4.0°C isotherm and extend roughly parallel of it.

June

Surface temperature in the east of Kamchatka Peninsula was comparatively

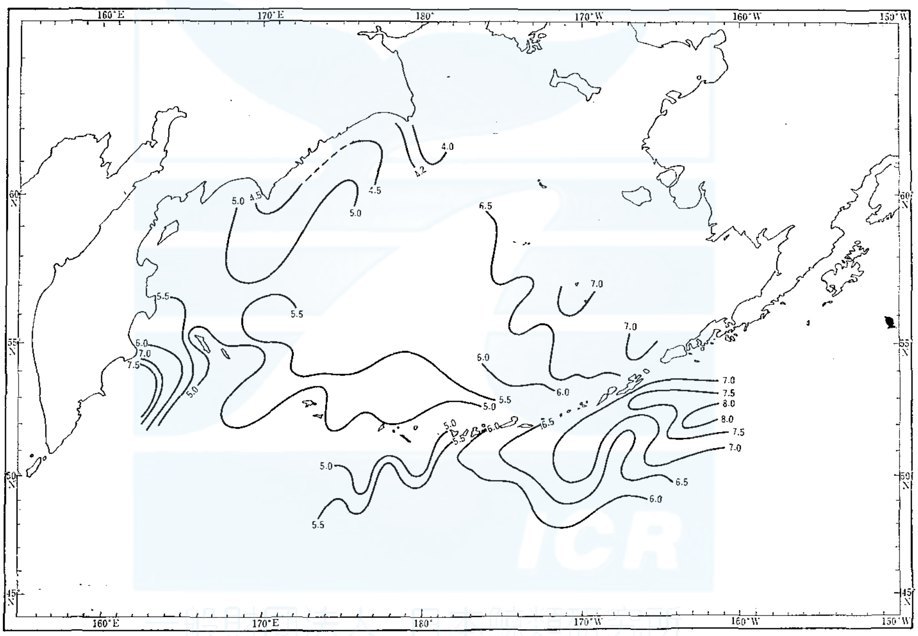

Fig. 3. Distribution of average sea surface temperature (°C) in June.

higher than that of May. The isotherm of 7.0°C extended towards the east and its eastern edge attained in 53°–30′N, 163°E. The water mass which extended towards the east is characterized by low water color and coastal water mass. Moreover, surface temperature was higher in coastal water and lower in offshore water mass.

Temperature at 0 and 30m depth in July of 1957 was as follows.

Depth (m)	Coastal water (θc)		Off shors water (θo)
0	θc	$>$	θo
30	θc	$<$	θo

Higher temperature in coastal water may be influenced by geographical difference of surface heating by solar radiation.

In the vicinity of the Komandorski Islands the 5.0°C-isotherm is located and largely meanders along the northern side of the Aleutian Islands. The southern side of the Aleutian Islands isotherms (5.0° and 5.5°C) run to east and west, and at the south of the Aleutian ridge there is cold water mass which is characterized by less than 5.0°C.

To the south of Aleutian Islands the main flow is from east to west and it was named the returning flow (Kitano 1958), which approaching longitude 180° with high temperature and low salinity at the surface.

The 6.0°C-isotherm reachs to 51°N, 178°W and at 178°W horizontal inclination of temperature increased to the west. Consequently, the extreme point of the returning flow in June may be considered to locate in the vicinity of 178°W longitude.

At 170°W longitude the isotherm of 7.0°C penetrated from the north-east to the southwest and at 167°W longitude isotherms (6.5° and 7.0°C) extended towards the northeast. From these phenomena, each water masses in this area were conjectured to formed complicated movement which was formed between the returning flow and the current with easterly component. The 6.5°C-isotherm locates in the north side of Unalaska Island, on the continental shelf to Alaska relativley high temperature 7.0°C-isotherm is tongue-shaped, extending towards the south. This is the water mass which is heated on the shallow waters of Alaskan continental shelf. At area from Cape Navarin to Cape Olyutorski isotherms run nearly parallel to Siberian Continent and temperature within 20 sea miels off the coast found less then 4.5°C.

July

The 8.5°C-isotherm covers most of the south waters of the Aleutian Islands. At near 53°N, 163°W isotherms lie with a complicated situation like that of June. The 8.0°C-isotherm lies at the north of the 8.5°C isotherm and it also lies along the Aleutian Islands like the 8.5°C-isotherm. In the neighborhood of the Bowers bank, there is a cold water area (below 8.0°C). This is a consequence of the upwelling which is formed by the bank, and it seems to him that the upwelling had developed in July. North side of the eastern Aleutian Islands the 7.0°C isotherm lies along the Islands and to the north of it the 7.0°C-isotherm extends towards the north-northwest mostly like the distribution of the 6.5°C-isotherm in June. The the water mass which penetrated from the Alaskan sea area is higher about 1.0°C than that in June.

Off Cape Navarin the 5.0°C-isotherm lie nearly parallel to Siberian Continent. Near 57°N, 178°E 10.0°, 9.5° and 9.0°C-isotherms run tongue-shaped.

August

The surface temperature attained the maximum value in the Bering sea and the northern part of the North Pacific. For instance, temperature at the east of Paramushiru Island run about 1.0°C-isotherm in May and the 11.0°C-isotherm in August respectively. To the southeast of Cape Kronotski 13.0°, 12.0° and

11.0°C-isotherms extend towards the northeast and the 11.0°C isotherm approaches to the south of Attu Island through the Komandorski Islands. North side of the Aleutian Islands in the neighborhood of Attu Island the 10.0°C-isotherm runs from the northwest to the southwest. The temperature value was generally higher 10.0°C off Kamchatka and 5.0–6.0°C at the adjacent waters of Attu Island than that of May.

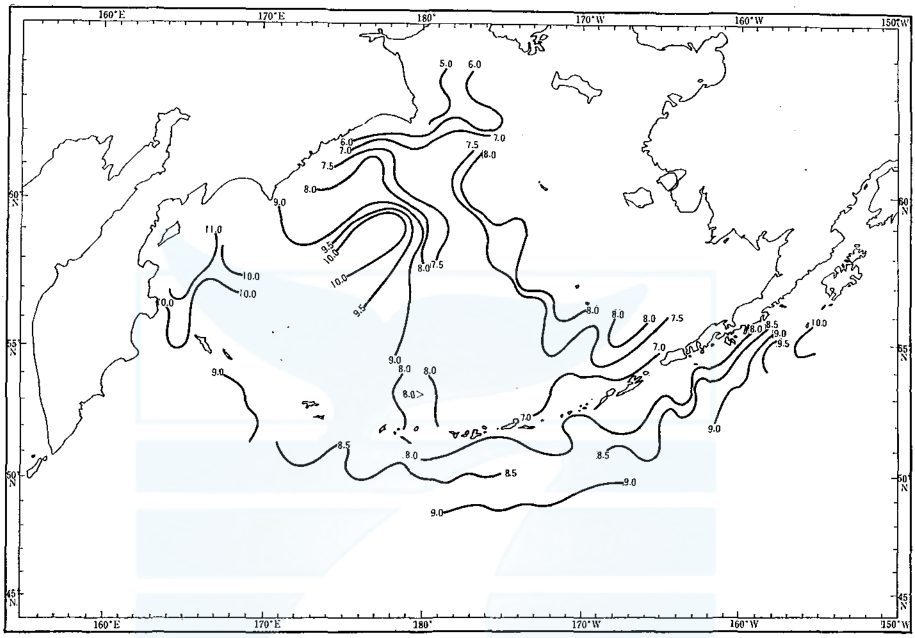

Fig. 4. Distribution of average sea surface temperature (°C) in July.

At the shallowest part of the Bowers bank 8.0° and 8.5°C-isotherms run parallel to each other and from these temperature distribution, it is clear that the upwelling area exists. And the isolated cold water area also is found due to the upwelling by the ridge at the central part of the Aleutian Islands, near of longitude 180°. Off Navarin Cape surface temperature is about 2.0°C higher than that of June and 7.0°, 8.0° and 8.5°C-isotherms run, and the inner part of Anadry Bay is supposed to have a cold water area formed by melted-ice.

In the neighborhood of St. Lawrence Island the 8.0°C-siotherm lies and off Cape Chaplina the 4.0°C-isotherm is found. In addition, temperature within 3.0°C were observed in August of 1958 (Nasu 1960).

Temperature distributions in the Chukchi Sea are summarized as follows.

Temperature at surface in the Chukchi Sea ranged from 3.7°C minimum to 11.2°C maximum (in August).

In general, in the eastern area of Chukchi Sea, the surface sea condition tends to higher temperature and the isotherms run parallel with the Alaskan coast line. In addition the distribution of temperature at surface is chatacterized by a decrease from the east to west.

September

In the Subarctic Pacific temperatures are decreasing. Near 45°N, 155°E there is tongue-shaped area with the 11.0°C-isotherm extending easterly and the 10.0°C-isotherm extending almost to Attu Island. Surface temperature in the sea area from 45°N, 155°E to Attu Island is higher at the west side and lower at the east side.

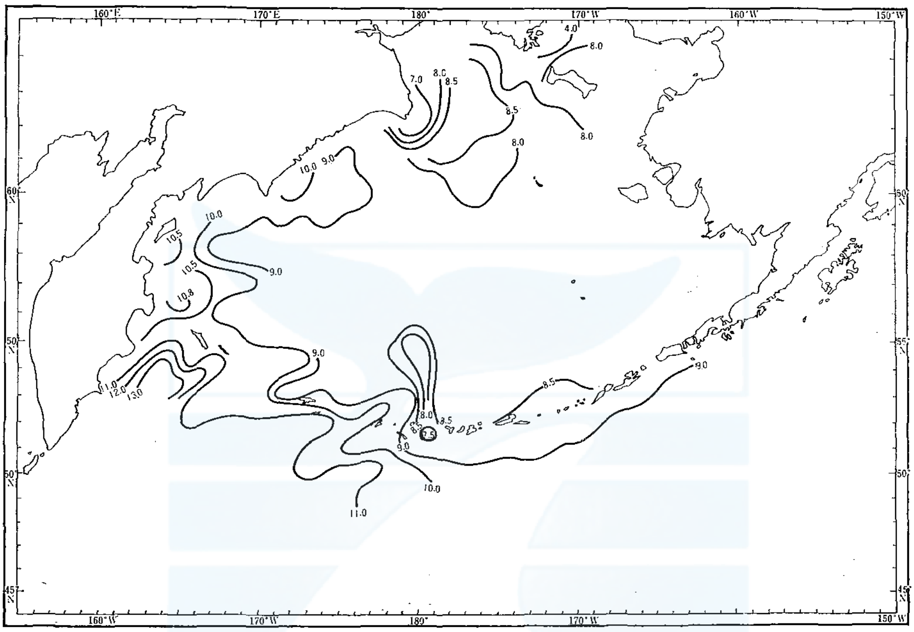

Fig. 5. Distribution of average sea surface temperature (°C) in August.

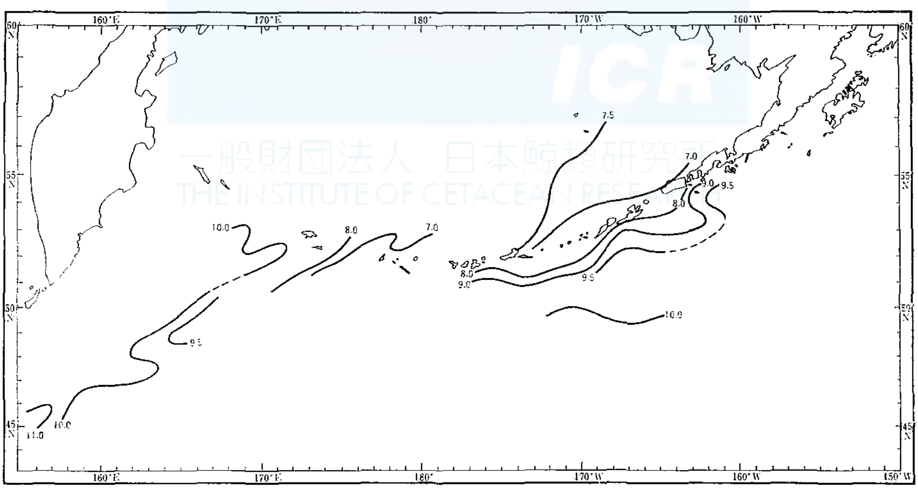

Fig. 6. Distribution of sea surface temperature (°C) in September.

Vertical distribution

Figs. 8–14 show the vertical distribution of temperature along the C,D,E, F,G,H and I (see Fig. 7).

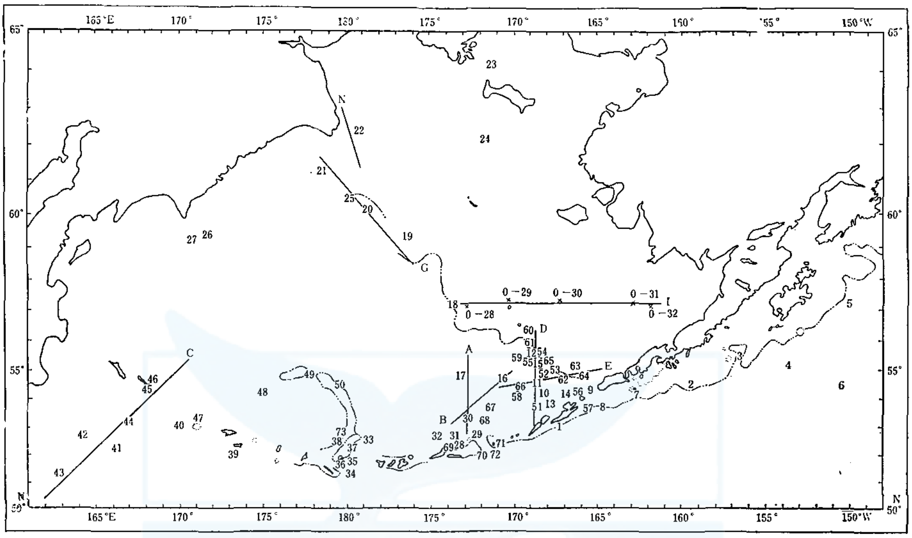

Fig. 7. Station positions obtained by Kōnan-maru no. 5 in the summer of 1955. (O-28 → O-32 : Data by Oshoro-maru)

C-line

Fig. 8 is the southeastward section of the Komandor Is. The cold water area found between Station 44 and 45. The thermocline lies in the upper 50 m in depth and its $\Delta\theta/\Delta D$ is about 0.5° C/50 m. The intermediate cold water lies below the 100 m and its core temperature shows below 1.5°C. Besides, the discontinious zone was formed at the intermediate cold water layer.

D-line

Fig. 9 shows the vertical section of D-line. Near 54°–30′N, 168°–30′W, the author shows the warm water mass which existed at 50 m with a 30 m layer and was characterized by more than 7.0°C (the maximum temperature was 9.3°C at 25 m at Station 51). In the upper layer of the warm water mass, there is cold water which is characterized by less than 7.0°C and the reverasl layer was formed. Moreover, the warm water mass appeared near 55°–10′N.

At 55°–10′N, 169°–00′W, the author recognized the remarkable upwelling and at the upper layer of upwelling, there was the warm water mass, where were formed the thermocline. It seems to him that there were not intermediate cold water.

E-line

Fig. 10 shows the vertical profile of temperature along the E-line. The warm

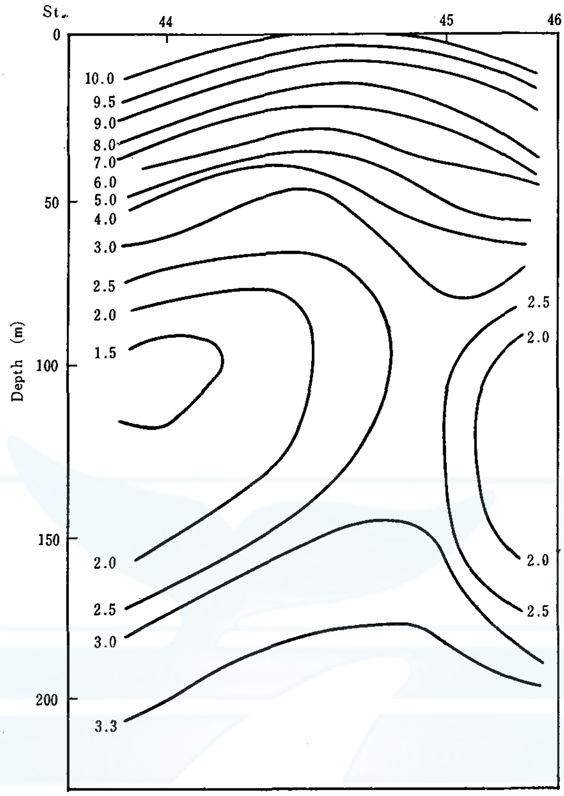

Fig. 8. Vertical Profile of temperature (°C) along the C-line.

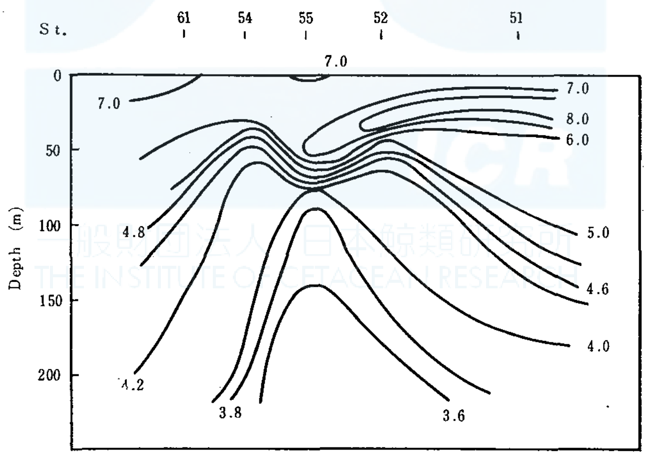

Fig. 9. Vertical profile of temperature (°C) along the D-line.

water mass which was characterized by moret han 7.0°C existed northwards at a shallow layer less than 50 m at St. 66, near 54°–20′N, 169°–30′W. At the warm water mass (about 25 m in depth), the inversion layer was formed and its temperature was 7.6°C (the surface water was 7.0°C). The water mass seems to be same one which was found in vertical section slong the D-line. At 54°-30'N, 166°W the temperature distribution at less than 30m suggest the warm

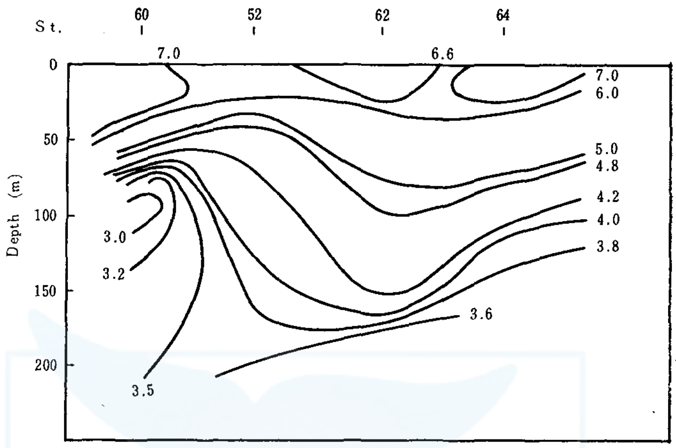

Fig. 10. Vertical profile of temperature (°C) along the E-line.

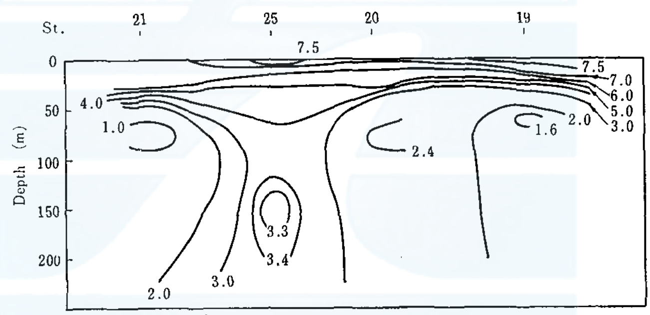

Fig. 11. Vertical profile of temperature (°C) along the G-line.

water mass which was characterized by more than 7.0°C and has a westward tendency. The spreading of the isotherms is probably and indication of Bristol waters. Moreover, at 167°-168°W the stratum less than 30 m the boundary was formed between the Bering Sea water (towards the east) and the Bristol Bay water (towards the west). At 54°-30'N, 169°-30'W, there is intermediate cold water, which has 3.0°C at the core, and it is clear that the small scale thermocline is formed near the upper layer of the cold water mass (about 70 m in depth). Below 100 m, the isotherm of 3.5°C climbs steeply. Generally the horizontal distribution of temperature at the layer below 50 m depth, decreases towards the west and increases towards the east.

G-line

Fig. 11 shows the vertical section of temperature along the G-line which was located from about 60 sea miles off Cape Navarin to the south-east. At 25 m depth, the 5.0°C and 6.0°C lines showed similar depth in every station and it may be considered that stable layer was formed at the surface.

At St. 21, the dichothermal water located near the 75 m depth (temperature minimum shows 0.6°C) and the comparatively remarkable thermocline was formed between the dichothermal water and upper layer of that. Below the dichothermal water, the temperature varies little towards the deep and its difference was 0.5°C from 100 to 200 depth.

St. 19, 59°–20′N, 176°–15′W, the dichothermal water lies at about 60 m in depth and its core water temperature shows 1.6°C, and the temperature below 75 m is mostly homogeneous. The 3.0°C line which extends from the 40 m depth at St. 19 and was very similar in depth to St. 20. At St. 25, the water mass with 3.0°–4.0°C in temperature eixsts below 60m depth and the temperature was low on the both sides of that water mass. From the vertical section, it is clear considered that the vertical boundary was formed at St. 25.

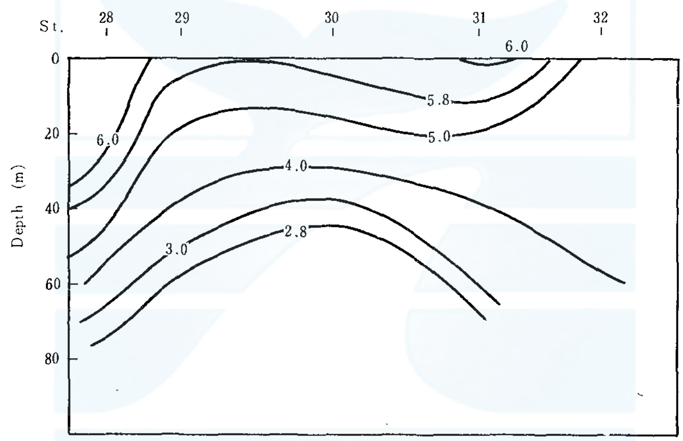

Fig. 12. Vertical profile of temperature (°C) along the I-line.

I-line

Fig. 12 shows the vertical profile of temperature slong the I-line by use of data obtained by Oshoro-maru. Each thermoclines rise at St. 0–28. East of St. 0–29 the comparatively cold water was characterized by less than 3.0°C in temperature below the 50 m depth and the cold water layer becomes deeper towards the west. The comparative warm water was characterized by more than 6.0°C in temperature located upper the 30 m in depth near St. 0–28 and the warm water layer becomes deeper towards the west, and at St. 0–28, the water masses are of two types, east area of St. 0–28 is cold and west area is warm.

Thermocline

It is well known that in the northern part of North Pacific and Bering sea the thermocline in summer season has been formed by the heating of surface layer. According to the observations at Ocean Weather Station (lat. 60°N, long. 145°W), the thermocine develops between 10 and 50 m in April (Tully et al 1960).

In order to analyze of the thermocline conditions, Fig. 13 and 14 show the station curves of temperature at each station in July and August. Then the thermocline located in almost all the northern part of the North Pacific Ocean, Bering Sea and a part of Chukchi Sea, but their depth and temperature gradient ($\Delta\theta/\Delta D$: °C/m where θ is temperature and D is depth) differ with sea area. On the thermocline, Tully (1957) has been discussed as follow. " Surface waters were warmed by varnal heating and continues to increase through summer to mid-September. "

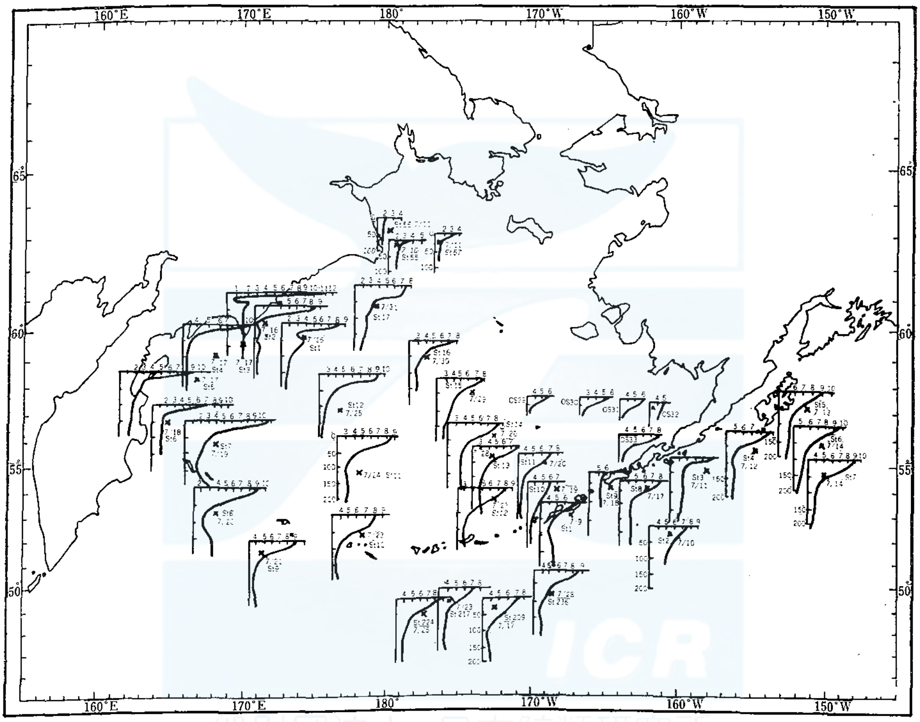

Fig. 13. Station curves of temperature in July.
St. 1∼12, 55, 56, 57 : 1957
St. 209, 224, 236 : 1959

In July, the most remarkable thermocline exists about 20 sea miles south off Cape Olyutorski, where the temperauter gradient is about—1.0°C and that layer is shallow depth. Such a remarkable thermoclines appeared from off Cape Olyutorski to Kamchatka Peninsula, and the sharp variation layer of temperature were roughly from surface to 25 m depth. The depth of thermocline have a tendency to downward in the south sea regions, i.e. to the east of south Kamchatka, near 51°–30′N, 162°–30′E the observed depth were 50–70 m (see Fig. 14). From Komandorski Island to Attu I., there were also comparatively remarkable thermocline which lied similar to that off south Kamchatka slighlty deeper than that of Cape

Olyutorski.

Central part in the Bering Sea the thermocline near 59°N, 175°W, especially was conspicuous in August and its depth was shallow, from surface to 25 m depth and temperature gradient was about–0.28°C. The temperature gradient observed on 29 and 30 July were about –0.09°∼–0.18°C and those depth were deep. From that fact, it may be considered that the thermoclines in the central part of Bering Sea develope conspicuously since the beginning of August. North-north-east of C. Navarin, lat. 63°–20′N, long 180° the thermocline was not observed in July, and below 20 m depth, there is a thermocline which might cause a sinking due to melting ice. To the east of C. Navarin, in July, the thermocline exists in the upper 20 m depth, below that was formed the homogeneous layer similar to the area north-north-east of C. Navarin. From the data collected on 2 and 3 August around St. Lawrence I. where the thermocline developes conspicuously similar to

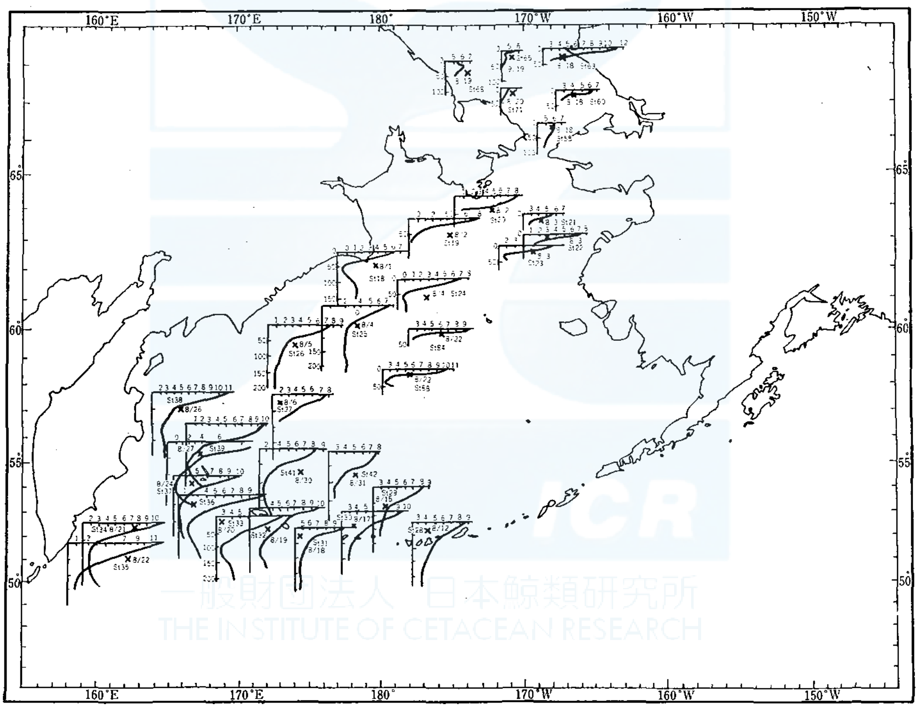

Fig. 14. Station curves of temperature in August of 1955 (St. 58, 60, 63, 65, 68, 71, 84 and 88 were carried out in 1958)

that off Cape Olyutorski and depth of that is shallow (about 20 m). The thermocline east of St. Lawrence was more developed than that of the west. (It is assumed that the thermocline at the east of St. Lawrence Island has arleady formed in July.) At the Chukchi Sea, north of the Bering Sea, the thermoclines were found on the side of Alaskan waters, but were not found on the side of Siberian waters (Nasu 1960).

The data obtained by Oshoro-maru during July of 1955 (Motoda et al 1956), the thermoclines in the Bristol Bay existed in the sea area west of 57°–16′N, 161°–40′W where the eastern most station in the observed region, and those depth were from surface to 50 m at each station. The temperature gradient increases to the Aleutian Is. To the north of Unalaska I. near 54°–05′N, 168°–10′W the thermoclines were not found and it may be caused by the vertical movement which took place due to physical action.

South of Unimak I. thermocline exists at the surface layer, and the temperature at the 10 m depth was perfectly homogeneous, which seems to represent upwelling by bottom topotraphy. At the southern side of Aleutian Is. the vertical temperature gradient at the west longitude area was larger than that found east of southern Kamchatka Peninsula.

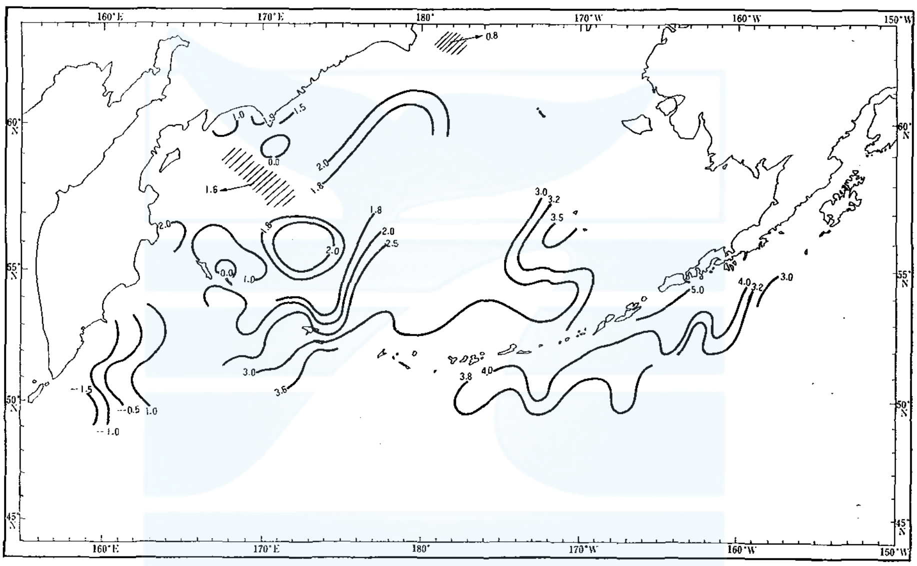

Fig. 15. Isotherm on the temperature minimum surface in summer of 1955, 1957 and 1958.

Intermediate cold water.

It is wellknown that in the Subarctic region a temperature minimum was observed at some depth in the summer. The structure which is associated with the temperature mininmum is termed dichothermal structure (Uda 1935, 1955, 1956).

As Hirano (1961) also stated, the intermediate cold water is one of the characteristics of the Subarctic Pacific.

Fig. 15 shows the isotherm on the temperature minimum surface in summer of 1955, 1957 and 1958. The minimum temperature was -1.5°C and occurred east of Paramushiru I. near 50°N, 159°E. The intermediate cold water extents to the Kuril Is. and exists in about 150 m in depth. The maximum value of the minimun temperature is 5.0°C isotherm and exists near 53°N, 165°W about 40 sea miles south of the Unimak Pass. Judging from the map of Bennett (1959) and Uda (1960), the 5.0°C-isotherm may extend south of Kodiak I. And in this region the depth of the minimum temperature existed at 60 m and increased from this area towards the south. Near 53°N, 161°W the minimum temperature covered a wide area at 75 m depth. The 3.5°C-isotherm occurred in a tongue near the Pribirof Islands north of Unalaska, and to the west of this area there were 3.2° and 3.0°C isotherm. The 3.2°C isotherm is notably meandered as far as 53°N, 171°W and the 3.0°C isotherm extents from 53°N, 172°W to south of Attu Island 52°N, 172°E.

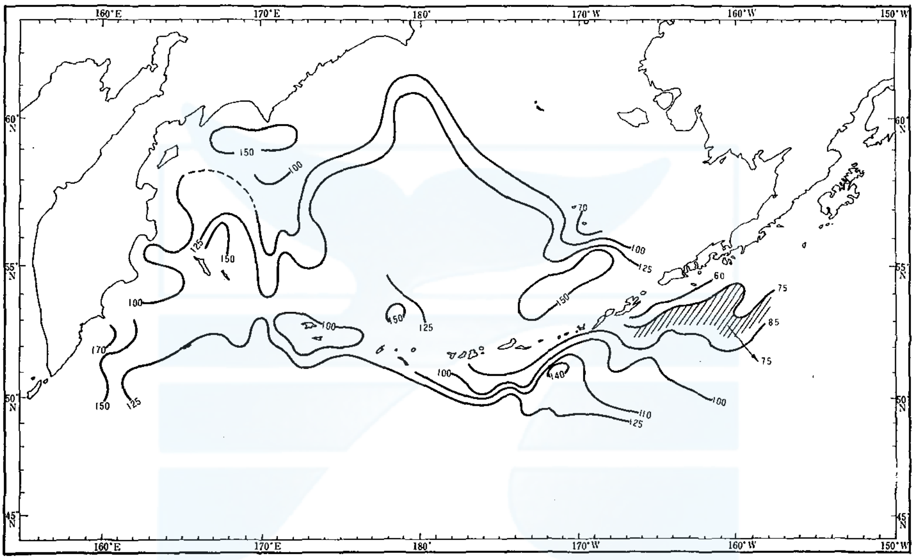

Fig. 16. Depth of temperature minimum (meters) in Summer (1955, 57, 58, 59)

The depth of minimum temperature north of Unalaska I. the 100 and 125 m line lie mostly similar to the contour line of 200 m and extent from near 61°N, 180° longitude to near 55°N, 170°E. In the northern-side of the Aleutian Is. the intermediate cold water increased in temperautre and decreased in depth towards Bristol Bay. East of Cape Navarin, there was a minimum temperature which was characterized by comparative low -0.8°C at 73 m in depth. At the south of Cape Olyutorski, intermediate cold water exists at 150 m in depth and has 0.0°C in temperature. At very small area, the distribution of minimum temperature waters differed with the east and west of Cape Olyutorski. That is:

	Temp. (°c)	Depth (m)
At the east	1.5	50
At the west	1.9	80

Near Cape Govena, the intermediate cold water existed, and was 0.7°C in temperature and 25 m in depth.

At the north of the Komandorski Is. the cold water area (less than 1.0°C in temperature) was found and was 0.0°C at its minimum temperature at the area close to the island. South of the Komandorski Is. the 1.8°C isotherm lies at the layer more than 100 m in depth. To the north of the Bering Sea, the minimum temperature around St. Lawrence I. in general, existed near the sea bottom.

Generally, the temperature minimum of intermediate cold water in the northern part of the North Pacific and the Bering Sea in summer vary from -1.6°C at its minimum to the highest value 5.6°C, and its core extents from 175m to 25m in depth.

There is an indication that the depth at the core of intermediate cold water is deep at the cold area and shallow at the warm area.

SALINITY STRUCTIRE

As the data of salinity are very few compared with that of temperature, it is not suitable for analysis concerning monthly mean. Consequently, in this paper the distribution by year's were shown. Moreover, the general distribution of ice in Febraury and April shown in Fig. 17 cited from the pilot chart which was published by U.S. Navy Hydrographic office.

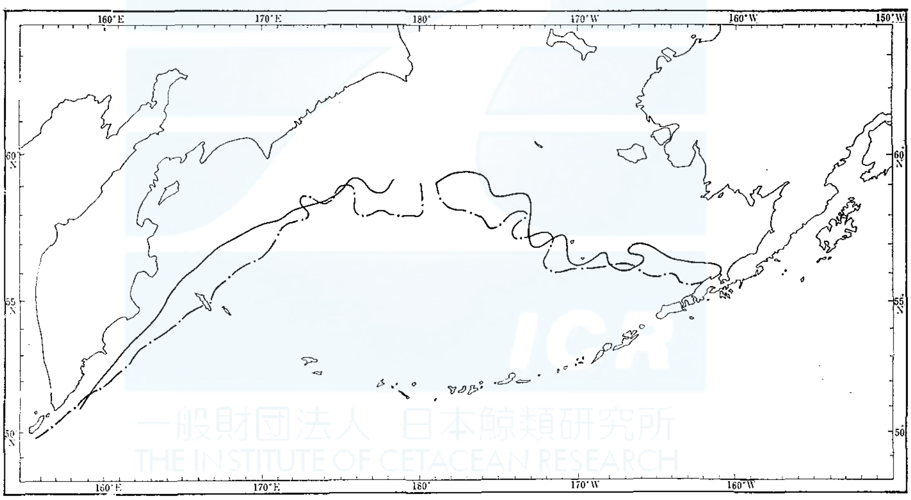

Fig. 17. Distribution of ice area, Solid line: April, Chain line: February

Horizontal distribution

June

Fig. 18 shows the horizontal distribution of salinity at the surface to the east of 170°W, the southern side of the Aleutian Is. At the north of Unalaska, 33.00, 32.80 and $32.50^{0}/_{00}$ located roughly parallel to one another and the 200 m contour line and those values decrease towards Bristol Bay. As shown by Fig. 17, it is clearly due to melted-ice. From the surface, the waters to Bristol Bay is characterized by high salinity and low temperature.

The surface distribution of salinity south of the Aleutian Is. was drawn by use of data in 1958. At latitude 52°N south of Unalaska I. the $32.65^{0}/_{00}$ isohaline existed to the east and west, and the low salinity area located north of the isohaline. South of $32.60^{0}/_{00}$ isohaline 32.70, 32.75, 32.80 and $32.85^{0}/_{00}$ isohalines locate from southwest to northeast, and it is supposed that the water mass which is characterized by high salinity extends from southwest to north with anticyclonic pattern.

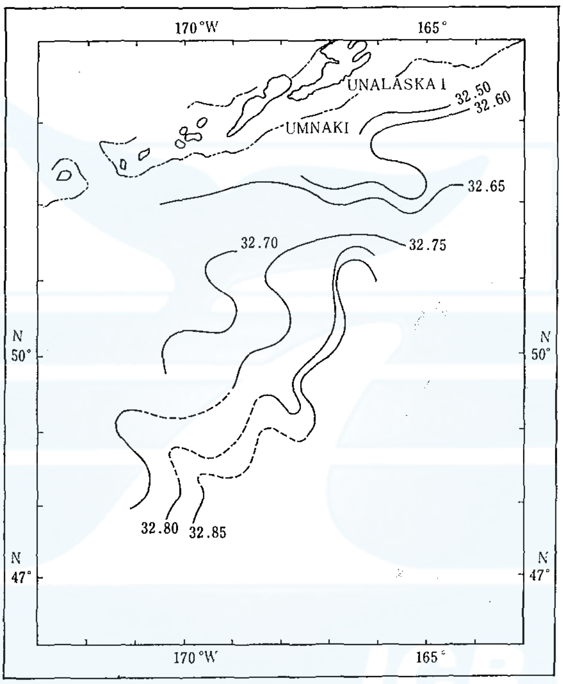

Fig. 18. Horizontal distribution of salinity at the surface in June of 1958.

July

Fig. 19 shows the horizontal distribution at the surface in July of 1957. The variation of salinity near $32.80^{0}/_{00}$ is scarecely changed, and $33.00^{0}/_{00}$ moved about 40 sea miles westward compared with that of June. It may be considered as due to influence of lateral mixing by advection of melted-ice in and near Bristol Bay. The distribution of salinity at the west longitude area south of the Aleutian Is. war drawn by use of data in 1958. At 50°N, 170°W, $32.70^{0}/_{00}$ isohaline in the form of tongue extends toward the southeast, and $32.70^{0}/_{00}$ isohaline runs in general from east ot west within the range from 177°W to 169°W. At the north of $32.70^{0}/_{00}$ isohaline, there was $32.65^{0}/_{00}$ isohaline which seems to be extended towards the east.

At the sea region to the east of Cape Navarin there was distinguished low temperature and salinity water mass which is characterized by less than 4.0°C in temperature and $24.60^{0}/_{00}$ in salinity. In addition, at this sea region melting pack ice was observed in June of 1957 (information from Mr. Ichihara), therfore, it may be considered that the low temperature and the salinity water mass which was already mentioned was formed in the immediate melted pack-ice.

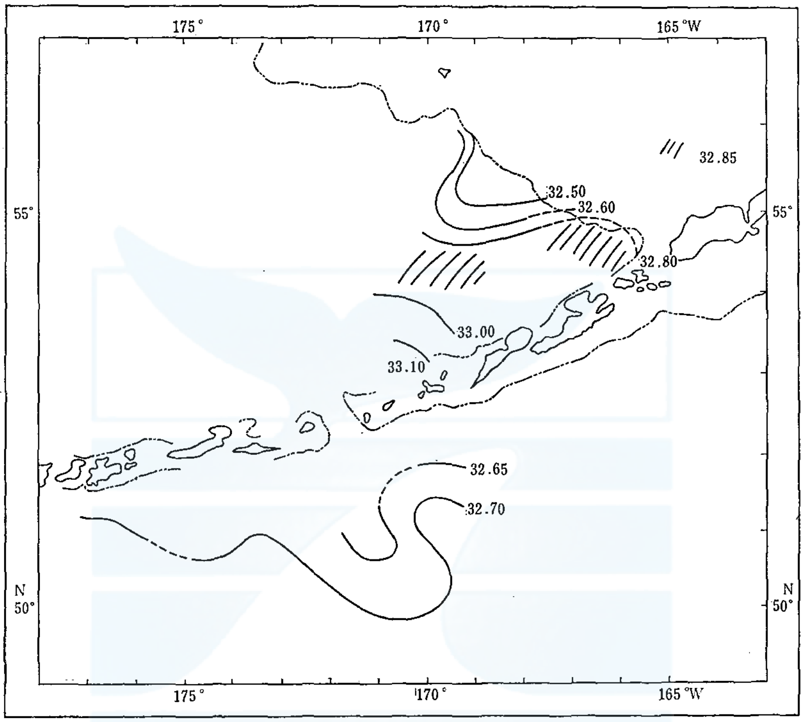

Fig. 19. Horizontal distribution of salinity at the surface in July of 1958.

To the East of Kamchatka, at the sea region between the Komandorski Island and Attu Island $32.90^{0}/_{00}$ isohaline located from south to north, and the salinity was low at the east and high at the west of the isohaline. Moreover, during the summer west of Kronotski low salinity water mass extended to the east (Kitano 1958).

August

As shown in Fig. 20, near Cape Navarin, $31,50^{0}/_{00}$ line was found parallel 30–50 sea miles off the coast of Siberian Continent, $32.50^{0}/_{00}$ line extends further northeast through the vicinity of 60°N, 168°E and locates south of Cape Navarin.

The warm area which is characterized by more than 10.0°C was similar to the area of $32.50^{0}/_{00}$.

The location of the $33.50^{0}/_{00}$ isohaline was also found near 61°–62°N 179°–30′W. However, compared to the western area of this region (vicinity of 60°N, 168°E) it is noted that relatively cold water (less than 10.9°C) extends. Conse quentry, it can be concluded that the cold and fresh water mass exists from Cape Navarin to the east. While the warm and high salinity water mass exists from Cape Navarin to the west.

In addition, in July of 1957 the high salinity water mass at the surface had closed with the land compared to that of August, it may indicate that the oceanic water mass had grown from July to August. The surface salinity in the Chuckih Sea in August of 1958 varies from 27.00‰ to 32.50‰. The high salinity region existed in the central part of the Chukchi Sea east and west of this region the low salinity region existed (Nasu 1960).

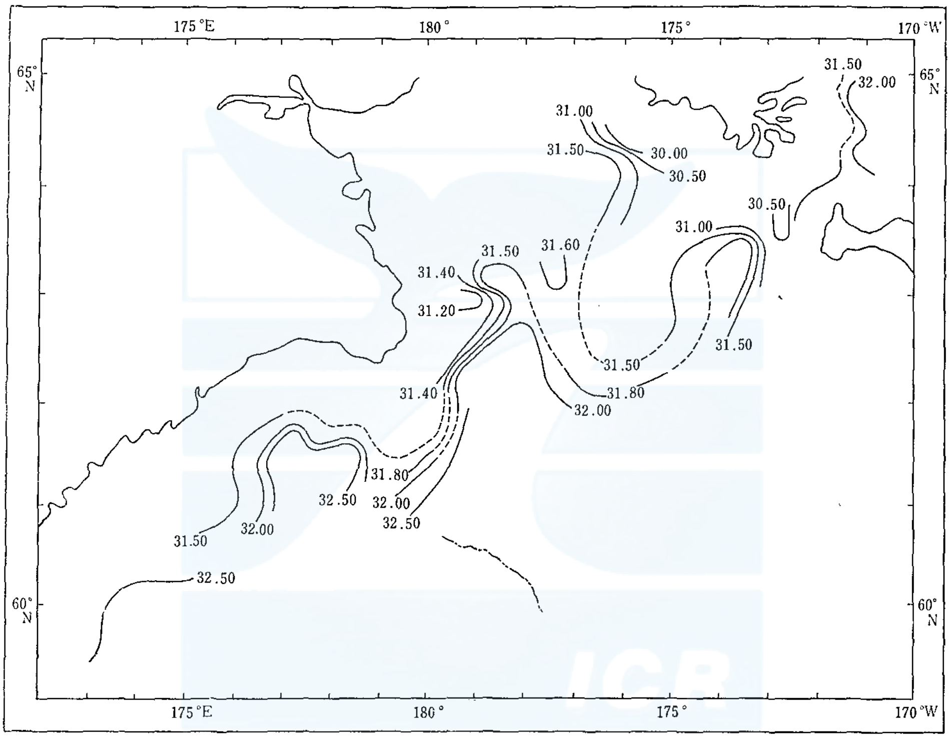

Fig. 20. Horizontal distribution of salinity at the surface in August of 1958.

The data of 1955, the separated salinity area (33.30‰ located near 52°N, 170°-30'W, and it shows 33.42‰ at the maximum. The surface temperature was less than 7.0°C and there was the separated cold and high salinity area, which is clearly formed by the influence of sea bottom topography.

Vertical distribution

C-line

Fig. 21 shows the vertical profile of salinity along the C-line. Below the surface salinity was high at St. 45 and low at St. 46 respectively. This tendency was prominent in layer less than 30 m in depth.

That is, the (isohalin) distribution decreases towards St. 46 and from the vertical (isohaline) distribution shown in Fig. 22 the pattern of distribution evidently varied with stations (St. 45 and 46) at layers more than 50 m in depth. In this region, the distribution of temperature also was divided into two types the 9.0°C and 11.0°C line, and the difference of temperature was clearly found below 50m in depth (Fig 23).

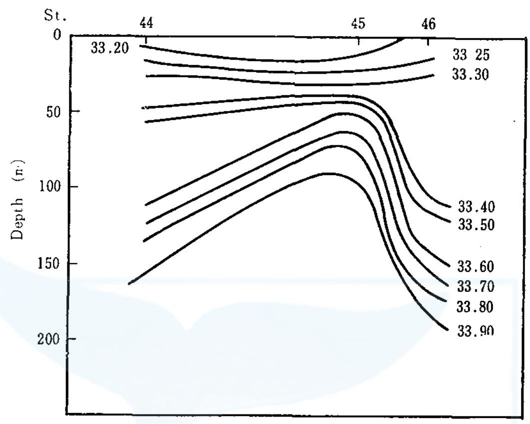

Fig. 21. Vertical profile of salinity along C-line.

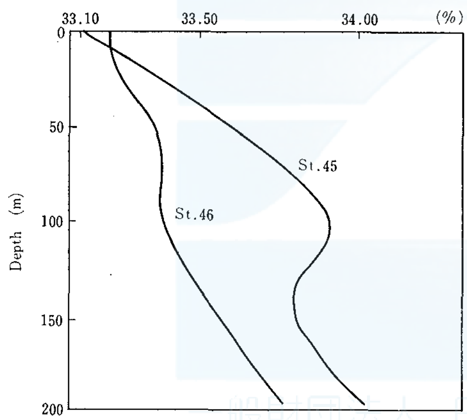

Fig. 22. Station curves of salinity.

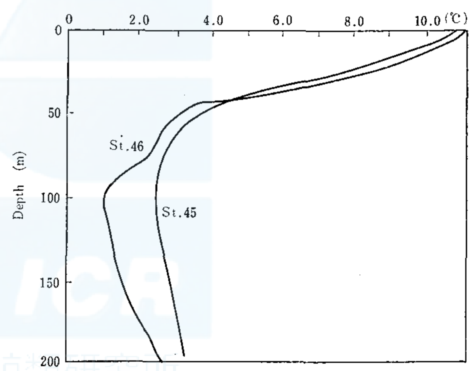

Fig. 23. Station curves of temperature.

Consequently, at the southeast of Medni I, it may be concluded that the notable structure of discontinuity was formed below the 30 m depth between the southern warm saline and the northern cold, low-salinity water mass.

At St. 46 the layer which was characterized by $33.70^{0}/_{00}$ existed at 50–100 m in depth and at St. 45 there was low salinity layer at about 140 m in depth.

D-line

Fig. 24 shows the vertical section of salinity along the C-line. At St. 54 the isohalines rise suddenly towards the surface similar to the isotherms. St. 45 is located at just the edge of 200 m contour line and the bottom topography from this station to the west became abruptly deeper. Accordingly, the sudden rise of these isolines are probably caused by the influence of some irregularity of the bottom topography. At the surface layer, the low salinity area (33.00‰) was found to the south

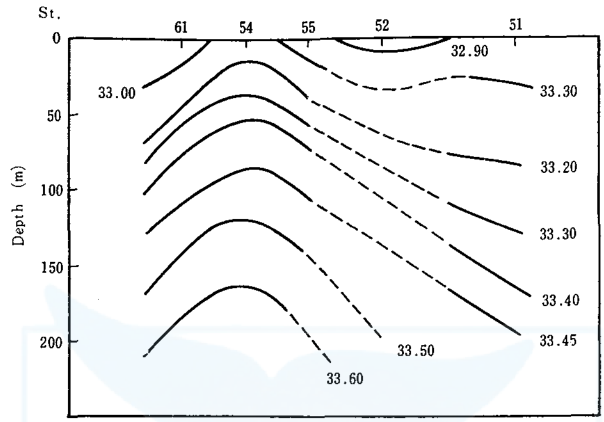

Fig. 24. Vertical section of salinity along the D-line.

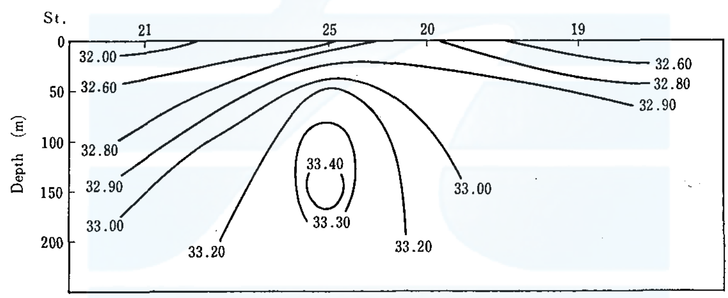

Fig. 25. Vertical section of salinity along the G-line.

of latitude 55°N where the temperature was more than 6.0°C. To the north of St. 54 the water mass is more than 6.8°C and less than 33.00‰ extended. Below 50 m the structure of discontinuity was formed on both the northern and the southern side of the cold, saline water mass which rose from a deeper layer. The warm low-salinity water which was locates less than 50 m depth may be transported from Bristol Bay.

G-line

The vertical section of salinity along the G-line shown in Fig. 25. 32.80‰ line was found as far as of St. 20 with the salinity being high in the southeastern side and low on the northwestern side of this line. Consequently, it was evident that in the layer above 25 m depth the warm, saline water mass existed to the southeast, and the cold, low salinity water mass existed to the northwest of St. 20. At St. 25, a local high salinity area which was characterized by more than 33.40‰

existed to about 150 m in depth with 3.3°C temperature, indicating dichothermal water. Morever, as already stated, the vertical section of the temperature along the G-line showed that the cold water mass existed both southeast and northwest of St. 25 warm area. Accordingly, below 50m depth it is evident that the cold saline water mass was formed to the north and south, respectively.

I-line

Fig. 26 shows the vertical section of salinity along the I-line. The low salinity water mass (32.00$^0/_{00}$) extends from near 20 m in depth at St. 31 to the east in the form of sinking. From the distribution of temperature it may be assumed that the deep water had risen near St. 28 and 29. In the surface layer of St. 28 there

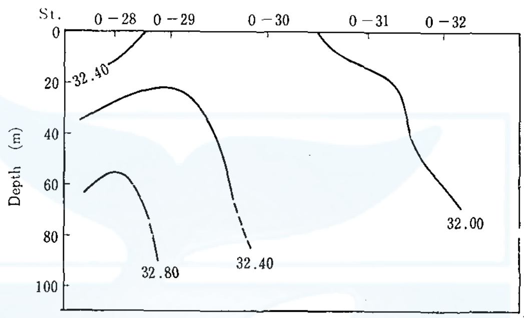

Fig. 26. Vertical section of salinity along the I-line.

is a zone of high salinity (32.40$^0/_{00}$) which coincided with the warm water (6.0°C<). Generally, at St. 28 the water masses can be devided into two types.

Low temerature, low salinity water mass: Easter of St 28.

High temperature, saline water mass: Wester of st. 28.

THE ANALYSIS OF WATER MASS

The analysis of water mass was made by using temperature and salinity diagrams.

J-line

Fig. 27 and 28 show a vertical section of temperature and salinity along the J-line. A relatively warm water mass was rising near the island to the north. This phenomena was conspicuous, and this water mass, which is characterized by more than 5.0°C in temperature, was found uniformly. At St. 11 the cold water of the deep layer was found as shallow as 100 m depth. High salinity water was also found above the deep layer. From the distribution of temperature and salinity, it can be assumed that the water mass which flows from the Aleutian Islands to the north was isolated by the rising of deep water at St. 11.

Fig 29 shows the temperature-salinity relation near J-line. Surface water which was characterized by more than 5.0°C in temperature and salinity of less than 32.66$^0/_{00}$ was found at St. 10 and 12, and was clearly divided from the relatively high temperature saline water mass of more than 5.0°C and 32.80$^0/_{00}$ found St. 11.

To the Aleutian Islands at St. 13 and 14 water mass which was characterized by about 6.0°C and 32.50‰ located, and seems similar character for that of St. 10 and 12. Dichothermal water of minimum temperature was found at St. 11, 15 and 16, at about 150m in depth. Dichothermal water was not found at St. 10, 13 and 14, near the Aleutian Islands.

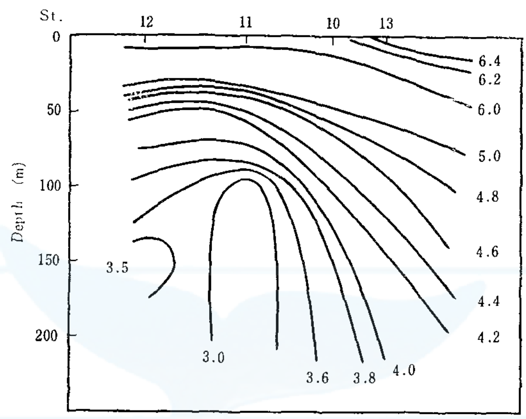

Fig. 27. Vertical section temperature along the J-line.

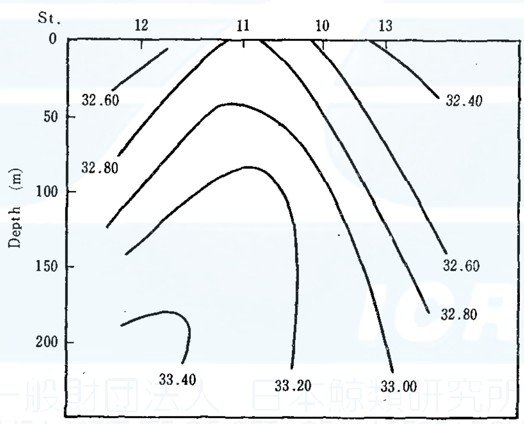

Fig. 28. Vertical section of salinity along the J-line.

Near the layer of 200 m depth, the water masses characterizing St. 13 and 14 were found to be quite similar At St. 11 there was a relatively high-salinity water mass which may have been mixed with the deeper water mass by upwelling. Consequently, the water masses at near 200 m depth are divided into two types. Those are water mass alongs the Aleutian Islands (St. 13 and 14) and the mixing zone (St. 10). The water mass near St. 15 also seems to be a mixing zone and was characterized by the low-salinity (33.00‰). It may be due to the advection of the waters of Bristol Bay. The water masses near the J-line can be divided as follows:

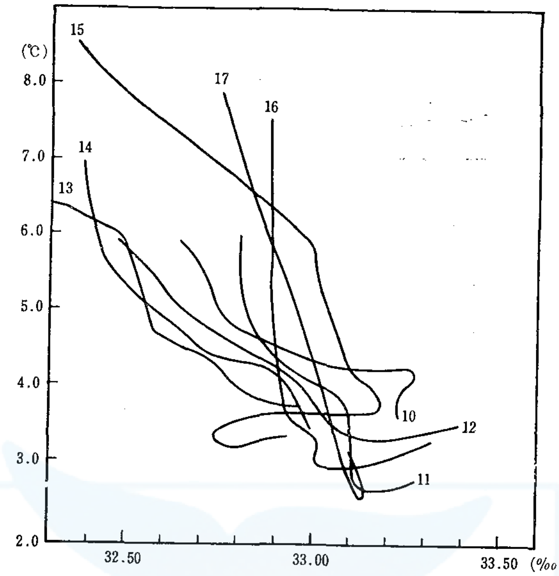

Fig. 29. Temperature and salinity at St. 10, 11, 12, 13, 14, 15, 16 and 17.

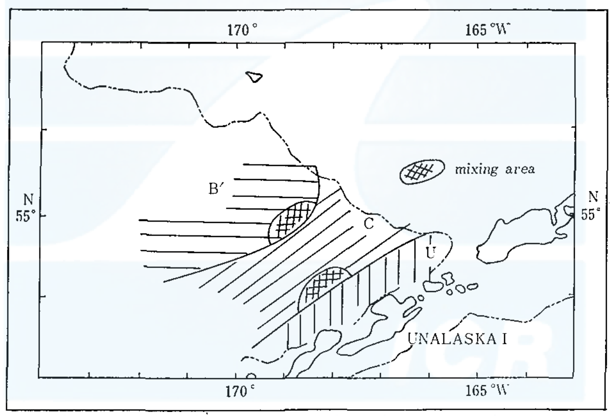

Fig. 30. Water types in the north area of Unalaska I.

That is,
B'—type
C—type
U—type
Mixing type

C-line

Fig. 31 shows the T—S characteristics of the water masses along the C-line. These are separated by three zones; an upper zone of warm, low-salinity water (above 25 m in depth): a intermediate cold zone characterized by a temperature minimum (near 100 m in depth): and a lower zone in which the temperature and salinity are both high. From the vertical section shown in Fig 8, the rising phenomenon of deep water was found at St. 45 and was more apparent from Fig. 21. It is theorized that the deep water was raised by the ridge located between St. 45 and 46. By analysis of the T—S diagram shown in Fig. 31, there were uniformly surface

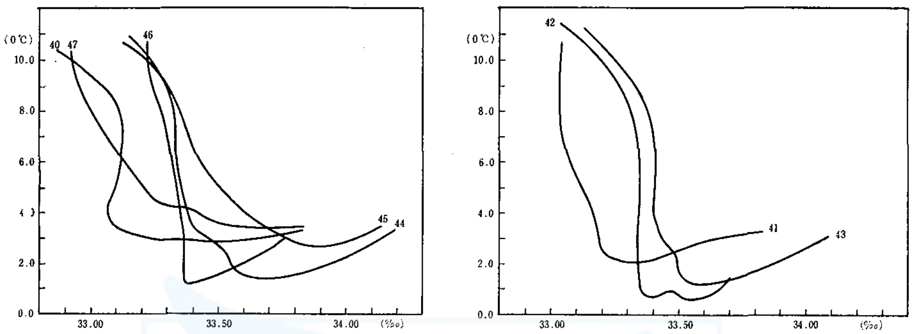

Fig. 31 Temperature and salinity at St. 10, 11, 12, 13, 14, 15, 16 and 17.

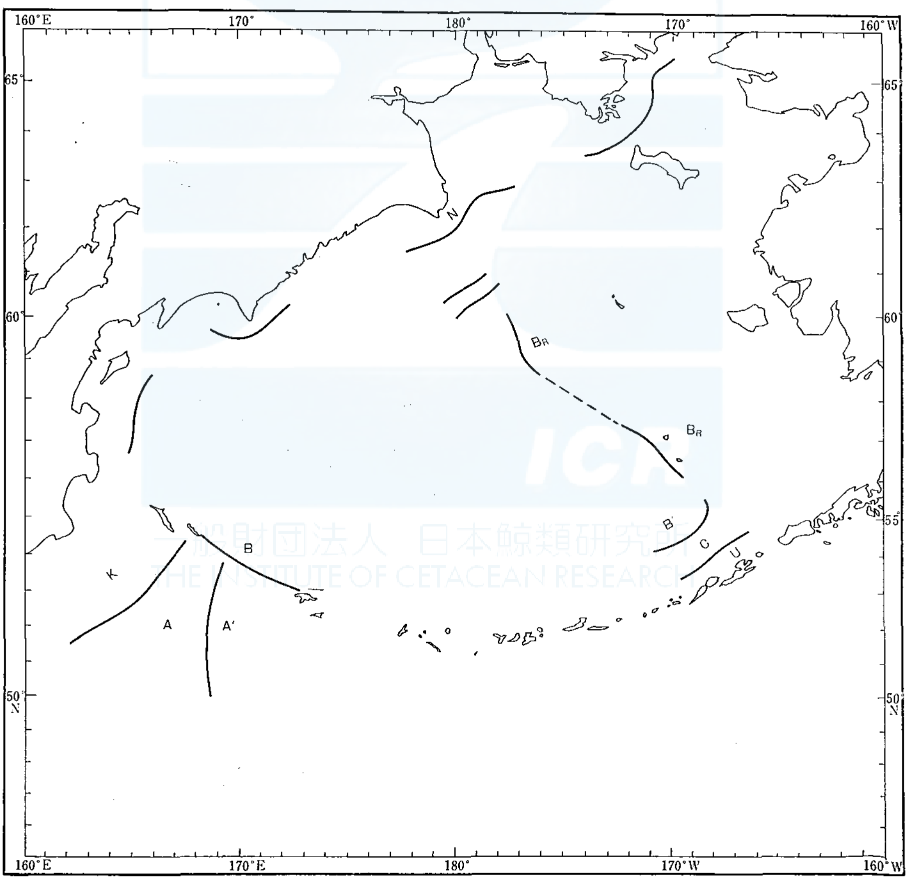

Fig. 32. Distribution of water mass.

waters in salinity about $33.30–33.40^0/_{00}$). To the west of Attu Island, near 53°N, 170°E, low salinity water was, of which the salinity was lower than that of the water mass along the C-line. Near 50 m of St. 45 high salinity water mass ($>33.60^0/_{00}$) was found, and suggested the rising of deep water. At St. 42 the temperature from surface to 50 m varied remarkable, however the salinity was homogeneous. This water mass may be conisdered that of coastel water off Kamchatka, in which the intermeidate cold water exists at relatively shallow depth. Near 100 m the water mass which is characterized by less than 1.5°C and 33.50–$33.60^0/_{00}$ located at St. 42, 43 and 44 respectively, and water masses at St. 40 and 47 were relatively warm and low salinity. At St. 46 there are cold and low

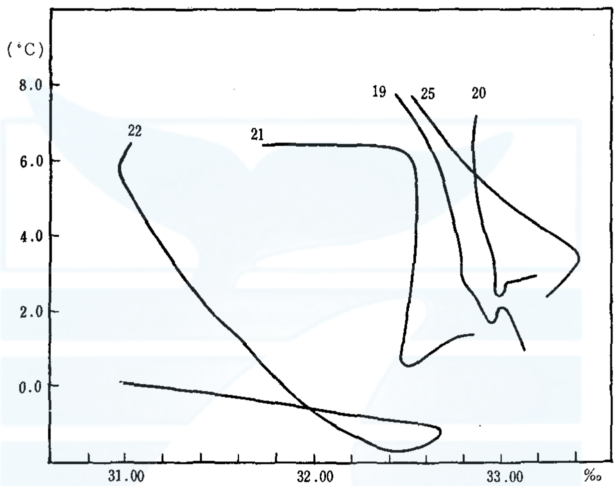

Fig. 33. T-S characteristics of the water masses at vicinity of the G-line.

salinity waters (temperature: about 1.2°C, salinity: about $33.40^0/_{00}$). Near 200 m depth, both temperature and salinity were higher than those at 100-150 m depth at each station. Analyzed water masses are termed A, A′, B and K for convenience, and the distribution of those is shown in Fig. 32. The summary for water masses are as follows.

A: Intermediate cold water developed, with the core at about 100 m, with warm and high salinity water near 200 m.

A′: As stated by Kitano (1958), A′ is a subtype of A, and is generally warmer and more saline than A below 50 m depth.

B: From surface to near 100 m depth, temperature varied anomalously with depth. Salinity was homogeneous, and the temperature minimum was found near 100 m. According to Kitano (1958), the B-type extended to the central area of the Bering Sea.

K: The core of intermediate cold water is located in shallow layer, with a temperature of less than 1,0°C.

G-line

Fig. 33 shows the T—S characteristics of the water masses at the vicinity of the G-line. In general, from 10 to 75 m depth at St. 22, near Cape Navarin, there is a prevalent cold water ($<-1.0°C$) which is apparently established by vertical convection during the period of cooling. At 100 m depth there is a low salinity water mass ($30.99^{0}/_{00}$) which is quite different from that observed at 75 m depth. At surface layer of St. 19, 20. 21 and 25 warm and high salinity water masses are found which may be divided with the water mass near St. 22. At the 25 m layer of St. 21 there is a relatively cold and low salinity water mass which must be influenced by the Siberian coastal area water mass. At St. 25 in general it was evident that the warm and high salinity water mass had intruded. At St. 19, generally, salinities are low at each depth layer, it was probably established by the convection between the low salinity of Alaskan coastal area and other. From Fig. 32, near Cape Navarim cold and low salinity water mass located in the vicinity of Siberian Continent where in the south, there was a warm and high salinity area near 60°–30′N, 180° longitude where salinity in the east decreased again. Consequently, water masses near Cape Navarin may be divided into three types. General distribution of water masses in the Subarctic region was shown in Fig. 32 which included Kitano's figure (1958), too. The water masses near Cape Olyutorski, St. Lawrence Island and the Chukchi Sea were examined by use of data obtained at sea surface.

HYDROGEN-ION CONCENTRATION (PH)

The hydrogen-ion concentration was determined by a comparator for sea water which consists of two series of color standard solutions, one was Cresol Red and

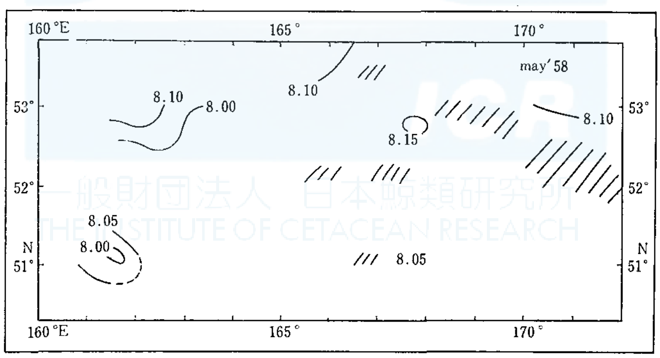

Fig. 34 a).

the other was Tymol Blue. The horizontal distributions of pH at the surface are shown in Fig 34 a) b) c) d). The pH values varied from 8.25 maximum to 7.95 minimum at the south of the Komandorski Is. and the adjacent waters of the Aleutian Is. The waters of high concentration of pH at the surface located in the northern area of Unalaska I., where the value was 8.15, and increased toward

Bristol Bay (8.20–8.25). The pH value in Bristol Bay was 8.4 to 8.5 according to data obtained by Oshoro-maru. In July of 1959, the eastern-most part of the 8.20 line was located more westerly than in 1958 and it may be deduced that the Bristol water mass is to characterized by a pH of less than 8.25 extended towards the west. Moreover, it may be assumed that the annual variation on the distribttion of pH is quite large. It may be influenced by the expansion and decay between the Bristol Bay and Bering Sea water mass.

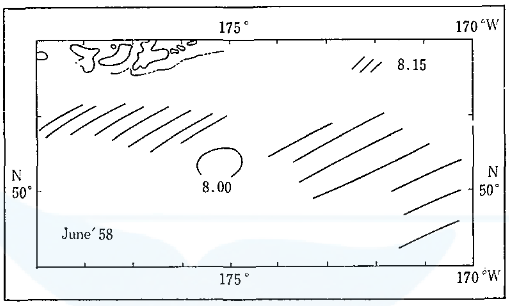

Fig. 34 b).

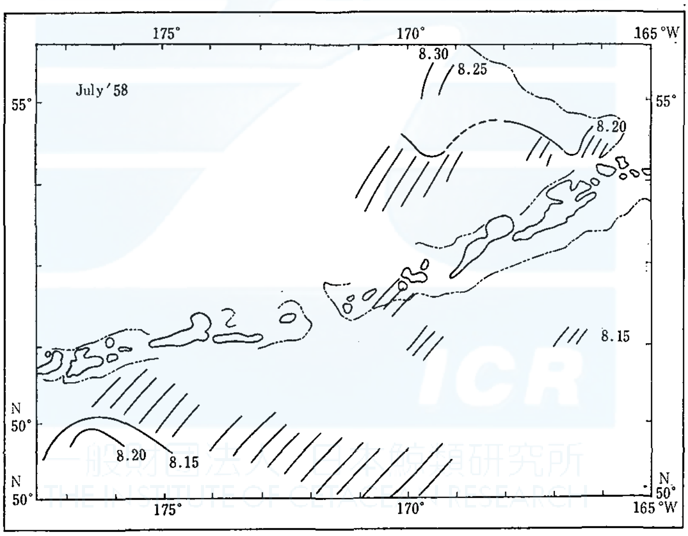

Fig. 34 c).

TRANSPARENCY

Fig. 35 a) b) show the isoline of transparency which were obtained by Secchi disc. In June 1958, near 50°–30′N, 172°–30′W where the transparency generally was high compared with that of the surrounding area and those value varied 7 to 18 m. The transparency was observed to vary between stations. That is, near 50°N, 178°W and 51°N, 172°W, high value area extended towards the north. This may be a significant factor in causing the branch of extension of the Kuroshio water mass. Near 50°N, 170°W, to the south there was an isoline of 7 m. From the distribution of transparency it is assumed that a dis continuous zone may be formed near 168°W to 172°W. The transparency at the northern side of Unalaska

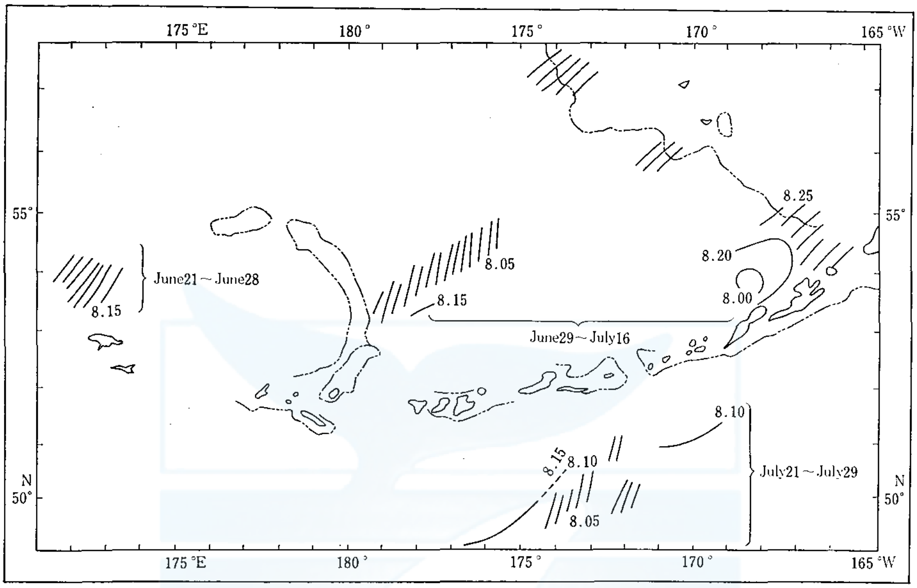

Fig. 34 d).

Fig. 34 a)~d). Horizontal distribution of pH at the surface.

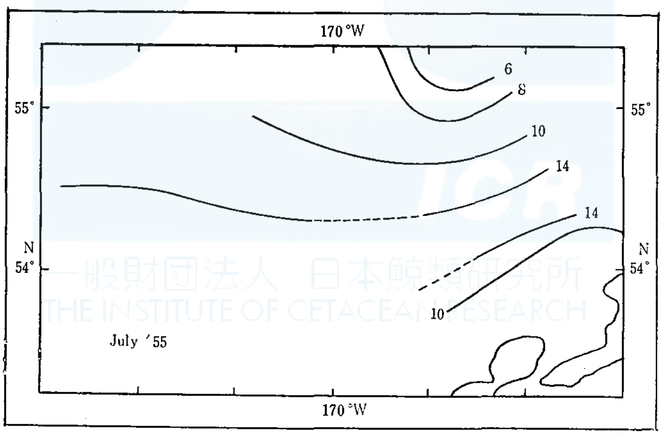

Fig. 35 a).

I., from 6 to 16 m, decreased towards the north, near 200 m contour line. The highest area which was characterized by more than 16 m, coincide with the C-water mass area (see Fig. 32), and it is probably due to the intrusion which flowed from the western area. In addition, the transparency near Unalaska I. was less than 10 m.

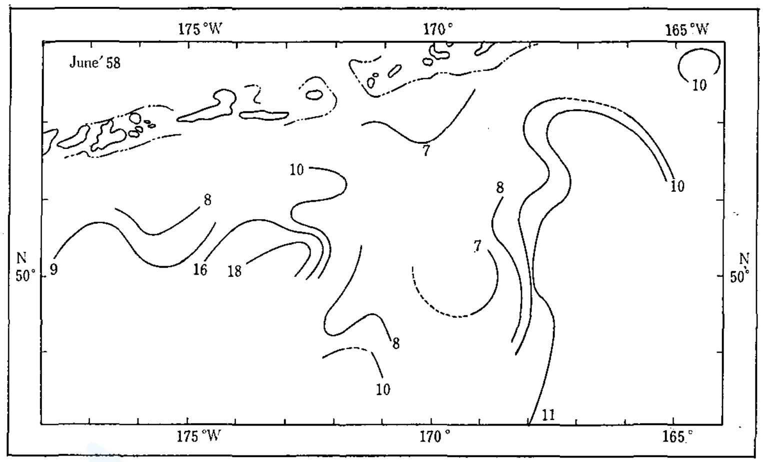

Fig. 35 b).

Fig. 35 a)~b). Transparency in summer (reading-meters).

DISSOLVED OXYGEN

Horizontal distribution

In general, from the data obtained by our observations the dissolved oxygen at the surface in the Bering Sea ranged from 4.43 to 11.05 CC/L and it decreased along

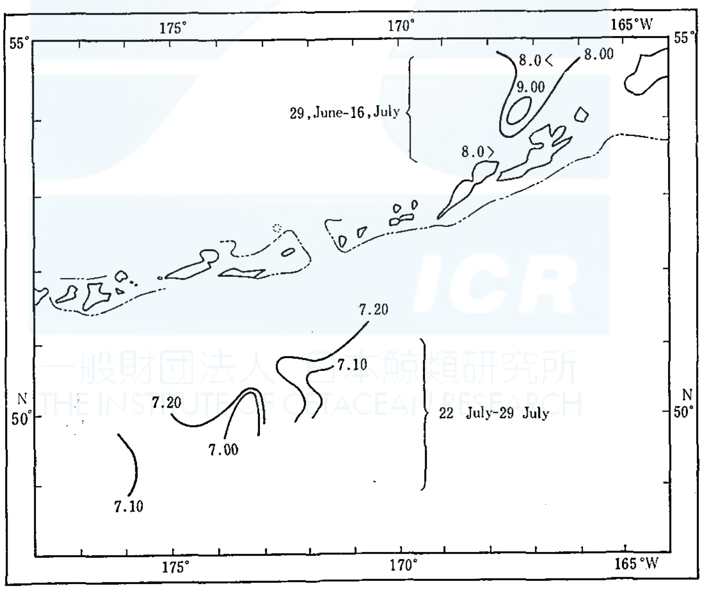

Fig. 36. Horizontal distribution of dissolved oxygen at the surface in June and July of 1959.

the Aleution Is. (the dissolved oxygen was decreased near Bowers Bank also) and increased towards the east region of Kamchatka Peninsula and Bristol Bay (Nasu

1957).

In the Chukchi Sea, the dissolved oxygen varied from 9.03 to 7.17 CC/L in August of 1958, and generally was less along the Alaskan coast and the higher along the Siberian coast (Nasu 1960). Fig. 36 shows the distribution of dissolved oxygen at the surface. To the northern side of Unalaska I. the 8.0 CC/L line is tongue-shaped and intrudes from Bristol Bay to the southwest. As already mentioned above, the dissolved oxygen is higher in the water mass of Bristol Bay and is lower along Unalaska I. where there is sea area, which is covered by less than 8.0 CC/L. Morever, at 49°–50′N, 170°–176°W there is the isolated region where the dissolved oxygen was greater than 9.00 CC/L. It may be considered due to the influence of some biological elements. To the south of the Aleutian Is. near 49°–51°N, 170°–176°W, the dissolved oxygen ranged from about 7.00 to 8.00 CC/L and generally is lower compared to that in the northern side of Unalaska I. 7.00 and 7.10 CC/L line extend from the south to the northward. On the other hand, 7.20 CC/L line locates from the north to the southward and is mostly tongue-shaped at 50°N, 172°–30′W. From the data of sea temperature, salinity and transparency, at 50°N, 172°W the author can be assumed that the oceanic front is formed between the cold and warm water mass.

Vertical distribution

C-line

Fig. 37 shows the vertical profile of the dissolved oxygen along the C-line. In general, as shown in the profiles of temperature and salinity, there is a boundary at St. 45. That is, the dissolved oxygen is higher at the northern side (B-water mass) and is lower at the southern side of the boundary (A-water mass), and the

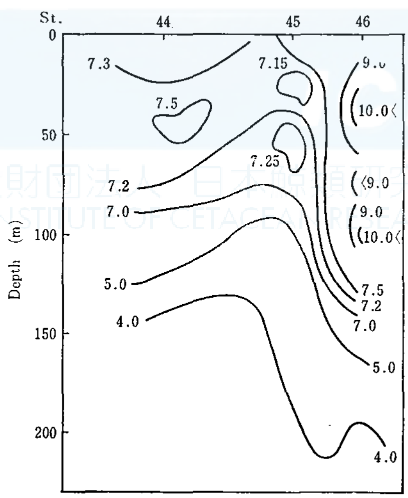

Fig. 37. Vertical profile of dissolved oxygen along the C-line.

isoline of it abruptly changes. The rising of low dissolved oxygen at St. 45 may be caused by upwelling formed by the ridge extending from the Komandorski Is. to the southeast. At St. 46, from the surface to near 100 m depth, there is high dissolved oxygen layer in which the value was over 9.0 CC/L (the value at 150 m depth was about 7.0 CC/L). It may be assumed that the marine productivity is high in the B-water mass of Bering Sea water. Above 100 m depth at St. 44 and 45 there is a water mass which is characterized by having water of about 7.5 to 6.0 CC/L. dissolved oxygen. From each station curves of the dissolved oxygen vertical change developes abruptly below 100 m depth, at St. 44 and 46, and are small at St. 45.

D-line

The vertical profile of the dissolved oxygen along the D-line is shown in Fig. 38. Below 50 m depth between St. 65 and 61 there is a transition layer which characterized by a abruptly change of the dissolved oxygen. The isolines of the

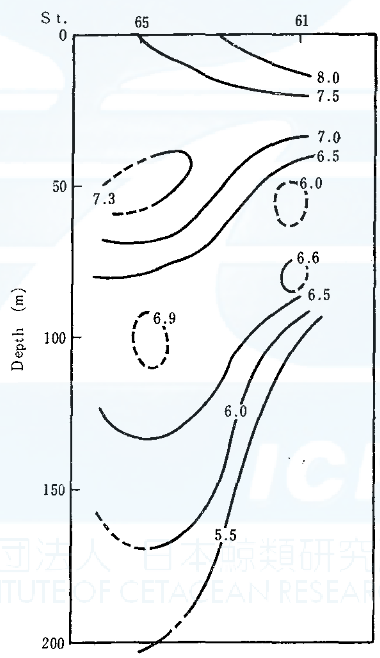

Fig. 38. Vertical profile of the dissolved oxygen along the D-line.

low dissolved oxygen rise from south to north. The phenomenon may be considered that the upwelling is fromed by the marine topography in which the contour line is steeply change from 200 m to downward. The existence of upwelling is also apparent from the vertical distribution of the dissolved oxygen at St. 61 and 65. To the very surface the intrusion of the high dissolved oxygen is found.

I-line

Fig. 39 shows the vertical profile of dissolved oxygen along the I-line. The water mass is characterized by more than 11.00 CC/L below 20 m to the east of St. 0–29. From the surface to 30 m between St. 0–28 and St. 0–29 11.00 CC/L, of which

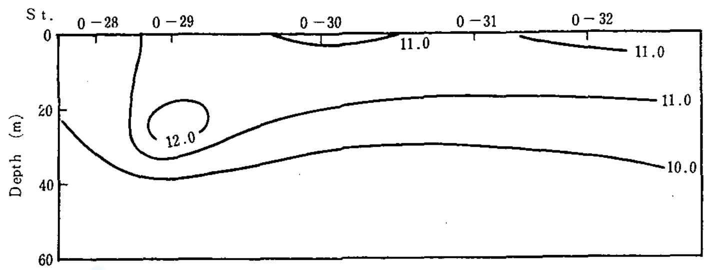

Fig. 39. Vertical profile of dissolved oxygen along the I-line.

the distrubution at a relatively shallow layer coincides with the water mass of more than 6.0°C in temperature and $32.40^{0}/_{00}$ in salinity. Such a distribution leads to a definition of two distinct water masses as a boundary to St. 0–28: the Alaskan water mass of low temperature and salinity with high dissolved oxygen, and the Bering Sea water mass (high temperature and salinity with dissolved oxygen).

ANNUAL VARIATION OF WHALE CATCH

Table 1 shows the number of whale caught by Japanese whaling expeditions in the Bering Sea and the northern part of the North Pacific. The fin whale is the most important specie in the waters, as mentioned in Table 1. Fig. 40 shows the daily catch of fin whale per a catcher boat. In the Fig. 40 we must be careful on the catch of fin whale during the operation of blue whale, because the catch of

TABLE 1. NUMBER OF WHALE CAUGHT BY JAPANESE WHALING EXPEDITIONS IN THE BERING SEA AND THE NORTHERN PART OF NORTH PACIFIC

Year.	Blue	Fin.	Hump.	Sei.	Total.	Sperm.	Right.
1940	34	295	108	3	440	182	
41	40	370	6	7	423	162	
52	55	213	37	14	319	0	
53	90	470	42	98	700	0	
54	145	1, 316	136	129	1, 726	490	
55	70	1, 360	117	21	1, 568	1, 084	
56	70	1, 415	37	48	1, 570	1, 598	
57	70	1, 405	6	166	1, 641	1, 700	
58	70	1, 331	24	330	1, 755	1, 500	
59	70	1, 450	0	32	1, 552	1, 800	
60	70	1, 393	0	203	1, 666	1, 800	
61	70	1, 452	9	4	1, 535	1, 600	3
62	48	1, 193	17	260	1, 518	2, 549	3
	902	13, 663	539	1, 315	16, 413	14, 467	6

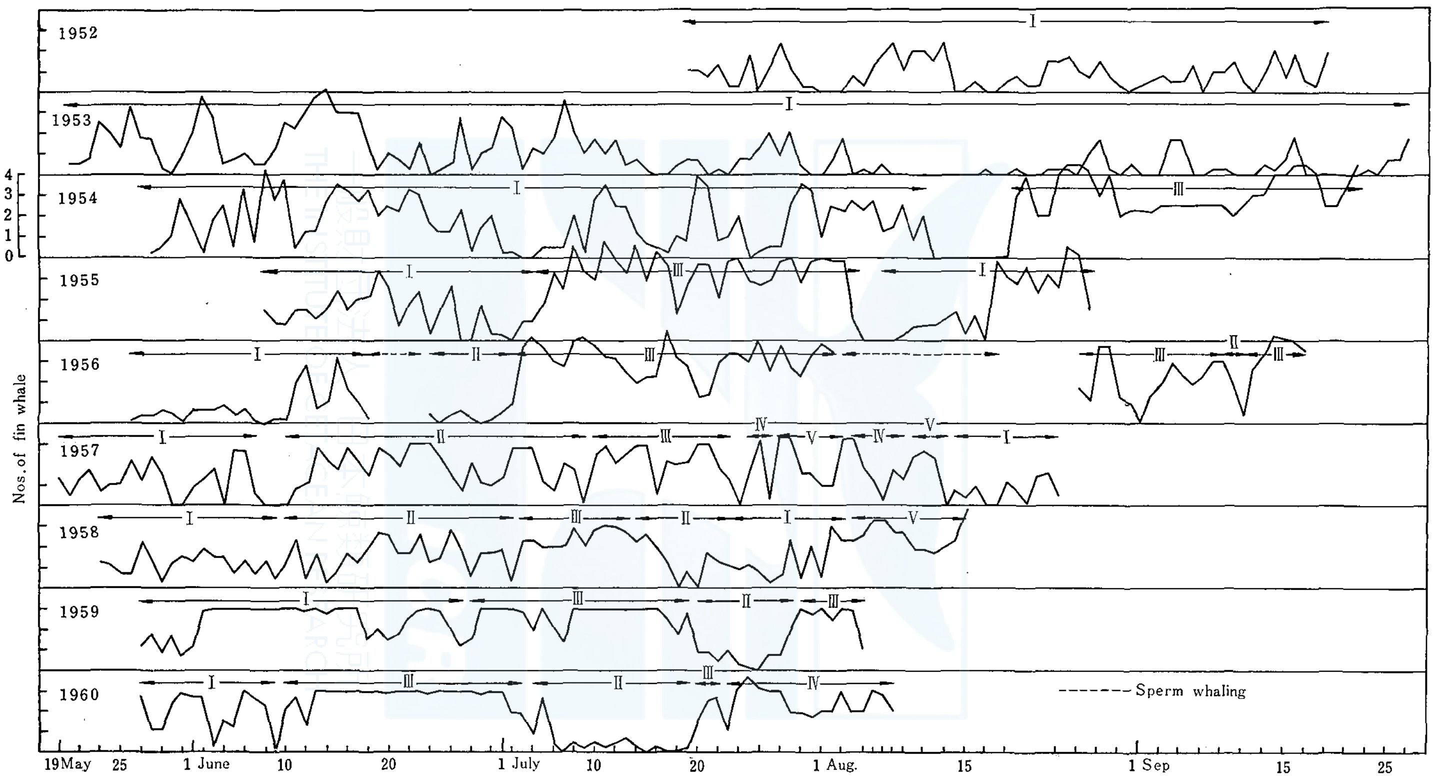

Fig. 40. Daily catch of fin whale per a catcher boat.
I: Off Kamchatka Peninsula.
II: Southern region of Aleutian Islands.
III: Off Unalaska Island.
IV: Off the west of St. Mathew Island.
V: Off Cape Navarin.

fin whale decrease by the catch of blue whale. The daily variation of catch has increased in recent years. However, the catch in 1959 and 1960 was relatively stable. Such a problem must be examined from the point of oceanography, meteorology, catch effort and other elements. From the catch tendency of each year, the fluctuation of daily catch off Kamchatka is relatively large, but that of 1959 shows a small daily variation. The whaling location in this year was a little different from that of other years. Whaling was carried out in the region north of the Komandorski Islands.

When compared to 1953 the catch off Kamchatka has a tendency to become better in the first half and worse in the latter half of the season.

As already stated, the whaling ground on the southern side of the Aleutian Islands (West longitude) shifted to the southward around on 50°N latitude from 1957. In this ground, the operation in 1957 and 1958 were holding out a stable catch, but the catch in 1959 and 1960 decreased. The operation carried out from middle to last decade of July in 1957 and from middle to last decade of June 1958 and from July 1959 and 1960. Whaling operation at the west region of St. Mathew Island carried out in 1957 and 1960. In 1957 and 1958 there were also whaling ground off Cape Navarin, where many fin whales were captured and the detail of whaling season is obscurity as there is lack of data in June and July, but it should be late (may be from last decade in July).

Operation in the northern ground of Unalaska Island commenced in 1954 and has carried out there ever since. The number of daily catch always stable condition every year in this ground, but the total caught whale are relatively small quantity in some years which is because of unnatural influence for the commercial production. From the yearly operation itmay be considered that the whaling season lasts from June into September. The variation of sperm whale caught did not show in Figure. From yearly operation the whaling ground is formed around the Aleutian Islands during the summer season, whose yearly fluctuation is very small, but 1960 many whales were captured at the vicinity of 57°N, 175°W.

It is convenience to use the center of whaling ground for the analysis of fluctuation of that at sea region off Kamchatka Peninsula and the northern region of Unalaska Island where the whaling operation are carried out at every year. A primary factots what the whaling grounds are formed consist mainly of meterology, submarine topography, oceanographic condition and others, in which the oceanographic condition is the most important factor. The oceanographic condition, namely, the physical, chemical and biological element in each year do not shown always stationary distribution.

CENTER OF WHALING GROUND

Off Kamchatka Peninsula

In order to obtain the center of whaling ground the author used following formula which was shown by Uda (1930).

$$\bar{X} = \frac{\Sigma nixi}{ni} \qquad \bar{Y} = \frac{\Sigma niyi}{ni}$$

, where x and y are location of caught whale. n is number of caught whale. $\bar{X}$ and $\bar{Y}$ are the center of whaling ground.

Fig. 41 shows the average center in the years 1952 to 1960 and the yearly center of ground. Next, Fig. 42 shows the yearly caught whale number of latitude and longitude respectivery at each grounds.

On the longitudinal variation, two peaks were found in 1952, 1953 and 1954, of which the operations were carried out during long time (the operation in 1956 and 1959 were carried mainly out at the northern region of the Komandorski Islands). Those peaks are generally near 164°E and 174°E, and the most peak

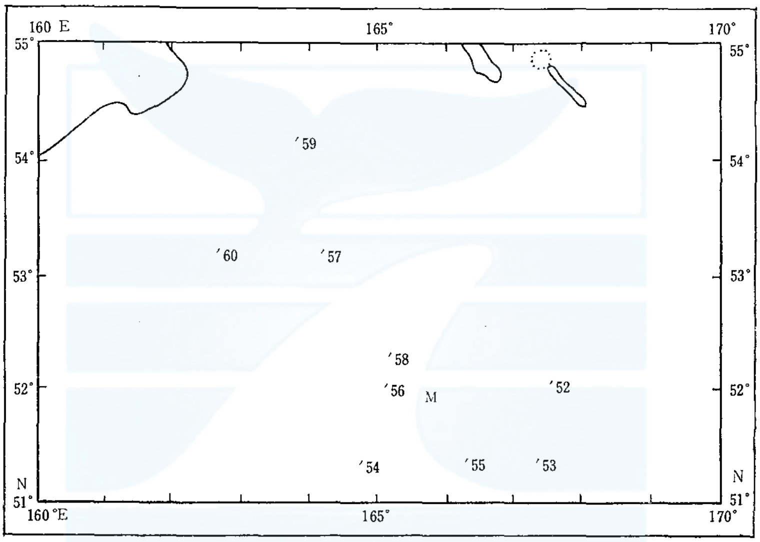

Fig. 41. Yearly center of fin whaling ground.
Ⓜ shows the average center in the years 1952 to 1960.

longitudinal catch was found near 164°E. The peak of latitudinal catch generally as at 52° to 53°N, and has a tendency to more barely towards the north. Such in 1956 and 1959 when the whaling ground was formed at the northern region of Komandorski Islands coincide with relatively higher in sea temperature. The problem of movement of ground must analyze from the point of migration of whales and whaling season.

The operation in this area is carried out in recently the beginning of all whaling season in the Subarctic Pacific area. The peak of latitudinal catch generally, is near 52°–30′N and average center of whaling ground in the years 1952 to 1960 locates near 52°N, 165°–30′E.

Off Unalaska island

As mentioned on the whaling operation in the region off Unalaska I. by Japanese

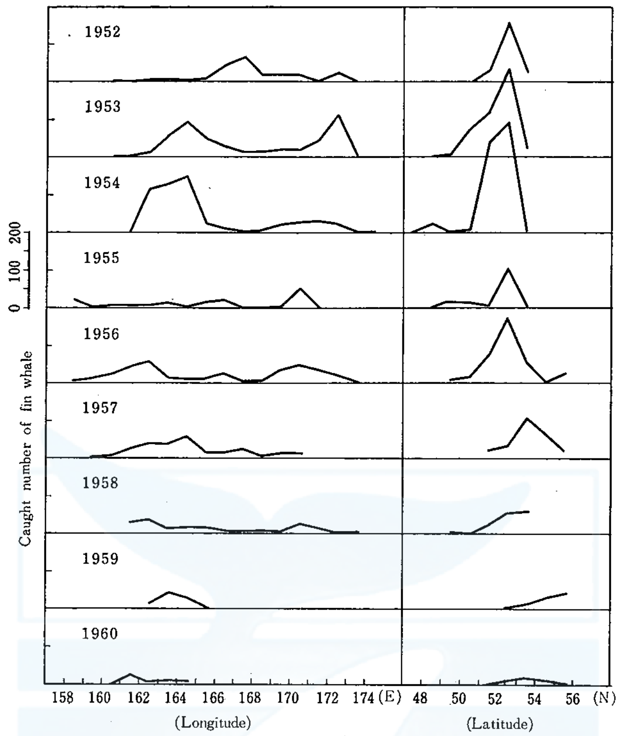

Fig. 42. Yearly caught number of fin whale in the ground off Kamchatka.

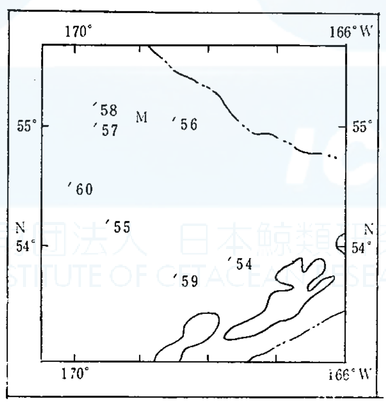

Fig. 43. Yearly center of fin whaling grouud. Ⓜ shows the average center in the years 1954 to 1960.

expeditions are began since 1954. From Fig. 43 the center of ground fluctuates in a small range. The average center of ground in the years 1954 to 1960 locates at 54°N 169°W and the peak of the latitudinal catch was found between 54°N and 55°N latitude (see Fig. 44). On the longitudinal between 169°W and 171°W, there are the center of catch.

In general, the whaling groun off Unalaska Island fluctuates in a smaller compared with that off Kamchatka Peninsula.

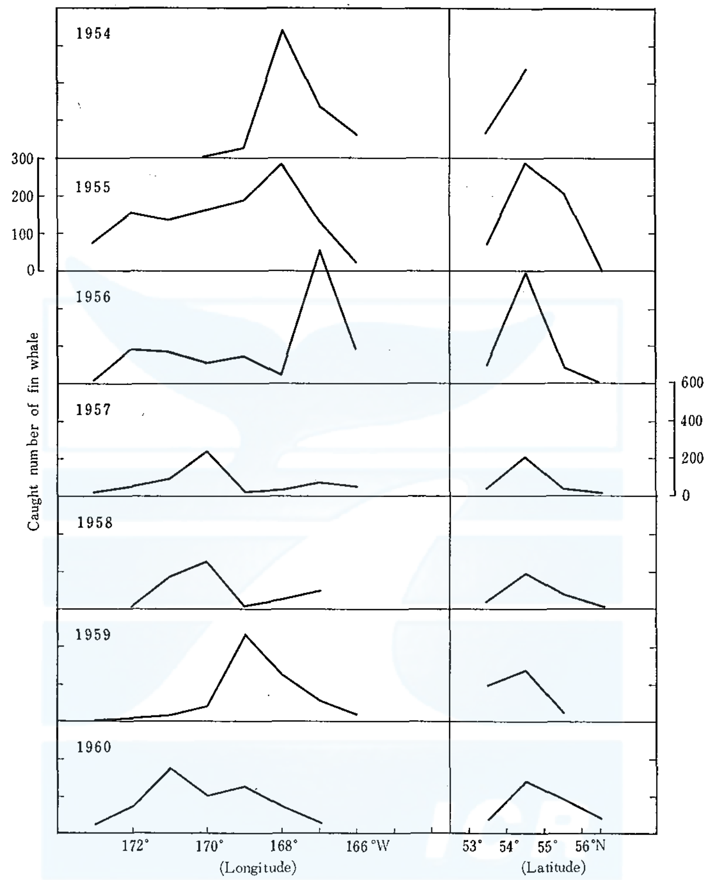

Fig. 44. Yearly caught number of fin whale in the ground to the north of Unalaska Island.

SPERM WHALING GROUND

Sperm whales are mainly captured along the Aleutian Islands 1960 was an exception. Fig. 45 shows the latitudinally number caught in the ground along the Aleutian Islands. The latitudinal range of ground covers from 170°E to 160°W indicates that the annual fluctuations are very small. The number caught at each latitude section varies somewhat each year, and in general, is more abundant in the region west of 177°W and is most abundant in the vicinity of 180° longitude.

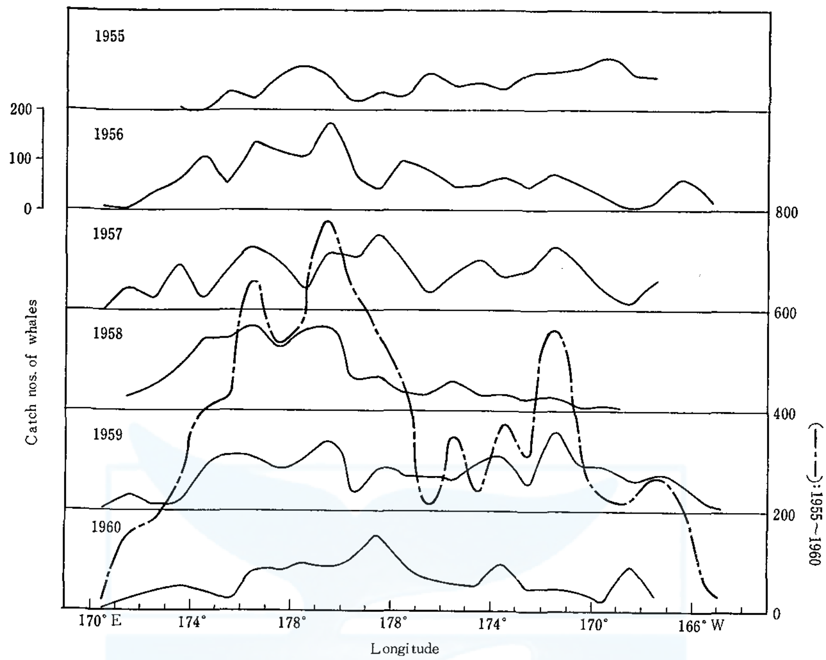

Fig. 45. Latitudinal number of sperm whale in the ground along the Aleutian Island. (except to the north of 55°N)

STRUCTURE OF WHALING GROUND

Fig. 46 shows the schematic hydrographic structure of the ground off northern region of Unalaska Island along the D-line. In the Fig. 46 black circle shows the number of fin whale caught in 1955 season. The hydrographic structure in this ground has formed the discontinuous zone at subsurface between the water mass which intrudes from the southern region of the Aleutian Islands and the Bering Sea from the water mass, which there also is upwelling zone. The quantity of dissolved oxygen, is lower along the Aleutian Islands and almost shows super-saturation at the head of the water mass which is transported from the southern region.

Uda (1960) stated that $Q=\int_{(A)}\int_{(Z)}\Delta O_2' d_Z d_A$ (where A: area, Z: depth, Oz: quantity of dissolved oxygen at Z m. in depth, $O'z$: super-saturation quantity of dissolved oxygen at Z m.) is directly proportional to the quantity of marine life, and Matsudaira et al (1956) reported that the marine production relationship is shown in following formula, based on the quantity of dissolved oxygen.

$$P = (Oz - O'z)$$

Where P is marine production,

O and O' are similar to Uda's formula.

Consequentry, $Oz - O'z$ may be considered for the indirect index of marine production. The source of the oxygen supply is air, phytoplankton etc. The oxygen which is supplied from air is transported to the deep layer by vertical turbulence of sea waters, etc, and is consumed there.

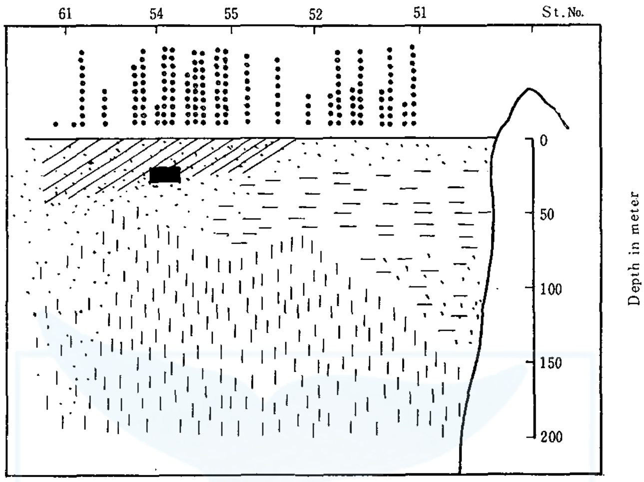

Fig. 46. Schematic hydrographic structure of the ground off region of Unalaska Island.
Small black circle: catch no. of fin whale.
Oblique: super saturation of disolved oxygen.
Black: the most dence stratus of dissolved oxygen.
And other notations show water mass.

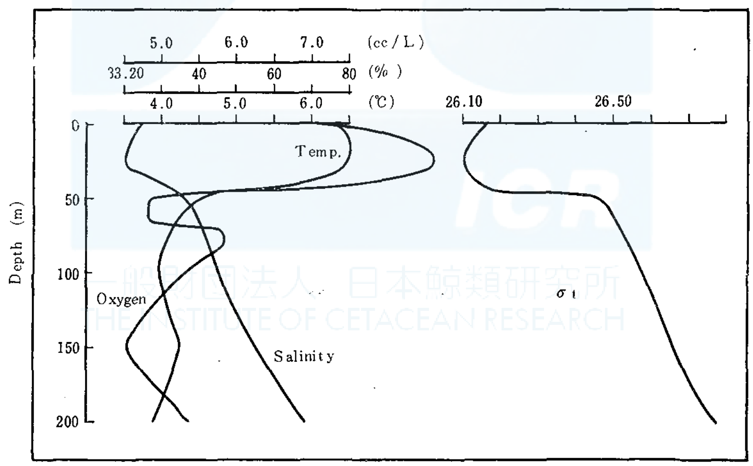

Fig. 47. Vertical distribution of temperature, salinity, dissolved oxygen and σt at St. 54.

When the dissolved oxygen is supplied from air, the quantity is the maximum at sea surface. As shown in Fig. 47, at St. 54 the quantity of dissolved oxygen is very large. Its saturation ratio is 122.40%, and mainly be produced by photosynthesis. At St. 54 the vertical stability ($E = 10^{-3} \frac{d\sigma t}{dz}$, where E is vertical stability, σt is density of sea water and Z is depth) is the most stable condition between 25 and 50 m. in depth, where the typical thermocline is formed also (see Fig. 47). This may be explained by an upwelling water mass during the winter season supplying the surface layer, where it is well known that phytoplanktons increase. Halse (1956) stated that in the Antarctic zone, with its pronounced stability, the large phytoplankton population were confined to a surface layer of 25–50 m. According to Mackintosh & Wheeler (1929), Hardy & Gunther (1935), Mizue (1951), Peters (1955), Marr (1956) and Nemoto (1957, 1959, 1962), it is well known that the staple food of baleen whale in the Antarctic and North Pacific Ocean is euphausiids, and Kemp et al (1932) stated that the distribution of blue and fin whales in the Antarctic waters is closely correlated with the euphausia distribution. It is also reported that these euphausiids feed mainly on phytoplankton (Barkley 1940, Einarson 1945, Ponomareva 1959) and zooplankton organisms (Ponomareva 1959). But Hardy (1935) described that the zooplanktons are distributed away from the concentration area of the phytoplanktons, in general, such an area is not always plenty area of zooplankton.

It also is known that the high concentration layer of the diatom exists less than about 50 meters of depth (Moberg 1928, Phifer 1934a, 1934b, Kokubo and Tamura 1934. The high concentration layer of the phytoplankton seems to the feeding depth of baleen whale. Consequentry, as stated by Marr (1956) and Nemoto (1962), baleen whales seem to feed at relatively shallow depth, but the problem on the feeding depth must be examined from the ecology of zooplanktons and other marine life, also.

Southern region of the Aleutian Is. in West longitude

In this region mainly fin whales were captured but some blue and sei whales were also captured. The whaling ground extends to east and west as a center to lat. 50°–51°N, and locates in the water mass of returnig flow (Kitano 1958). From the distributions of surface temperature in June and July (some whales were sighted in the season) the ground seems to be closely with the oceanic front which is formed between the northerly branch of Kuroshio Extention and the Aleutian Gyral. In order to analyze the structure of the whaling ground, the auther tried study of the upwelling and sinking, whose conputation was based on the formula devised by Saito and Kanari (1961).

Fig. 48 shows the distribution of upwelling and sinking between 25 and 200 meters in depth along 50°N latitude. At 177°W, sinking exists as deep as 200 m. at least. In the area between 171°W and 176°W there is upwelling at relatively shallow depth which seem to extend toward the west, according to Kitano (1958). Between 174° and 176°W sinking is formed to depth of 100 to 200 m. Near 171°W upwelling exists as deep as at least 200 m. At 170°W sinking generally is formed as far as 200 m, condition being similar to those found at 177°W. From these conditions fin whale generally were captured in the area where the upwelling exists from relatively deep layer, being especially plentiful near the boundary zone which exists between the sinking and upwelling areas. Vertical structure along 167°–57′W is shown in Fig. 49, where the fin whale catch between 168° and 169°W, was totaled. Thermocline exists between 20 and 40 m depth, with isopycnal rises between 50° and 51°N.

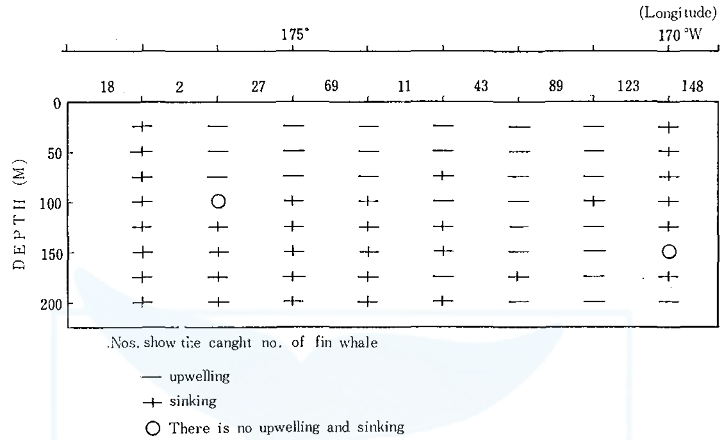

Fig. 48. Vertical distribution of upwelling and sinking along 50°N Latitude.

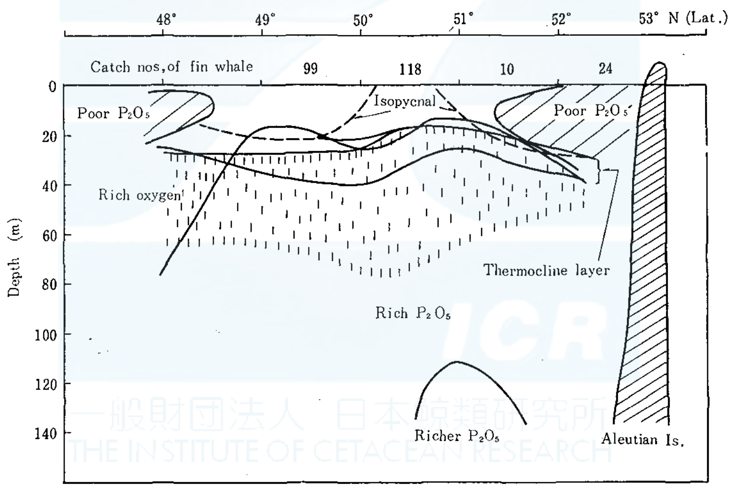

Fig. 49. Schematic structure in the fin whaling ground along 167°57′W.

The maximum layer of dissolved oxygen is found between 20 and 80 m, with thickness being larger where the quantity of phosphate is low at relatively shallow depth, and especially is lower south of 48°–30′N and north of 51°–20′N.

The water mass which is characterized by having water of relatively high concentration of phosphate rises north of 49°N, and zone of the highest concentration is found near 110 m depth at 51°N. Many fin whales were captured between 49° and 51°N, where an upwelling region exists in which the waters in the deep layer have rich phosphate waters and the maximum layer of dissolved oxygen is most thick.

Off Cape Navarin

This whaling ground is located near the mixing zone formed between the water mass along the Siberian continent, characterized by low temperature and salinity, and the oceanic water mass of relatively high temperature and salinity. Fig. 50 shows the schematic figure of water masses and the distribution of fin whale caught (nos. is shown in the Fig. 50). In the Fig. 50 oceanographic data used is that of middle July, and the whaling season is shown from the last of August.

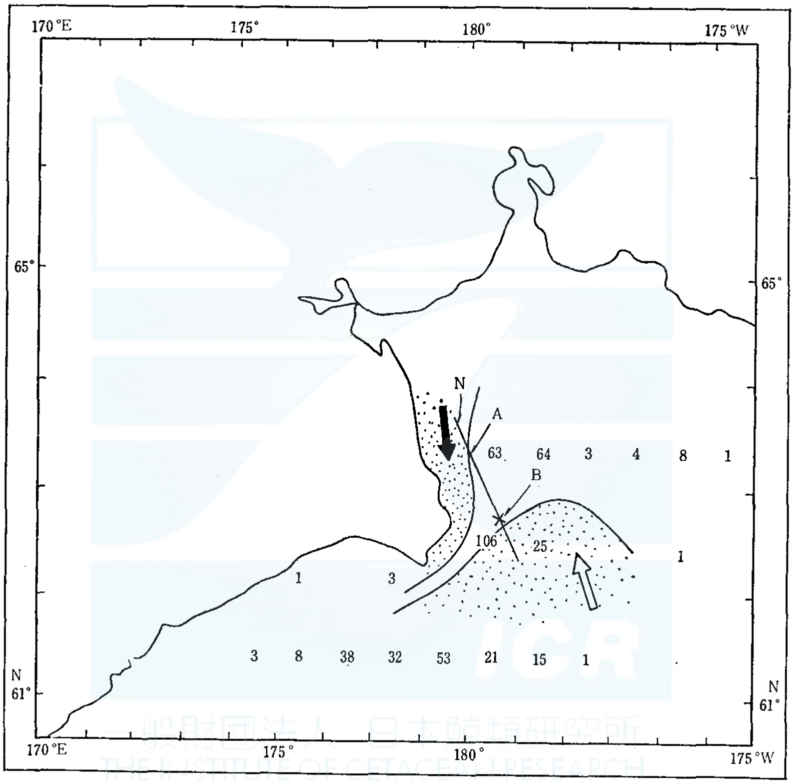

Fig. 50. Schematic picture of water masses and the distribution of fin whale caught. Solid lines show the boundary of water mass.

Moreover, the vertical section of temperature along the N-line is shaown in Fig. 51. The water mass off Cape Navarin further can be definited to three zones (it was definited to two zones in the article of water mass analysis), as follows:

1. Pure melted-ice water: is characterized by marked cold (less than 2.2°C) and low salinity (less than 26.00‰).
2. Zone off Cape Navarin: is characterized by relatively warm (more than 6.0°C) and high salinity (more than 30.00‰).

3. Mixing zone: locates between the pure melted ice-water and water mass off Cape Navarin.

These water masses are termed conveinentry N, ON and M-type, respectively. From Fig. 51, it is seen that a typical discontinuous zone is formed between N-type and M-type, and is considered the vertical boundary as Tsujita (1954) described it in his treatise on the mackerel fishing grounds of Tsushima. Such a vertical boundary can also be assume to form near pack-ice in the Antarctic.

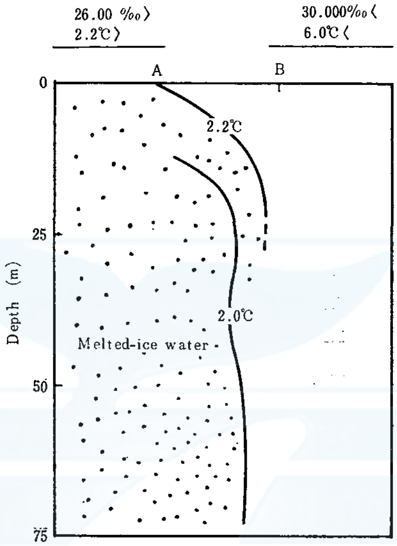

Fig. 51. Vertical section of temperature along the N-line.

From the distribution of surface temperature as shown on current chart (Uda 1960, Fleming 1955), it is clear that the water mass of N-type is moving towards the south along the Siberian continent and the ON-type is flowing towards the north. In addition, many fin whales were captured in the mixing zone (especially narrow area).

SUMMARY

1. In this paper the oceanography and whaling grounds are discussed based on the data obtained by whaling factory and whale marking boats.

2. The monthly mean distributions of surface temperature during 1955—1959 were examined.

May: Temperature distribution to the east off Kamchatka Peninsula, in general, may be considered as due to the influence of coastal and off shore water mass.

On the both side of the Aleutian Islands, isotherms run towards the east and west roughly parallel to each other.

June: Isotherms in the vicinity of the Aleutian Islands run similar to those

of May. On the continental shelf to Alaska relatively high temperature 7.0°C–isotherm is tongue-shaped, extending towards the south.

July: In the neighborhood of the Bowers bank there is a cold water area which is characterized by below 8.0°C.

Temperature in the Alaskan Sea area is high about 1.0°C than that in June. In the vicinity of the Cape Navarin the 5.0°C and 6.0°C isotherms lie nearly parallel to Siberian Continent.

August; The surface temperature in the northern part of the North Pacific and the Bering Sea attained the maximum value in August.

September; Temperatures in this season are decreasing.

3. Thermocline located in almost all the northern part of the North Pacific Ocean, Bering Sea and a part of Chukchi Sea, but their depth and temperture gradient ($\Delta\theta/\Delta D$) differ with sea area and season.

4. The temperature minimum of intermediate cold water in the Subarctic Pacific region vary from -1.6°C at its minimum to highest value 5.6°C, and its core extents from 175 m to 25 m in depth.

5. As the data of salinity was very few compared with that of temperature, it is not examined concerning monthly mean. However, the distribution of some months by year's were shown and discussed.

6. The analysis of water mass was made by using temperature and salinity diagram.

a) Northern sea area of Unalaska Island can be divided into four water masses as shown in Fig 30.

b) Water mass off Kamchatka Peninsula can be divided into four types. That is,

A: Intermediate cold water developed, and saline water near 200m.

A′: Subtype of A.

B: From surface to 100 m in depth, temperature varied anomalously with depth. Salinity was homogeneous.

K: Intermediate cold water was located in shallow layer, with a temperature of less than 1.0°C.

c) Near Cape Navarin cold and low salinity water mass located in the vicinity of Siberian Continent where in the south, there was a warm and high salinity. Water mass near Cape Navarin may be divided into three types.

7. The waters of high concentration of pH at the surface located in the area of Unalaska Island and increased towards Bristol Bay.

8. The transparency shows the higher in the C–water mass (see Fig. 32) and lower near Unalaska Island.

9. The dissolved oxygen at the surface in the Berig Sea range from 4.43 CC/L to 11.05 CC/L and it decreased along the Aleutian Islands and increased towards the east region of Kamchatka Peninsula and Bristl Bay.

10. According to catch distribution from 1952 to 1960 in general, fin whale grounds divided in to five area.

That is,

a) Off Kamchatka Peninsula

Whaling grounds off Kamchatka Peninusla located from the east area of Kamchatka Peninsula to the vicinity of Attu Island. Such in 1956 and 1959 when the whaling ground was found at the northern region of the Komandorski Islands coincied with relatively higher in sea-temperature.

b) Southern side of the Aleutian Islands

Whaling ground on the southern side of the Aleutian Islands (west longitude) shifted to the southward around on 50°N longitude since 1957. The whaling ground extends to east and west as a center to lat. 50°–51°N, and located in the water mass of returning flow (Kitano 1958).

c) Off Unalaska Island

Whaling operations in the northern ground of Unalaska Island commenced in 1954 and has carried out there ever since. The center of ground fluctuates in small range.

d) Off the west of St. Mathew Island

Whaling operations in this area carried out in 1957 and 1960.

e) Off Cape Navarin

Whaling in this area carried out in 1957 and 1960. This ground is located near the mixing zone formed between the coastal water mass along the Siberian Continent and the oceanic water mass of relatively high temperature and salinity.

11. The results of Japanease whaling expeditions indicate that blue and sei whales are found mainly in the southern waters of the Aleutian Islands.

12. Humpback whales are most prevalent in the waters south of the Aleutian Islands (especially east of 170°W) and are also found in near Cape Navarin and in Chukchi Sea.

13. Sperm whales are mainly captured along the Aleutian Islands.

REFERENCES

BARKLEY, E. (1940). Nahrung und Filterapparat des Walkrebschens *Euphausia superba* Dana. *Zeitschr. f. Fish. u.d. Hilfwiss. Beih.*, 1 : 65–156.

BARNES, C. A. & THOMPSON. T. G. (1938). Physical and chemical investigation in Bering Sea and portion of the North Pacific Ocean. *Univ. of Washington, Publ. in Oceanogr.*, 3 (2) : 35–39.

BENNET, E. B. (1959). Some Oceanographic Features of the Northeast Pacific Ocean during August 1955. *J. Fish. Res. Bd. Canada*, 16 (5) : 565–633

EINARSSON, H. (1945). Euphausia, 1. Northern Atlantic species. *Dana Rep.*, no. 27 : 1–85.

HARDY, A. & GUNTHER, E. R. (1935). The plankton of the South Georgia Whaling Grounds and Ajacent Waters, 1926–27. *Discovery Rep.*, 11 : 1–377.

FLEMING, R. H. (1955). Review of the oceanography of the northern Pacific. *Bull. Intern. North Pacific Fish.*, 2 : 1–43.

HIRANO, T. (1957). The Oceanographic Study on the Subarctic Region of the Northwestern Pacific Ocean 1. *Bull. Tokai Reg. Fish. Res. Lab.* no. 15 : 39–55.

—— (1961). The Oceanographic Study on the Subarctic Regin of the Northwestern Pacific Ocean—IV. On the Circulation of the Subarctic Water. *Bull. Tokai Reg. Fish. Res. Lab.*, no. 29 : 11–39.

KAWAKAMI, T. & NASU, K. (1956). [Report of the Whale Marking Research in the Bering Sea and the Northern Part of the North Pacific Ocean.] *Nihon Hogei Senpaku Sōbi Kaizen Iin Kai.*

KAWAKAMI, T. & ICHIHARA, T. (1958). Japanese whale marking in the North Pacific in 1956 and 1957. *Norsk Hvalfangst-Tid.*, no. 6: 285–91.

KELLOGG, R. (1929). What is known of the migration of the whalebone whales. *Ann. Rep. Smithonian Inst.*, 1928. 467–94.

KEMP, S. & BENNETT, A. G. (1932). On the Distribution and Movements of Whales on the South Georgia and South Shetland Whaling Ground. *Discovery Rep.*, 6: 167–90.

KITANO, K. (1958). Oceanographic Structure of the Bering Sea and the Aleutian Waters. *Bull. Hokkaido Reg. Fish. Res. Lab.*, no. 19:

MATSUURA, Y. & MAEDA, K. (1942). [Biological investigation of the Northern Pacific whales]. *Report for whaling*, 9 (1).

KOKUBO, S. & TAMURA, T. (1934). On the seasonal and vertical distribution of the plankton of Aomori Bay. *Sci. Tohoku Imp. Univ.*, 4 *Ser.*, *Biol.*, 8 (4): 297–333.

MACKINTOSH, N. A. & WHEELER, J. F. G. (1929). Southern blue and fin whales. *Discovery Rep.*, 1: 257–540.

MARR, J. W. S. (1956). *Euphausia superba* and the Antarctic surface currents (An advance note on the distribution of the whale food). *Norsk Hvalfangst-Tid.*, no. 3: 127–34.

MATSUDAIRA, C., IWASAKI, H. & TSUDA, T. (1956). On the quantitative ecology of the marine population in the boundary zone—1. On the relationship between the dissolved oxygen and the phosphate in the sea water. *Bull. Jap. Soc. Sci. Fish.*, 21 (11): 1134–40.

MIZUE, K. (1951). Food of whales (in the adjacent waters of Japan). *Sci. Rep. Whales Res. Inst.*, no. 5: 81–90.

MOBERG, E. G. (1928). The interrelation between diatom, their chemical environment, and upwelling water in the sea, off the west coast of southern California. *Proc. Nat. Acad. Sci.*, 14 (7): 511–18.

MOTODA, S. & ANRAKU, M. (1951). An observation on the vertical distribution of Plankton at Ishikari Bay, Hokkaido. *Jour. Oceanogr. Soc. Jap.* 6 (4): 194–201.

MOTODA, S. et al. (1956). Hydrographic data obtained principally in the Bering Sea by training ship " OSHORO MARU " in the summer of 1955.

NASU, K. (1957). Oceanographic condition of the whaling grounds in the waters adjacent to Aleutian Islands and the Bering Sea in summer. *Sci. Rep. Whales Res. Inst.* no. 12: 91–101.

—— (1960). Oceanographic investigation in the Chukchi Sea. *Sci. Rep. Whales Res. Inst.* no. 15: 143–57.

NEMOTO, T. (1957). Foods of baleen whales in the Northern Pacific. *Sci. Rep. Whales Res. Inst.*, no. 12: 33–89.

—— (1959). Food of baleen whales with reference to whale movements. *Sci. Rep. Whales Res. Inst.*, no. 14: 149–290.

NIKULIN, V. G. (1946). On the distribution of whales in the adjacent sea to Chukchi Peninsula, cited from the translation by H. Sakiura in Geiken Tsushin.

PETERS, H. Z. (1955). Uber das Vorkommen des Walkrebschens *Euphausia superba* Dana und seine. Bedeutung fur die Ernahrung der sudlidhen Bartenwale. *Arch. Fischereiwiss.*, 6: 288–304.

PHIFER, L. D. (1934, a). Vertical distribution of diatom in the Strait of Juan de Fuca. *Univ. Wash. Publ. Oceanogr.*, 1 (3): 83–96.

—— (1934, b). Phytoplankton of East Sound, Washington, February to November, 1932. *Ibid.*, 1 (4): 97–110.

PONOMAREVA, L. A. (1959). Eüfauziidy Okhotskogo i Beringova morei. An USSR Trudy Inst. *Okeanol.*, 30: 116–47.

SAITO, Y. & KANARI, S. (1960). On the relations between the distribution of sea water temperature, wind-stress-curl, upwelling and sinking. *Journ. Tokyo Univ. Fish.*, 46 (1–2): 1–19.

SLEPTSOV, M. M. (1955). *Biologiia i promysel kitov gal'nevostochnyx morei.* Moscow,

TAGUCHI, K. (1956). [The salmon resource (Onchorhynchus Sp.) and salmon fisheries, in Northern waters of Asian Side.] Northern Water Fishery Resources Investigation Conference.

TOMILIN, A. G. (1935). Kitoboinyi Promysel v SSSR Rybonoe Khxiaistro.

Townsend, C. H. (1935). The distribution of certain whales as shown by logbook records of American whaling. *Zoologica*, 19 (1): 1–50.

Tsujita, T. (1954). On the observed oceanographic structure of the Tsusima fishing grounds in winter and ecological relationship between the structure and fishing conditions. *Journ. Oceanogr. Soc. Japan*, 10 (3): 158–170.

Tully, J. P. (1957). Some characteristics of sea water structure. *Pro. Eighth Pacific Sci. Cong., III Oceanography:* 643–61.

Tully, J. P., A. J. Dooimead & S. Tabata (1960). An anomalous increase of temperature in the ocean off the Pacific coast of Canada through 1957 and 1958. *Jour. Fish. Res. Bd. Canada*, 17 (1): 61–80.

Uda, M. (1935). [The origin, movement and distribution of dichothermal water in the northern sea region of Japan.] *Umi to Sora*, 15 (12): 445–52.

—— (1953). On the convergence and divergence in the NW Pacific in relation to the fishing grounds and productivity, *Bull. Jap. Soc. Sci. Fish.*, 19 (4): 453–38.

—— (1955). The fluctuation of Oyasio current in relation to the atmospheric circulation and to the distribution of the dicnothermal waters in the North Pacific Ocean. *Rec. Oceanogr. Works Japan*, 2 (2): 43.

—— (1958). On the abyssal circulation in the Northwest Pacific Area. *Geophys. Mag.*, 28 (3): 411–16.

—— (1960). [Fisheries Oceanography.] Koseisha Koseikaku, Tokyo.

—— (1960). Oceanography of the Sub-Arctic Pacific. *Fish. Res. Bd. Canada Ms. Rep.*, 51: 44–58.