OCEANOGRAPHIC INVESTIGATION IN THE CHUKCHI SEA DURING THE SUMMER OF 1958

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INTRODUCTION

This paper is the result of investigation conducted by the author in the waters of the Chukchi Sea (Arctic Ocean) during August of 1958. This observation was carried out on board of the "Fumi-maru No. 16", belonging to the Taiyō Fisheries Co., Ltd.

The observation in the Chukchi Sea has begun in Aug. 16, and completed in Aug. 20. During the season, 19 stations were occupied, covering the region shown by Fig. 1.

At each oceanographic station, the records of vertical temperature distribution were obtained from bathythermograph. Planktons were collected almost at all stations and sediments of the bottom were taken

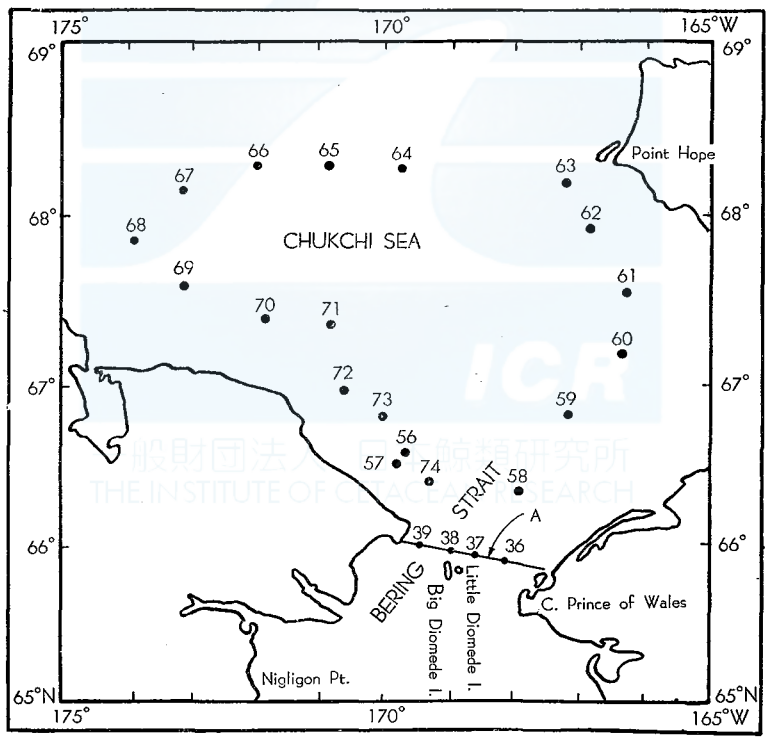

Fig. 1. Location of bathythermograph stations (56–74) and hydrographic stations established by the U.S.C.G.C. Chelan in 1934 (36–39).

at St. 59, 63 and 69 only. Furthermore, a sample for measurement of radio-activity was taken at St. 70.

Materials gathered at the surface include observation of temperature and of chlorinity, dissolved oxygen and hydrogen-ion concentrations of the waters.

The author wishes to express his thanks to Captain Sumio Tanaka and Mr. Eiichi Tanaka, the members of the Taiyō Fisheries Co., Ltd. and the crew on board of the "Fumi-maru No. 16", who helped him during the season.

The author is greatly indebted to Dr. Michitaka Uda, Professor of the Tokyo University of Fisheries, who gave me many kind advices and read through the paper, and to Dr. Hiroshi Niino, Professor of the Tokyo University of Fisheries, who examined samples from the sea bottom.

Thanks are also due to Mr. Katsuo Ohkubo, a member of the Tokai Regional Fisheries Research Laboratory, who measured radio-activity of the waters.

TEMPERATURE AND SALINITY

Fig. 2 shows the distribution of temperature and salinity at the sea surface. Temperature and salinity at the surface in the Chukchi Sea obtained by the survey, ranged from 3.7°C minimum to 11.2°C maximum. The maximum temperature area located at the WSW off Point Hope, and the isotherms in that area run quite similar to the contour line in the topographical distribution.

Isohaline at the surface, 31.50‰ line, runs parallel to the Alaskan continent. In general, in the eastern area of the Chukchi Sea, the surface sea condition tends to higher temperature and lower salinity, and those isoplethes run in paralleled with the Alaskan coast line as already stated by La Fond & Pritchard (1952). It is especially conspicuous off Point Hope.

In addition, the warm and low salinity water may be considered as due to the influence of heating by solar radiation on ice-melted water. The distribution of water temperature at the surface in the Chukchi Sea is characterized by a decrease from the east to the west. On the other hand, the distribution of salinities show increase from the east to the west and its maximum, 32.00‰ located at near 170°–172°W on 68°20′ N line. The values of salinity decrease from the higher saline area to the Siberian coast, where the water masses are modified into these less than 5.0°C in temperature and 30.00‰ in salinity.

The high salinity in the central part of the Chukchi Sea may be due to the influence by the northward current from the Bering Strait, in the adjacent waters to the Siberian coast. While the low saline water

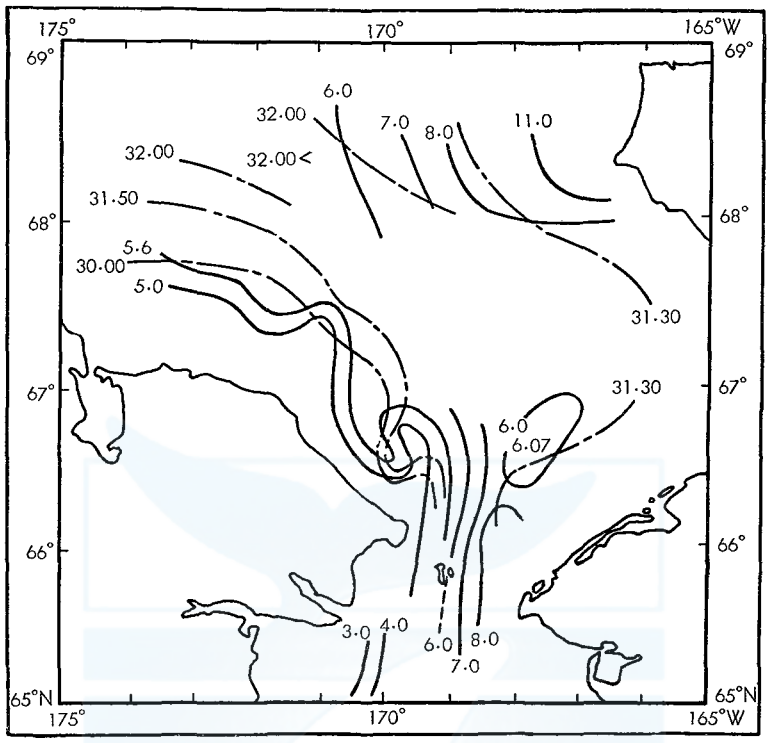

Fig. 2. Horizontal distribution of temperature and salinity at surface.
Solid line—temperature. Broken line—salinity.

may be due to the melting ice and the inflow of coastal waters.

From the distribution of temperature and salinity the cyclonic eddy seems to be located in the vicinity of 66°40′N, 170°W. In addition, the coldest portion is found in the north of the Anadyr Bay and its temperature at the surface is below 2.5°C. It seems that the coldest area exists stationary.

In the eddy area near to 66°40′N, 170°W, origin of southward current is considered as the Bering water mass, and northward direction of flow for east of the Diomede Islands. That is, from distribution of surface temperature as denoted by G. Ratmanoff (1939) northward current is affected by the cyclonic eddy of large scale located near to 67°30′, 170°W and its flow extends to southward.

The cold water mass along the Siberian coast flows with speed of about 1 knot (G. Ratmanoff, 1939) and it formed oceanic front with the northward Bering water mass. Moreover, observation from the vessel many foams were recognized on the front. It is clear that the collision of those water masses was remarkable at its situation of the front. Comparatively value below 6.0°C was found at near 66°40′N,

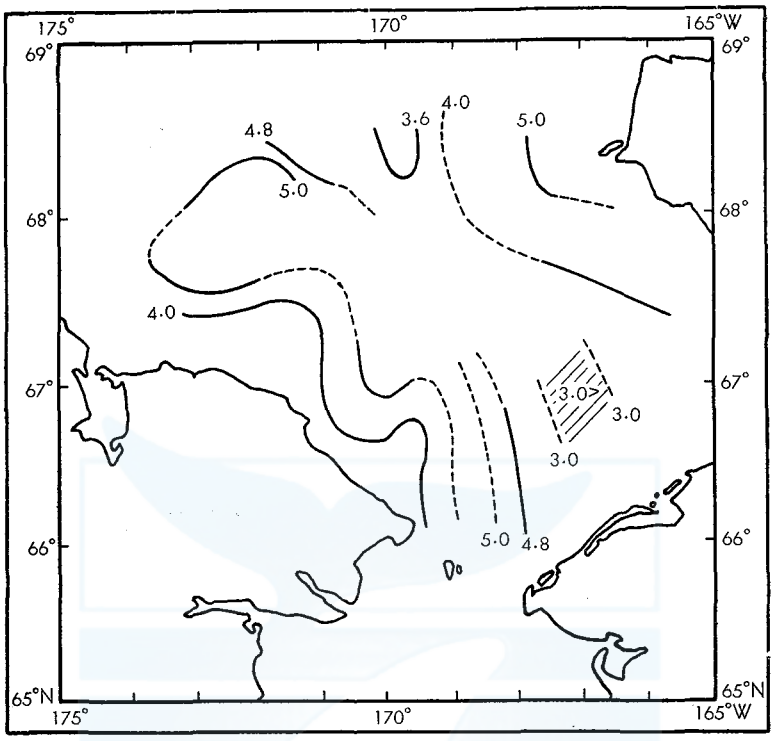

Fig. 3. Horizontal distribution of temperature at 25 m.

167°30′W due to upwelling around by the bank located in the north of Prince of Wales.

A northward flow was shown by all kind of surface observations carried out from the Bering Sea to the Chukchi Sea. Moreover, northward flow in the Bering Strait was already stated by Barnes and Thompson (1938) and Uda (1959, 1960), the water belonging this current is divided into two types of water in the center of Strait (Goodman et al., 1942).

VERTICAL DISTRIBUTION OF TEMPERATURE

It is well-known that the thermocline develops in the summer season under the influence of heating by the solar radiation in high latitude. The thermocline existed at the Chukchi Sea and also conspicuous one at St. 59–63. The steep vertical gradient of temperature was found at St. 62 and 63, forming most notable thermocline. It is a characteristic feature that the shallow depth of the thermocline at St. 62, ranged from 5 to 10 m depth. Off Point Hope, at St. 63 the maximum 11.7°C was observed at 7 m depth. Such sub-surface maximums in temperature were frequently observed at the north of 70°N near the boundary of

the ice zone (La Fond & Pritchard, 1952).

Bathythermograph data taken from the Chukchi Sea shows that during the summer the thickness of the upper mixing layer was mostly less than about 15 meters depth. Accordingly, it seems to be less than 15 meters approximately in which the influence of heating by solar radiation attains during the summer season. In addition, the upper mixing layer in northern part of North Pacific, is generally less than 20 meters depth (Fleming, 1955).

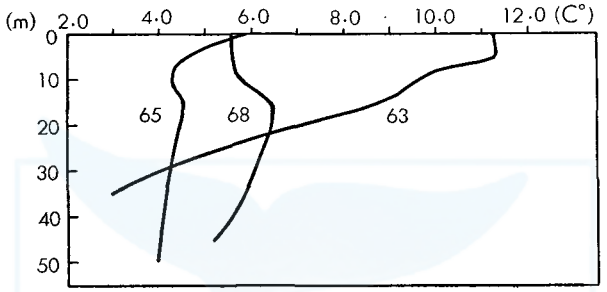

Fig. 4. Station curves of temperature.

In the observation carried out at St. 63, surface temperature rise to 11.0°C or more in midsummer. According to the data obtained by USSR research vessel, the vertical distribution of salinity at near St. 63, indicates most homogeneous pattern from the surface to the bottom layer.

As shown in Fig. 4 the gradient of temperatures to vertical direction, are larger in the eastern part than the west, and the differences between the max. and min. temperature, at St. 66, 67, 69 and 71 were less than 1.0°C. Especially, the water column at St. 69 was well mixed from the surface to the bottom and the vertical temperature below 5 m depth was perfectly homogeneous with 5.5°C. It seems to represent sinking by the convergence which was formed in between the Siberian coastal water and northward flow water from the Bering Sea.

The vertical distribution of temperature along the line at 68°20′N is shown in Fig. 5. It indicates that the horizontal distribution of temperature at the surface layer, decreases toward the west and increases toward the east, meanwhile in the bottom layer below 40 m depth, temperatures increase from the east to the west. The cold water with temperature less than 3.5°C at St. 63 locates from 35 m depth to bottom. Warm water layer at St. 66 was found above 30 m depth. It should be due to the Bering water mass which flowed into the north from the Bering Strait. Comparatively the cold water mass locates at St. 65 above 5 m depth with considerable thick layer. It may be affected by the southward flow

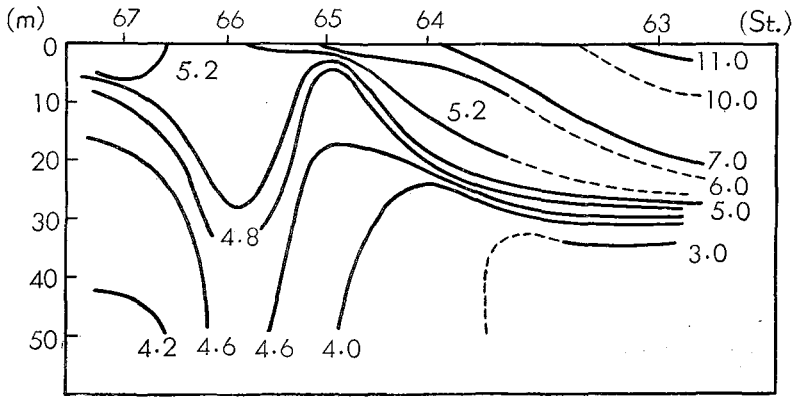

Fig. 5. Profile of temperature along the latitude of 68°20'N.

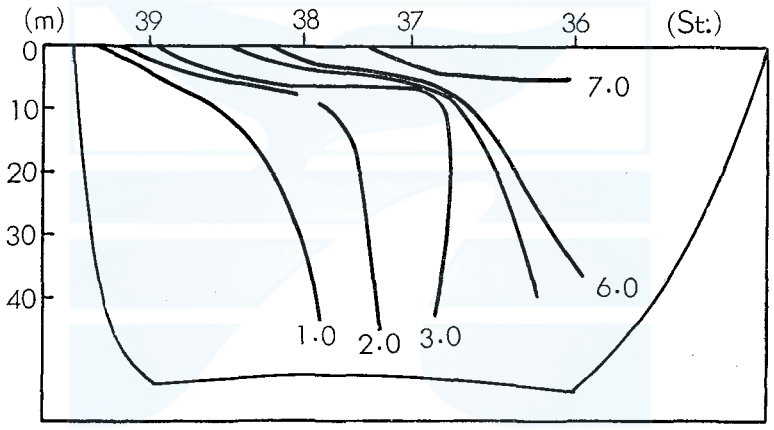

Fig. 6. Profile of temperature along the A-line.

from the waters near the North Poles. Hereby, an oceanic frontal surface is formed and the water mass is divided into two types at the eastern part and the west.

As a rule, the thermocline in the Chukchi Sea is more developed on the side of Alaskan waters than that on the side of Siberian waters and its depth, as stated by La Fond Pritchard (1952), increases from the east to the west. Basing on the vertical distribution of temperature the vertical convection in waters is supposed to be more developed to the west.

Next, the profile of temperature along the A-line, is shown in Fig. 6*. It shows that the Alaskan warm water mass in the Bering Strait locates from the Diomede Islands to the east area. Moreover, the cold water mass located at the west of the Alaskan warm water mass, has shown

* Fig. 6 was drawn by use of data obtained by United States Coast Guard Cooperated with the Oceanographic Laboratories of the University of Washington in 1939.

a flow with general northward direction, and turning to the north-west. This cold water mass indicates subsidence at St. 37. It seems that a convergence might be formed between the warm water mass at the east and the cold water mass at the west.

DENSITY

The density of sea water depends upon the temperature and salinity. Usually, the general distribution of the density is roughly parallel to the isotherms and isohalines (solenoidal field).

The horizontal distribution of density at the surface is given in Fig. 7, in which the isopycnal of maximum value above 25.00 runs in NNW direction from the central part of Bering Strait meandering to the central part of the Chukchi Sea. It corresponds to the northward flow from the Bering Sea.

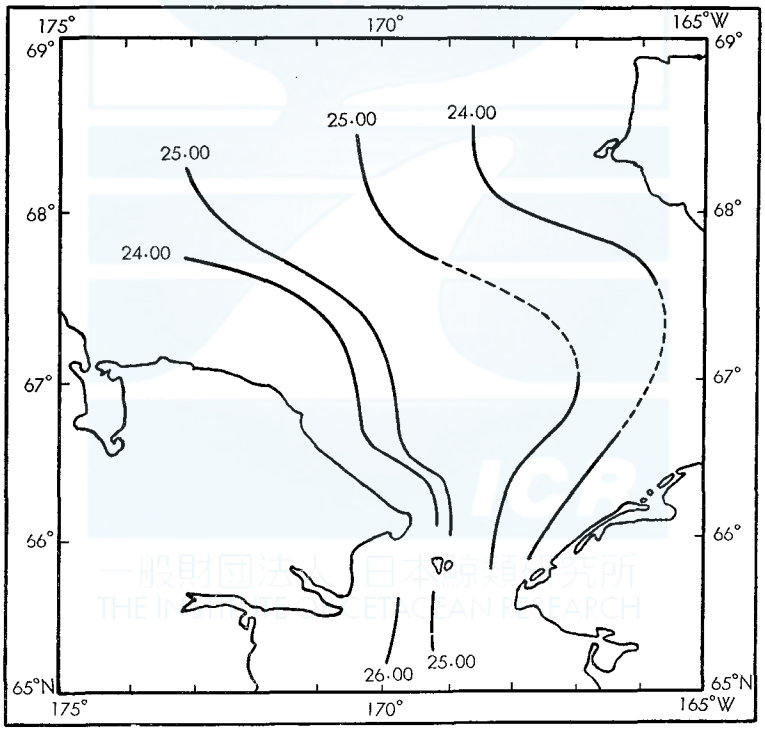

Fig. 7. Horizontal distribution of σ_t at surface.

Lower density waters were found along the Alaskan and the Siberian coast. Furthermore, along the Alaskan coast the minimum density is found in Kotzebue Sound (La Fond & Pritchard, 1952). Those lower density along the coasts seems to be due to the melted ice-water in addition to the run-off from the land.

The isopycnic line of 24.00 in the Alaskan waters is roughly parallel to the coast and 25.00 line is parallel to the west of 24.00 line. In the Siberian waters the lines of 25.00 and 24.00 are roughly parallel to the coast. Furthermore, the density varies most rapidly in this region. This condition is brought about by the convergence formed between the Siberian coastal waters and the central waters of the Chukchi Sea.

DISSOLVED OXYGEN

The horizontal distribution of dissolved oxygen at the surface is given in Fig. 8. The concentration of dissolved oxygen at the surface in the coverage area of observation varied from 9.03 cc/L maximum to 7.17 cc/L. An area with the minimum concentration was found off Point Hope, which corresponded to the area in the maximum temperature. The highest concentration was found at near 68°10′N, 173°00′W off Siberian coast.

Isopleth of 7.50 cc/L extends meandering from the center of Bering Strait to the north-east. Proceeding eastward from the isopleth of 7.50 cc/L the water of relatively low concentration of dissolved oxygen below 7.50 cc/L extends broadly.

In the western part, 7.5, 8.0 and 8.5 cc/L isoplethes are parallel to each other, and those isoplethes were concentrated more densely than the eastern area. This phenomenon is considered due to the convergence between the Siberian water mass and the Alaskan water mass as already denoted in the chapter of temperature. Concerning the horizontal distribution at the surface, the oxygen concentration is low along the Alaskan waters and high along the Siberian waters.

HYDROGEN-ION CONCENTRATION (pH)

The hydrogen-ion concentration was determined by a comparator for sea water which consists of 2 series of color standard solutions, one was Cresol Red and the other was Tymol Blue. The horizontal distribution of pH at the surface is shown in Fig. 8. The pH values taken by the observation in the Chukchi Sea are about 8.15 to 8.30. The distribution of pH roughly corresponds to that of dissolved oxygen. The waters with relatively lower concentration of pH below 8.20 extends to the Alaskan waters a like to the area below 7.50 cc/L in dissolved oxygen.

Isopleth of 8.20 extendeds from the Bering Sea to the NNW direction, and runs parallel to the west of 8.30 line. The horizontal distribution of pH shows its increase from the east to the west and the closely con-

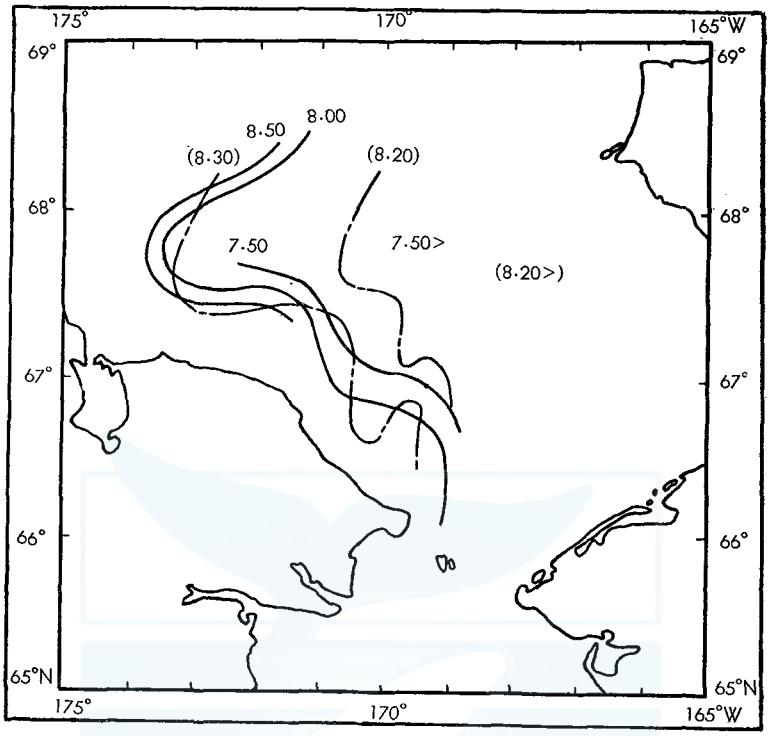

Fig. 8. Horizontal distribution of dissolved oxygen and pH at surface.
Solid line—dissolved oxygen. Broken line and parenthesis—pH.

densed isopleth at about 170°W longitude.

It is well-known that the pH values become high when the photosynthetic activity of marine plants have reduced the content of CO_2 (Sverdrup et al., 1946). The waters of high concentration of pH were also characterized by higher concentration of dissolved oxygen. Consequently, the productivity in the sea water might be inferred indirectly by the values of pH. In general, the productivity in the Chukchi Sea tends to increase in the west and decrease in the east.

WATER COLOR AND TRANSPARENCY

The colors of the sea water were determined by the Forel's scale. Fig. 9 indicates the distribution of water colors. In the investigated area the minimum value of color of water observed at near 66°30′N, 168°W and the maximum value (4–5) was found at the north of 67°N, 168°W.

Value of 5 in water color extends widely from the central part of the Chukchi Sea to the Siberian waters.

Transparency by Secchi disc varies from 7 to 12 m and those isoplethes is located like a isotherms in the distribution. That is, the isoplethes of

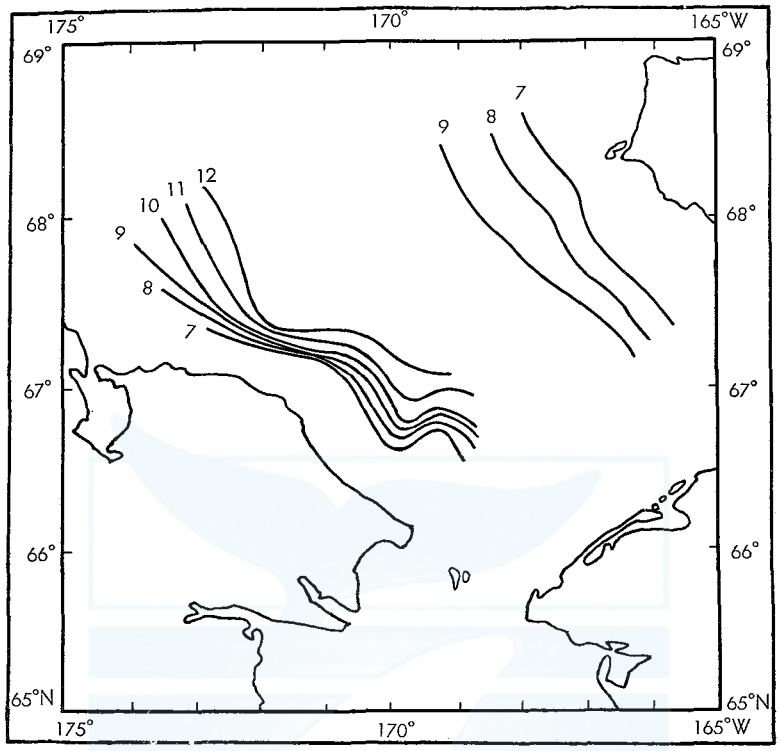

Fig. 9. Iso-line of transparency.

7, 8 and 9 m run parallel to the Alaskan coast and to the Siberian coast, the isoplethes of 7–12 m more or less meander. Lateral intervals of those isoplethes are roughly similar to the dissolved oxygen and hydrogen-ion concentration. It is clear in the distribution of the isopleth of transparency that the discontinuous line was formed by the different water masses along the Siberian coast.

GENERAL OCEANOGRAPHIC CONDITION

Fig. 10 indicates the regions of higher dissolved oxygen and hydrogen -ion concentrations. Furthermore, the boundary line inferred from temperature and salinity, and the current rips observed from the ship were also shown in Fig. 10. A presumptive current-pattern was indicated from data obtained by this investigation, referring to previous data. It revealed a cyclonic eddy located at near 67°30′N, 170°W. At near 66°40′N, 170°W another relatively conspicuous small cyclonic eddy seems to be formed due to the northern eddy and the southern coastal waters along the Siberian coast.

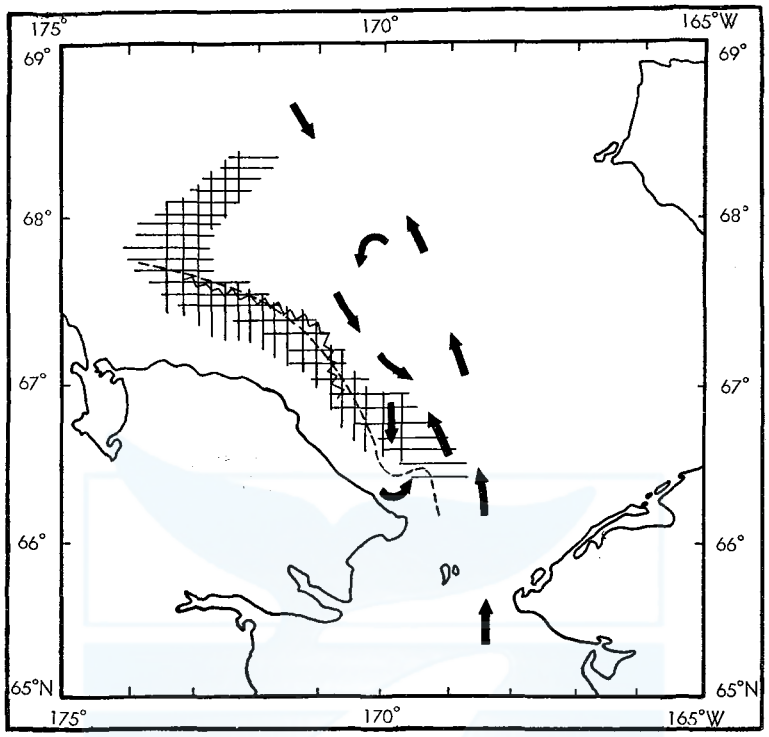

Fig. 10. Summarized oceanographic condition.
Longitudinal line—high value regions of pH. Lateral line—concentrated area of dissolved oxygen. Arrow—presumptived current. Dotted line—boundary line of water mass. Undulating line—current rips were observed from the ship.

General oceanographic conditions are as follows:

Temperature: higher in the east and lower in the west.

Salinity: higher in the central region, and lower to the east and the west.

Dissolved oxygen: higher in the west and lower in the east.

Furthermore, marine productivity seems to be higher in the Siberian waters and low in the Alaskan waters.

SEDIMENT OF THE BOTTOM

Bottom sediments were sampled with a extemporizedly made dredge from the sea bottom at about 50 m depth. The dredge also brought up the specimens of bottom life.

Samples collected at each station are as follows:

St. 59. fine sand—round sand grains round consist of quartz, felsper and pyroxene without life.

St. 63. gravel—gravels consist of andesite, quartz trachyte and hornstone without life.

St. 69. sandy silt with pebble—Sands consist of quartz and felsper with many spong spicule.

Furthermore, few diatoms were found in those sediments. The gravels were sandstones and quartz trachyte.

RADIO-ACTIVITY OF SEA WATER

St. 70—Result of measurement for sample 637 cc, radio-activity was not recognized at all (-2.0 ± 1.1 CPM).

DISTRIBUTION OF WHALES

Inspection in the previous reports (Nikulin, 1947; Data obtained by "Yūki-maru" in the Arctic voyage of 1927) showed that larger whales in the Chukchi Sea were fin, humpback, greenland, right and gray whales.

Fig. 11 shows the locations where all the larger whales were observed from the "Fumi-maru No. 16". Also the Fig. 11 indicated the locations where gray whales were observed.

The number of the sightings during the season are as follows:

Fin whale	1
Right whale	2
Gray whale	82
Unknown	1
Total	86

Only one fin whale was observed around 50 sea miles off west of Point Hope. On Aug. 22, 1927 many fin whales were seen from "Yūki-maru" in the cyclonic eddy area at about 66°40′N, 170°W. Fin whales were seen off Cape of Serdzekamen and in the Bering Strait by the observations from the lands. 70 fin whales were seen in October.

Consequently, many fin whales seems to migrate around the Siberian waters in the Chukchi Sea at least from the early summer to October.

78 gray whales were seen in the convergent area close to the Siberian coast on August 20. These whales seem to have been fed on the livings concentrated by the convergence.

Many gray whales were observed at the east of the St. Lawrence Island in the Bering Sea. It is well-known that the gray whales migrate from the Bering Sea to the Arctic Ocean. Migration route of gray whales from the northern part of the North Pacific to the Bering Sea have been stated (Kellogg, 1929; Gilmore, 1955; Ichihara, 1958). The

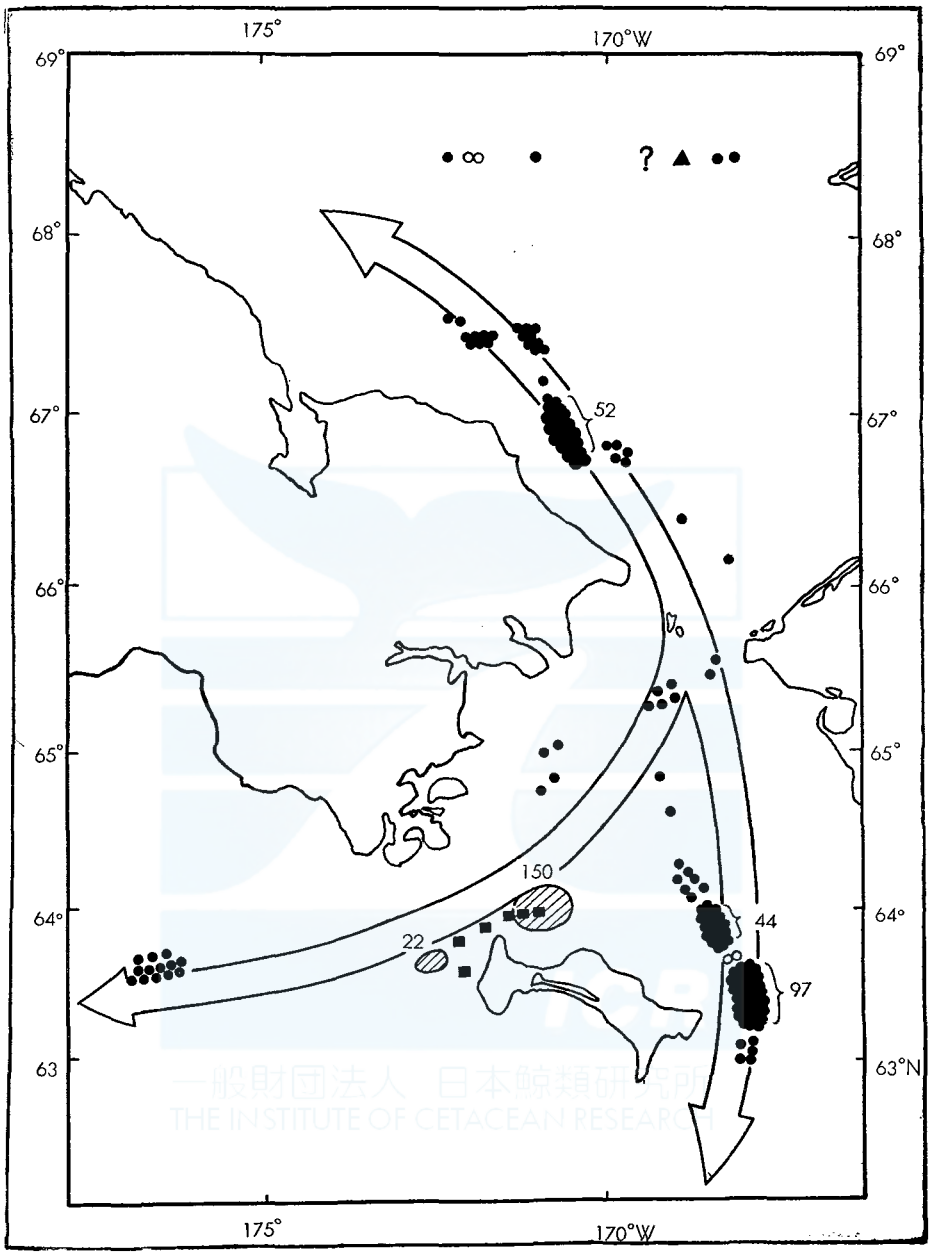

Fig. 11. Location of sighted whales.
Black circle—gray whale. White circle—right whale. Black triangle—fin whale. Question mark—unknown. Black square—sighted location on July 28th, 1957. Oblique line—sighted location on Aug. 2nd, 1955. (Black square and oblique line indicate the gray whales.)

author wishes to keep his opinion that there might be a migration route of the gray whales at the east of the St. Lawrence Island, too.

SUMMARY

1. The oceanographic and whales sighting survey in the Chukchi Sea was carried out from Aug. 16 to Aug. 20.
2. The water temperature at the sea surface indicates a trend to decrease from the east to the west. On the other hand, salinity shows its increase toward the west and its maximum area located at the central part of the Chukchi Sea. The salinity decreases from the maximum area to the the Siberian coast.
3. The cyclonic eddy seems to locate at near of 66°40′N, 170°W.
4. The vertical gradient of water temperatures are greater to the east and less to the west. The horizontal distribution of temperature at the surface layer decreases toward the west and increases toward the east, meanwhile in bottom layer below the 40 m depth, temperature increases from the east to the west.
5. The maximum values of density were found at the central part of the Chukchi Sea.
6. The horizontal distribution of dissolved oxygen at the sea surface shows the lower along the Alaskan waters and the higher along the Siberian waters.
7. The values of pH increased from the east to the west, and the isolines condensed closely at about 170°W longitude.
8. Marine productivity in the Chukchi Sea appears to increase in the western part and decrease in the eastern part.
9. During the season number of sighted whales are 1 fin whale, 2 right whales, 82 gray whales and 1 unknown whale.
10. The author wishes to keep his opinion that there might be a migration route of the gray whales at the east of the St. Lawrence Island, too.

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