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The oceanographical research in the Northeastern Pacific—II

Tomio HENMI*

Abstract

Oceanographical observation and biological research in the eastern boundary region of the North Pacific Ocean were carried out on the fisheries training and research ship "Keiten Maru" of Kagoshima University from June to July, 1976.

When the present results are compared with those obtained last winter (1975), some differences are found in the oceanic characteristics and the distribution of zooplankton, as summarized follows.

1) In the subsurface water layer, the thermocline can be well observed, and it becomes gradually shallower in an easterly direction. The depth of the thermocline was shallower during this summer than during last winter, though the vertical gradient of the thermocline did not show a remarkable difference.

2) The appearance of a short-time-scale-upwelling around 136°W was suspected during the summer.

3) The remarkable transition zone of salinity was observed around 128°W.

4) Based on a study of each temperature-salinity diagram a discussion of the characteristics of the water masses is given. The temperature-salinity diagrams of this region were divided into five groups this summer, and three groups last winter.

5) The main current axis in the meso-scale eddies of the western waters shifted to the east about 200 miles compared with that of last winter and the maximum-flow-speed was far less in the summer than that observed last winter. The main current axis in the region of the California Current is almost in the same place but the maximum-flow-speed was somewhat slower this summer than that observed last winter.

6) Of the total number of zooplankton in this region *Copepoda* were in the majority followed by *Ceratium*. The gross number of occurence of zooplankton, especially *Copepoda*, was smaller in the summer than in the winter. On the other hand, it is pointed out that *Ceratium* and Appendicularia were more abundant in the summer than last winter throughout this region.

1. Introduction

It is well known that high marine productivity among such species as tuna, marlin, skipjack and sardine in the eastern North Pacific Ocean (especially off the coast of California) is caused by the upwelling of water masses. The circulation and upwelling in this region have been studied by many oceanographers: Sverdrup and Fleming (1941)[1], Wooster and Reid (1963)[2], Tibby (1941)[3], Munk (1950)[4], Roden (1971)[5] and Yoshida (1955[6], 1967[7]).

As part of the university student training program, oceanographical observation

* Training ship Keiten maru, Faculty of Fisheries, Kagoshim University.

and biological research of the tuna fishing grounds were carried out on the training ship "Keiten Maru" of the Kagoshima University in the upwelling region of the eastern North Pacific Ocean from Dec. 1974 to Feb. 1975. Those results were presented in a previous paper[8] (Henmi 1976).

The author of the present paper carried out oceanographical observation and biological research on the Keiten Maru from Jun. to July, 1976 in the same region of the eastern North Pacific Ocean.

The general features of the oceanic condition and the distribution of zooplankton in this region are discussed by comparison with the previous paper. The present paper is concerned with a report of the main results.

The author wish to express their sincere thanks to Prof. Yoshida of Tokyo University for many helpful discussion and suggestions concerning this work and to the crew of the Keiten Maru for their skillful handling of the ship during our research.

2. Materials and Methods

The oceanographical research was made on the Keiten Maru (G. T. 860 ton), the

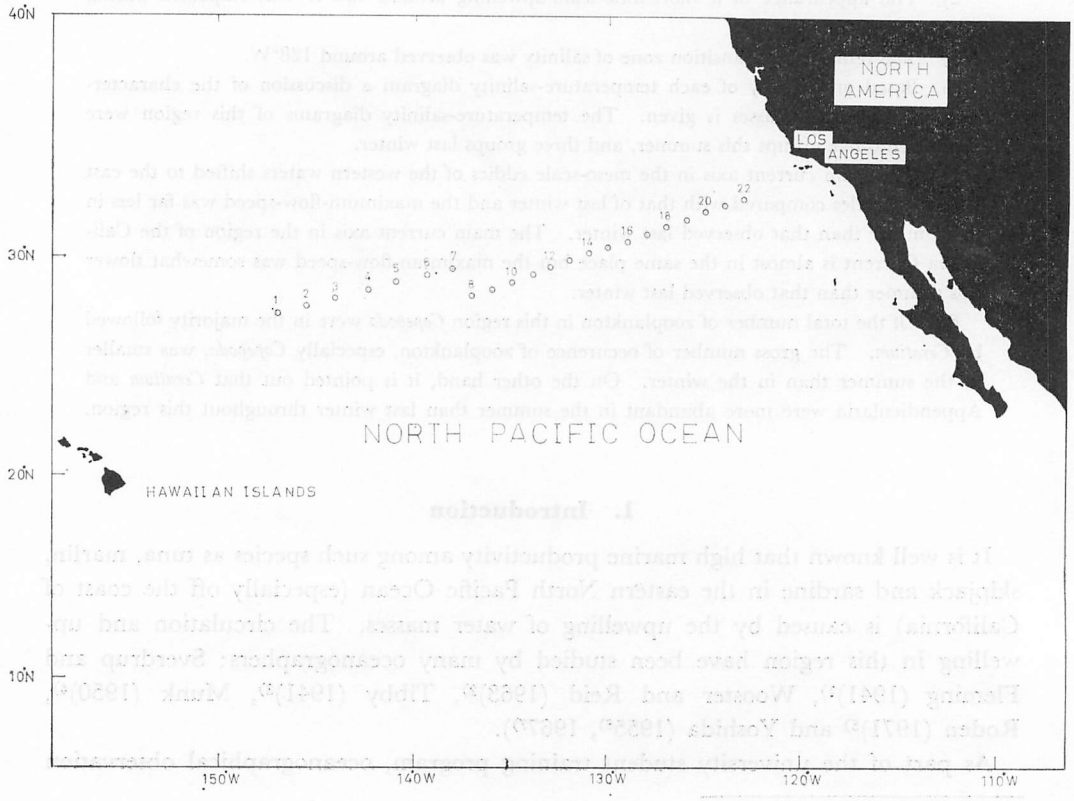


Fig. 1. Map showing the oceanographic stations by the S.T.D. system and collections of plankton.

fisheries training and research ship, Faculty of Fisheries, Kagoshima University, in the eastern boundary region of the North Pacific Ocean.

The first series of the observation were made in the northeast area of the Hawaiian Islands (Lat. 27°N–29°N, Long. 138°W–147°W) from June, 1, to 11, 1976 and the second series, off the coast of California (Lat. 28°N–32°N, Long. 123°W–137°W) from June, 30, to July, 3, 1976.

The observational stations are shown in Fig. 1. The first observation point will hereafter be referred to as the western waters and the second series, as the eastern waters. The oceanographical data were obtained with S. T. D. (Plessy Model 9040) and zooplankton were collected with Marutoku net (45 cm in mouth diameter, 100 cm in length, bolting silk net GG 54).

The methods of the oceanographical observation and the sampling of zooplankton were quite similar to those reported in the previous paper. The representative traces for water-temperature and for salinity in the western waters and in the eastern waters are shown in Fig. 2, (a), (b), (c), (d), (e) and (f).

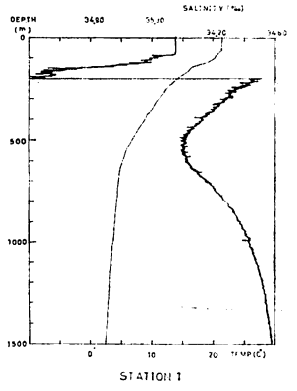


Fig. 2. (a)

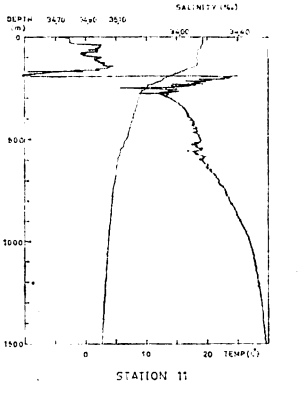


Fig. 2. (b)

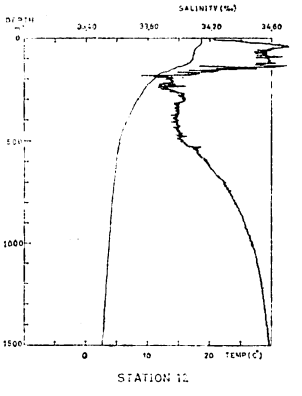
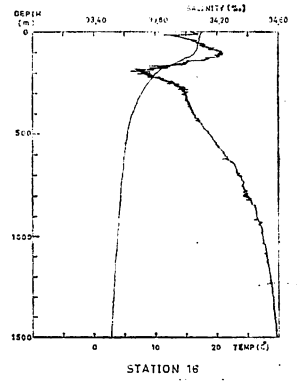


Fig. 2. (c)



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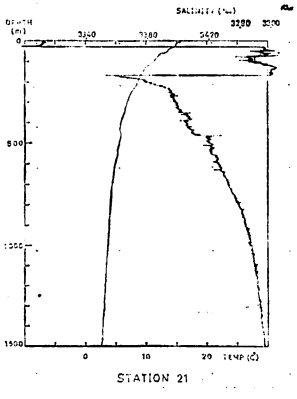

Fig. 2. (e)

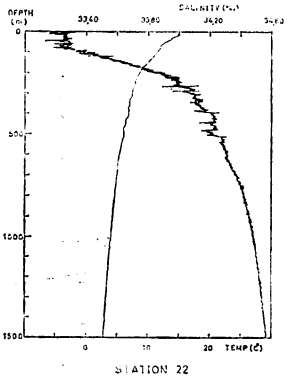

Fig. 2. (f)

Fig. 2. The S. T. D. traces for temperature and for salinity, an example.

The values of temperature and salinity at each station were summarized in Table 1 and the individual number of zooplankton in one cubic meter was tabulated in Table 2.

3. Results and Discussions

(1) The vertical distribution of water temperature and salinity

The vertical distribution of water temperature in the western waters and the eastern waters are shown in Fig. 3, (a), (b).

It is indicated in Fig. 3, (a), (b) that the value of the water temperature of the surface water at 147°W and 123°W were 21.4°C, 15.1°C respectively. The water temperature of the surface water became lower as the continental coast is approached from offshore. The depth of the thermocline was at the depth of 100m–200m between from 138°W to 147°W and became shallower eastward from 136°W.

The vertical gradient of the thermocline is 6°C/100m around 146°W and 7°C/100m around 136°W. This may not seen to be a remarkable difference. A remarkable peak of the isotherms found at the depth of 100m around 136°W seems to be indicative of the existence of an upwelling. During the observation period, an easterly wind was predominant. It was not clear that the upwelling phenomenon around

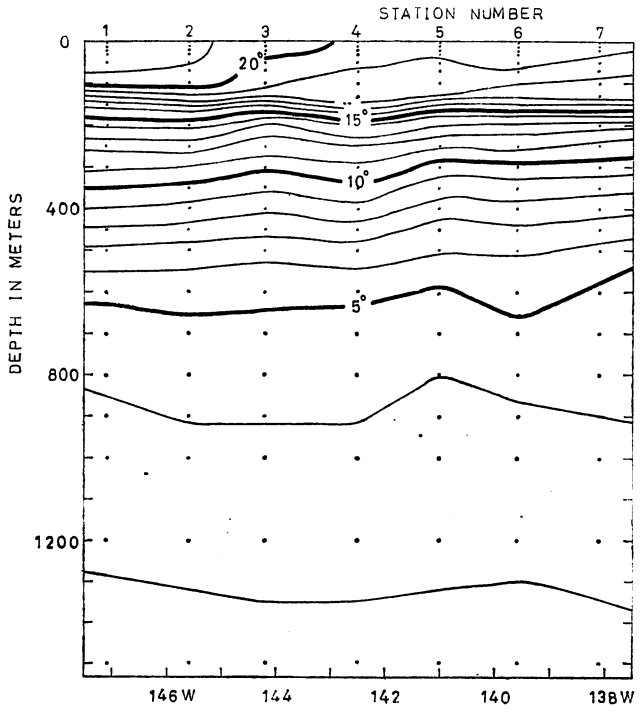

Fig. 3. (a)

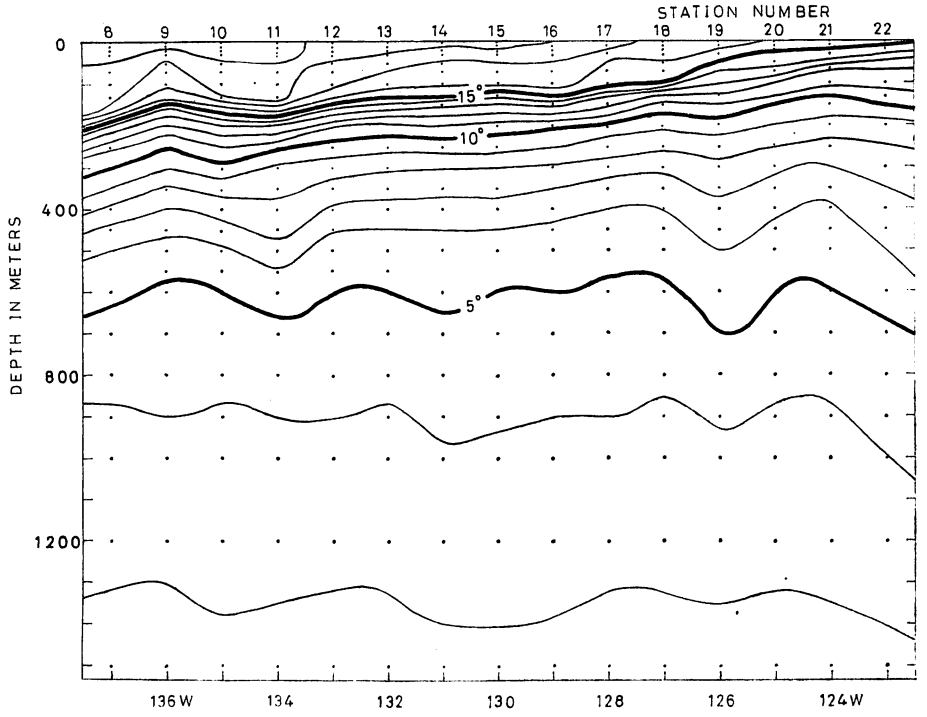

Fig. 3. (b)

Fig. 3. Vertical distribution of temperature along the latitude of 27°N-29°N, between 138° W and 147°W, (a) and along the latitude of 28°N-32°N, between 123°W and 137°W, (b).

136°W was due to these winds; but the phenomenon may be supposed to be a short-time-scale upwelling similar to the phenomenon of the upwelling around 128°W in the research of last winter.

In general, the water temperature of the surface water was highest in the western waters and lowest in the eastern waters but the horizontal inclination of the water temperature was smaller in the summer of 1976 than that in the winter of 1975. It seems that the depth of the thermocline was shallower in the summer of 1976 than that in the winter of 1975, though the vertical gradient of the thermocline did not show any remarkable difference according to the seasons or years. The slope of isotherms below the 600m depth was more undulating in the summer of 1976 than that in the winter of 1975, which may suggest the aspect of the fluctuation of the North Pacific subarctic intermediate water.

The vertical distribution of salinity in the western waters and the eastern waters are shown in Fig. 4, (a), (b).

Regarding vertical distribution of salinity (Fig. 4, a, b), an area of the surface water with a salinity lower than 33.50‰ extends from the east to around 128°W in the surface layer and saline water with a salinity exceeding 35.00‰ was found around 143°W.

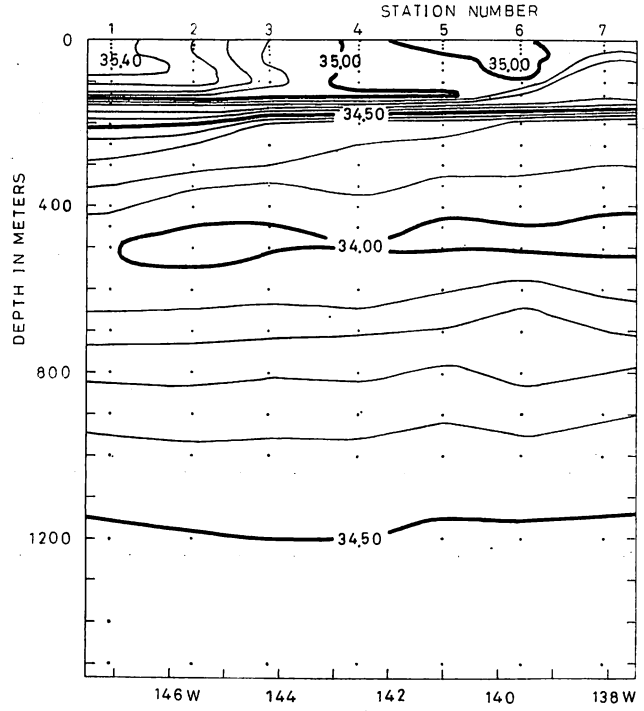

Fig. 4. (a)

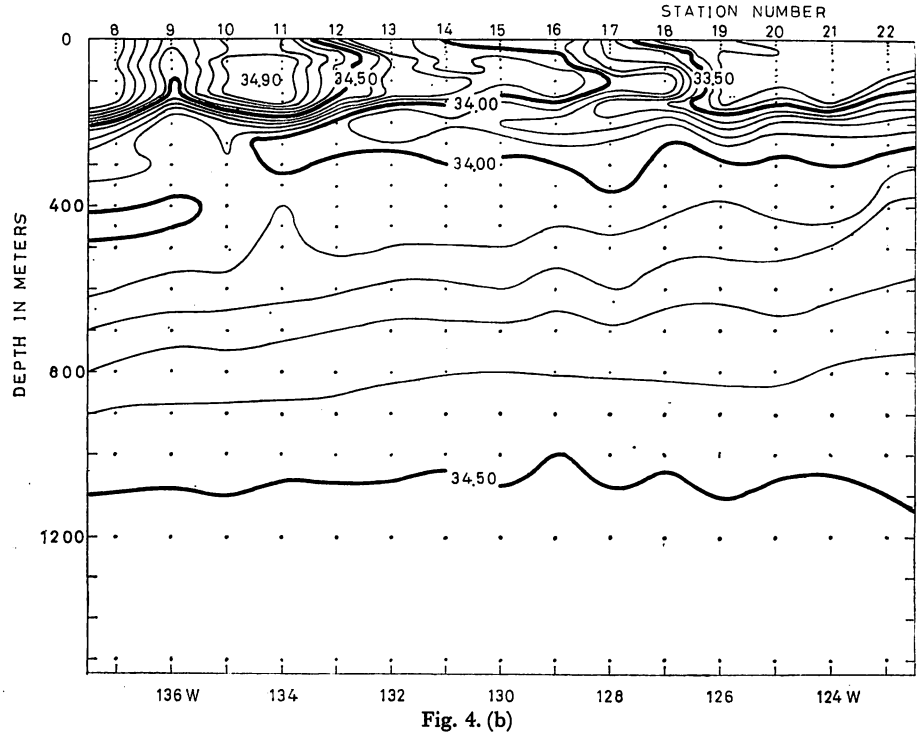

Fig. 4. (b)

Fig. 4. Vertical distribution of salinity along the latitude of 27°N-29°N, between 138°W and 147°W, (a) and along the latitude of 28°N-32°N, between 123°W and 137°W, (b).

The surface water with a salinity of 34.90‰ is found in the region 134°W–135°W, forming a remarkable transition zone of salinity to the higher salinity water around 129°W. The transition zone corresponds almost exactly to the abovementioned upwelling and it was found that the vertical mixing of the water masses is distinguished.

The numerical value of salinity gradually decreases toward the east and the saline water with salinity higher than 34.00‰ is stretched out as far as 131°W–127°W. The transition zone of salinity is formed of saline water and lower salinity water which originates in the subarctic water in the region of the California Current. The remarkable peak of the isohalines at a depth of about 300 m around 127°W may suggest the existence of an upwelling of the North Pacific intermediate water. At a depth of about 300 m, it may be seen that the aspect of the slope of isotherms is almost similar to the slope of isohalines.

In the research of last winter, the remarkable transition zone was formed around 128°W but it was found to be somewhat to the east in this research. This zone was also described at the same position in the vertical distribution of salinity in the report by Roden (1969). It is considered that during the year, irrespective of the season, the transition zone is formed from the saline water of the eastern North Pacific Central water which originates in the North Pacific Current and the low salinity water originating in the California Current. It is obscure, however, what the cause of the abovementioned phenomenon is.

(2) Temperature-salinity relation

The representative tempreature-salinity diagram in the region of the eastern North Pacific Central water and the diagram of the water in the region of the California Current are drawn making use of the NORPAC DATA (1955)[9] and the DATA of SVERDRUP. The former is hereafter to be referred to as the Cn-water type and the latter, as the Ca-water type, respectively.

From data collected during the summer and last winter, temperature-salinity diagrams were drawn. The characteristics of the water masses are discussed and compared with the abovementioned two water types. As a result of this study, the temperature-salinity diagram are divided into five groups for the summer period and three groups for the winter period, shown in Fig. 5 and Fig. 6 respectively.

1. The first group (Fig. 5, a)

This group is found in the region of Lat. 27°N–29°N, Long. 142°W–147°W and almost similar to the Cn-water type. It is seen that the aspect of high salinity is found in the layer at the depth of about 300m. The intermediate water at a depth of about 500m may be recognized as the North Pacific subarctic intermediate water having 6.5°C in temperature and 34.00‰ in salinity.

2. The second group (Fig. 5, b)

This group is found in the region of Lat. 28°N–30°N, Long. 134°W–141°W. The temperature-salinity diagram is almost similar to Cn-water but the comparatively low

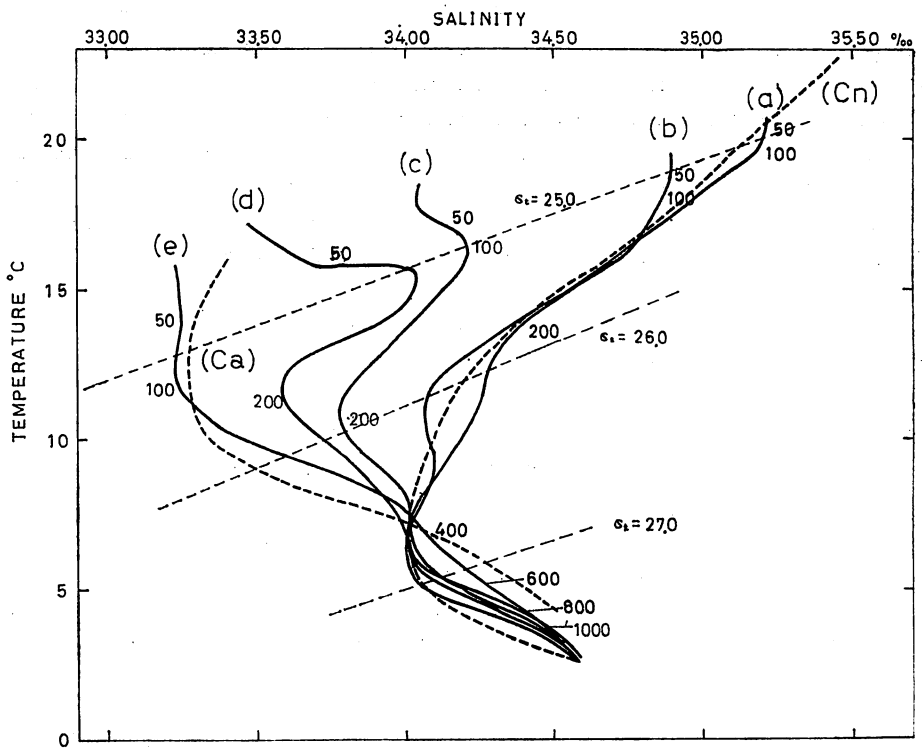

Fig. 5. Average T-S curves in the eastern North Pacific Ocean in summer of 1976. Cn, eastern North Pacific Central water mass; Ca, California Current water mass.

temperature and low salinity water is found in the layer from the surface to a depth of 150m. It is seen that the lower salinity water is found at a depth of about 200m and 450m. The lower salinity in the layer at the depth of about 450m corresponds almost exactly to the minimum salinity of the Cn-water.

3. The third group (Fig. 5, c)

This group is found in the region of Lat. 29°N–30°N, Long. 129°W–132°W and the numerical value of the temperature and salinity in the surface layer is lower than that of the Cn-water. The temperature-salinity diagram shows quite a difference to the second group; i. e. the numerical value of salinity in the surface layer is lower than that of the second group. Saline water with a salinity of 34.20‰ is found in this layer at the depth of about 100m and lower salinity water is found in the layer at the depth of 200m and it is 0.25‰ lower than that of the lower salinity in the second group. It may be considered that the type of this temperature-salinity diagram indicates on the plane of relation an equivalent rate of mixture of both the Cn-water and the Ca-water. It is not clear that a remarkable intermediate water layer exists at the depth of about 500m in the second group.

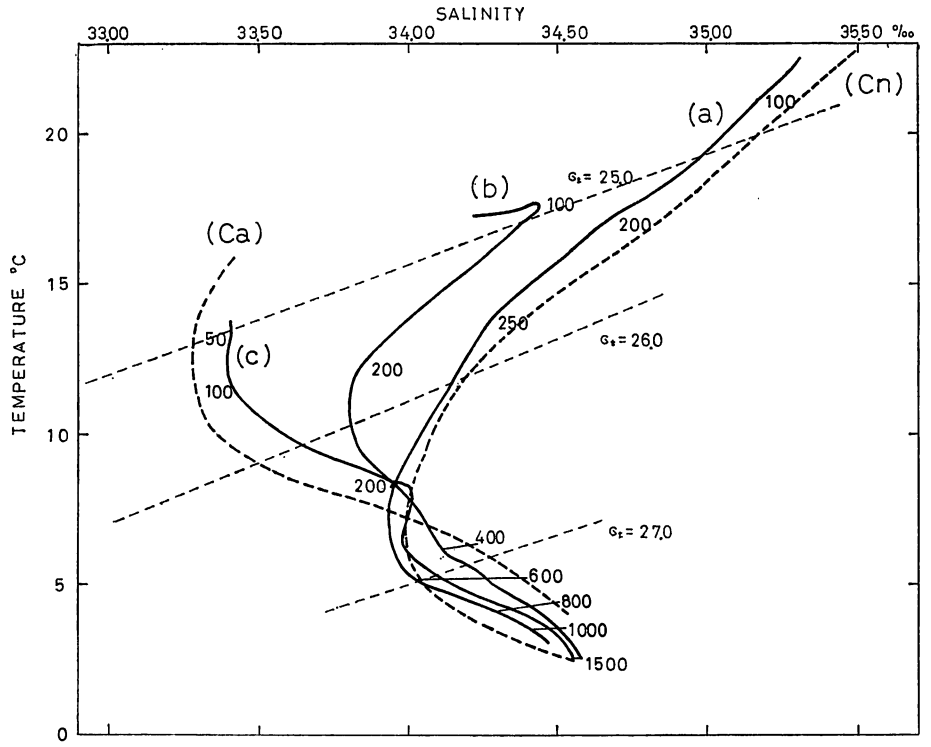

Fig. 6. Average T-S curves in the eastern North Paeific Ocean in winter of 1975. Cn, eastern North Paeific Central water mass; Ca, California Current water mass.

4. The fourth group (Fig. 5, d)

This group is found in the region of Lat. 31°N, Long. 127°W–128°W. The numerical value of salinity in the upper layer above the depth of 150m is lower than that of the third group and it is 0.60‰ lower at the surface, 0.20‰ lower at the depth of 100m and 200m respectively. It may be considered that this diagram suggests the existence of a transition zone of salinity, which is found around 127°W as stated above (chapter 2).

5. The fifth group (Fig. 5, e)

This group is found in the region of Lat. 31°N–32°N, Long. 123°W–126°W. The type of temperature-salinity diagram corresponds almost exactly to that of Ca-water.

As indicated in Fig. 6, (a) the first group of temperature-salinity diagram of last winter is found in the region of Lat. 26°N–28°N, Long. 140°W–150°W and corresponds almost exactly to the Cn-water type. The numerical value of salinity in the upper layer above the depth of 300m is somewhat lower than that of Cn-water. It is found that North Pacific subarctic intermediate water exists at the depth of about 500m. The type of this temperature-salinity diagram is almost similar to the water

type of the first group. (Fig. 5, a)

The second group (Fig. 6, b) of temperature-salinity diagrams from last winter is found in the region of Lat. 31°N, 128°W–129°W. The numerical value of the temperature and salinity in the surface layer is lower than that of Cn-water. It is seen in this figure that a comparatively high salinity of 34.45‰ is found at the depth of 100m and the lower salinitys exist at the depth of 250m and 500m respectively. The lower salinity at the depth of 500m seems to be indicative of the existence of subarctic intermediate water. This type of temperature-salinity diagram is equal to the water type of the third group. (Fig. 5, c)

The third group of temperature-salinity diagrams from last winter (Fig. 6, c) is found in the region of Lat. 31°N–32°N, Long. 123°W–127°W. It is recognized that the aspect of low temperature and high salinity is seen in the upper layer above the depth of 200m, though the temperature-salinity diagram is about the same as the Ca-water type. The type of this temperature-salinity diagram is almost similar to the water type of the fifth group. (Fig. 5, e)

(3) Southward and northward flow

The distribution of south-north component of geostrophic current referred to 1,500m depth in the western waters and the eastern waters of the eastern North Pacific Ocean are shown in Fig. 7, (a), (b) and their transport volumes are listed in Table 3.

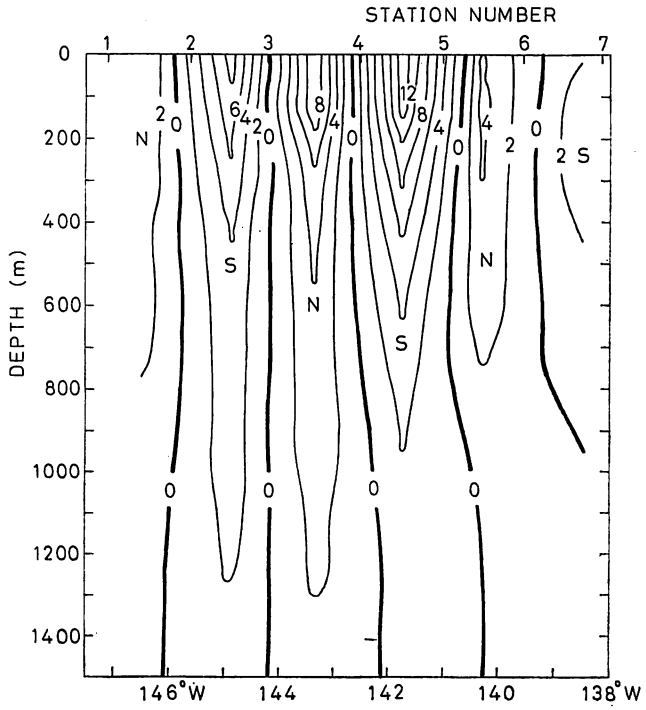

Fig. 7. (a)

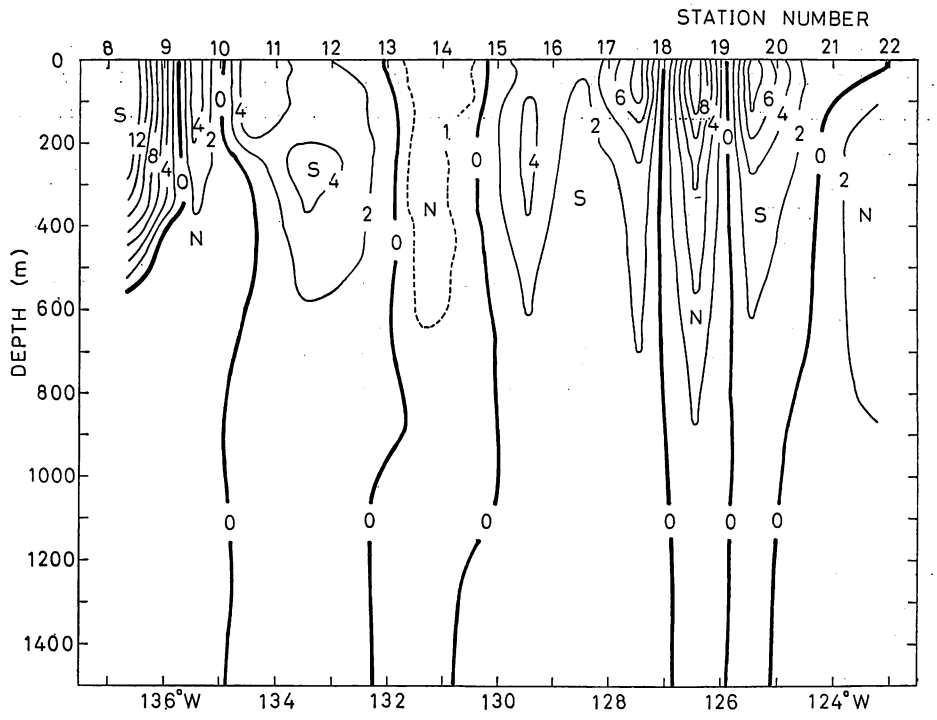

Fig. 7. The north-south component (cm/sec) of calculated relative current velocity referred to 1,500m; (a) along the latitude of 27°N-29°N, between 138°W and 147°W, (b) along the latitude of 28°-32°N, between 123°W and 137°W

Table 3. Values of the current velocity and the transport of component of geostrophic current in the eastern North Pacific Ocean.

	Position of current axis (Long. W)	South-North component	Current velocity (cm/sec)	Transport ($10^5 m^3$/sec)
	144°–50′W	South	9	49.7
Western	143°–30′W	North	10	53.1
Waters	141°–30′W	South	14	67.0
	140°–20′W	North	5	34.3
	135°–30′W	North	6	26.8
	134°–20′W	South	6	63.8
Eastern	121°–20′W	North	2	17.3
Waters	127°–30′W	South	9	71.9
	126°–30′W	North	12	36.3
	125°–30′W	South	9	33.1

In the western waters, the component of the direction of the current shows the alternate distribution of the south and north components. This is considered to be indicative of the irregular meso-scale eddies. Such as stated in the previous paper, these eddies exist in this region all the time, though it has not been established wheth-

er these eddies are caused by the wind-spun vortex accompanied with the subtropical gyre in the eastern boundary region of the eastern North Pacific Ocean or those caused from the topographical effect of Hawaiian Islands or those due to baroclinic instability. It seems that the scale and the situation vary very much, irrespective of the season.

The main current axis is situated around 141°–30′W in the southward flow and around 143°–30′W in the northward flow. The maximum speed of the southward flow is higher than that of northward flow. The numerical value of the maximum speed of the southward flow and the northward flow are ca 14 cm/sec, 10 cm/sec and the volume transport of the southward component and the northward component are ca 67.0×10^5 m^3/sec, 53.1×10^5 m^3/sec respectively.

The current axis of the southward flow shifts to east about 200 miles compared with that of last winter. The maximum speed observed this summer is far slower than that observed last winter.

In the region of the meso-scale eddies around Lat. 24°N–29°N, Long. 140°W–146°W, a comparison was made of the amount of the total transport of the water masses for this summer, ca 20.4×10^6 m^3/sec; for last winter, ca 36.7×10^6 m^3/sec; and of that reported by SVERDRUP et al. (1937), ca 24.3×10^6 m^3/sec. It is shown that the amount of the total transport of water masses for the last winter was comparatively larger than for the other two.

In the eastern waters, the North Pacific Current is blocked by the west coast of the North American Continent causing the southward flow of the California Current; however the northward flow that accompanies the California Current is a portion of the local eddies turning in a clockwise direction and seems to nearly correspond to the phenomenon of the thermocline spread. (Fig. 3, b)

The current axis of the southward flow is situated around at 127°–30′W and 125°–30′W. The numerical value of the maximum speed of the southward flow is ca 9 cm/sec and the volume transport of the southward component is ca 71.9×10^5 m^3/sec and ca 33.1×10^5 m^3/sec respectively. The current axis of the northward flow is situated around 126°–30′W and the numerical value of the maximum speed of the northward flow is ca 12 cm/sec and the volume transport of the northward flow is ca 36.3×10^5 m^3/sec. The current axis of the southward flow and northward flow are almost similar to those observed last winter but the maximum speed of the current is somewhat slower than those investigated last winter.

In the region of the California Current around Lat. 30°N–33°N, Long. 124°W–130°W, a comparison was made of the amount of the total transport of the water masses for this summer, ca 14.1×10^6 m^3/sec; for last winter, ca 26.4×10^6 m^3/sec; and of that reported by SVERDRUP et al. (1937), ca 22.1×10^6 m^5/sec.

Similar to the total transport in the region of the meso-scale eddies, this comparison shows that the total transport of last winter has a tendency to be larger than that of the others.

Based on our observation, it seems that the circulation of water masses in the east-

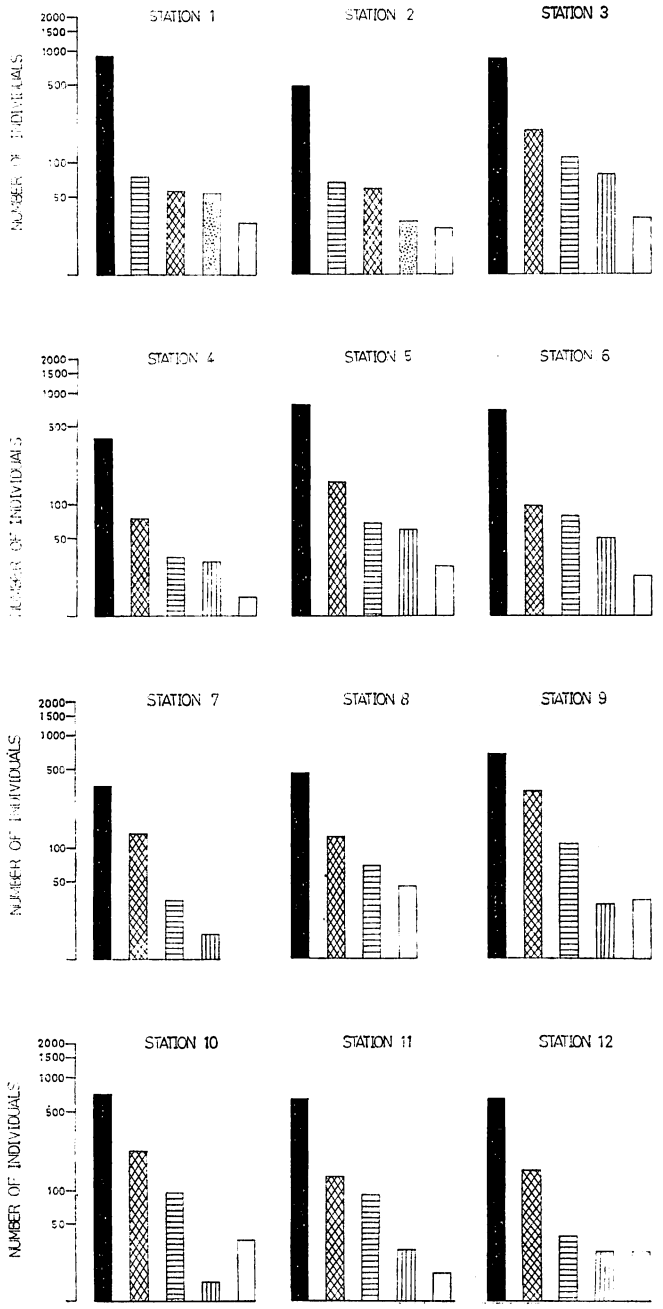

Fig. 8. Occurrence of the estimated number of zooplankton organisms per cubic meter of sea water at each station.

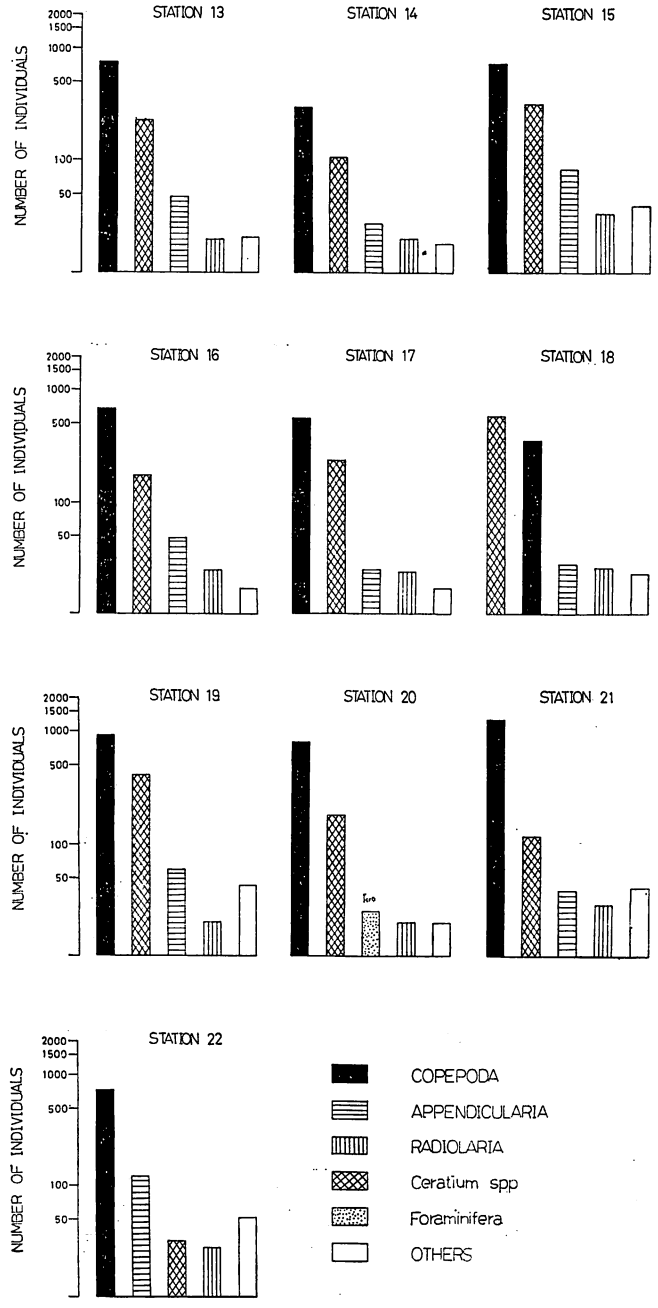

Fig. 8. (Continued)

ern North Pacific Ocean is comparatively somewhat better in winter than in summer.

It is not clear whether the difference of the total transport is caused by the method of taking the motionless surface in the Dynamic calculation, by the geographical difference of the observation point, or due to the data used in this paper, which may exhibit certain seasonal and annual variations.

(4) Distribution of zooplankton

The distribution of zooplankton in the eastern North Pacific Ocean is shown in Fig. 8.

The zooplankton communities in this region are representative of *Copepoda, Ceratium, Appendicularia, Radiolaria, Foraminifera. Copepoda* occupies the greater part, next one is *Ceratium* and the rate of the number of occurence are about 70%, 20% in total individual number in this region. *Chaetognatha, Polychaeta, Ostracoda, Thaliacea* have a wide range but the number of individuals is very few. The total number of zooplankton varied from about 460 to 1,500 individuals per cubic meter.

The eastern North Pacific Ocean may be divided into three major salinity zones: the water mass (137°W–147°W) of high salinity with higher than 35.00‰ in salinity; the water mass (129°W–136°W) of 34.00‰–34.90‰ in salinity; the water mass of low salinity with less than 33.50‰ in salinity. The average number of occurence in each water mass is 843 individuals in the first group, 974 individuals in the second one and 1139 individuals in the third one respectively. It seems to be the tendency for the number to increase in the lower salinity water in this region.

When a comparison of the total number of zooplankton per cubic meter found this summer and that found last winter is made, it is found that the total number of zooplankton is not remarkably different in the water mass with high temperature and high salinity water at Lat. 27°N–29°N, Long. 141°W–147°W but the number decreases sharply in the water mass with low temperature and low salinity water at Lat. 31°N–32°N, Long. 123°W–127°W. This area is especially characterized by a very low individual number of *Copepoda. Copepoda* were greater in total number last winter than this summer and the individual number of *Ceratium, Appendicularia* were very few but it is pointed out that *Ceratium, Appendicularia* were more abundant this summer than was observed last winter throughout in this region.

It is obscure whether these phenomena are caused by an abundance of nutrient-salts in the cold water flowing from a relatively high latitude to the South, or by upwellings occurring in many places or by a deficient supply of nutrient-salts from below because the surface water had become stable vertically.

4. Summary

The oceanographical research in the eastern North Pacific Ocean was carried out, in the winter season from Dec., 1974 to Feb., 1975 and in the summer season from June to July, 1976 again. The results obtained are summarized as follows:

(1) In the subsurface layer, the thermocline can well be identified and it become

gradually shallower in an easterly direction. The depth of the thermocline was shallower in the summer than in the winter, though the vertical gradient of the thermocline did not show any remarkable difference.

(2) The appearance of a short-time-scale upwelling around 136°W was suspected in the summer, though it was found around 128°W last winter.

(3) The remarkable transition zone of salinity was observed around 128°W.

(4) The temperature-salinity diagrams in this region are divided into five groups in the summer, and three major groups last winter; i. e. they can be classified as the California Current zone, the eastern North Pacific Central water zone and the mixing zone of both water as stated above.

(5) The main current axis was situated around 141°–30′W in the western waters and around 127°–30′W in the eastern waters and the maximum-flow-speeds were 14 cm/sec and 9 cm/sec, respectively. The main current axis shifted to the east about 200 miles in the western waters but was at almost same place in the eastern waters. The maximum-flow-speed is far less in the western waters and somewhat less in the eastern waters compared with that observed last winter.

(6) *Copepoda* exists in greater numbers, next is *Ceratium*. The rate of the number of occurence was about 70%, and 20% in total individual number in this region. *Radiolaria, Foraminifera, Ostracoda* and *Thaliacea* occurred very widely, though the number of individual was very small. The gross number of zooplankton is not remarkably different in the western waters but it decreases very greatly in the eastern waters, especially the individual number of *Copepoda* is very small. *Ceratium, Appendicularia* were more abundant in the summer than in the winter throughout this region.

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Table 1. S. T. D. data at each observing station.

Depth	Station 1 Lat. 27°-26′.0N Long. 147°-07′.2W Jun. 1. 1976 Temp. (°C)	Salinity (‰)	Station 2 Lat. 27°-47′.5N Long. 145°-37′.4W Jun. 2. 1976 Temp. (°C)	Salinity (‰)	Station 3 Lat. 28°-22′.2N Long. 144°-11′.2W Jun. 3. 1976 Temp. (°C)	Salinity (‰)
1	21.4	34.45	21.3	35.28	20.1	35.10
10	21.4	34.45	21.3	35.28	20.1	35.09
20	21.4	34.45	21.3	35.28	20.1	35.09
30	21.4	34.45	21.3	35.30	20.1	35.09
50	21.3	34.45	21.2	35.34	20.0	35.08
70	21.2	34.45	21.0	35.38	19.6	35.12
100	20.4	35.32	20.7	35.37	19.5	35.05
130	18.3	35.15	19.7	35.16	19.0	35.03
150	16.4	34.81	18.1	34.85	17.6	34.82
200	14.2	34.54	15.1	34.52	13.7	34.27
250	12.3	34.35	12.8	34.29	11.8	34.25
300	11.2	34.28	11.3	34.24	10.7	34.21
350	10.0	34.21	10.0	34.11	9.4	34.09
400	8.9	34.13	8.9	34.06	8.6	34.09
450	7.8	34.05	7.7	34.00	7.4	34.00
500	6.8	34.01	6.8	33.96	6.6	33.99
600	5.2	34.03	5.4	34.04	5.4	34.06
700	4.5	34.16	4.7	34.17	4.7	34.18
800	4.2	34.28	4.2	34.27	4.3	34.29
900	3.8	34.37	3.9	34.36	4.1	34.36
1000	3.6	34.43	3.7	34.42	3.8	34.43
1200	3.2	34.52	3.2	34.51	3.3	34.50
1500	2.5	34.58	2.6	34.56	2.7	34.56

Depth	Station 4 Lat. 28°-40′.0N Long. 142°-31′.8W Jun. 4. 1976 Temp. (°C)	Salinity (‰)	Station 5 Lat. 28°-48′.8N Long. 141°-01′.8W Jun. 5. 1976 Temp. (°C)	Salinity (‰)	Station 6 Lat. 29°-22′.6N Long. 139°-34′.2W Jun. 6. 1976 Temp. (°C)	Salinity (‰)
0	19.8	34.99	19.9	35.03	19.5	35.01
10	19.8	34.98	19.8	35.04	19.5	35.02
20	19.8	34.99	19.0	35.03	19.5	35.02
30	19.7	34.98	19.0	35.00	19.5	35.05
50	19.3	34.97	19.0	34.94	19.4	35.06
70	18.8	34.97	18.6	34.91	18.8	35.08
100	18.6	34.93	18.7	34.91	18.0	34.95
130	18.9	35.07	17.9	35.07	17.5	34.76
150	18.1	34.80	15.7	34.70	15.8	34.71
200	14.2	34.20	12.8	34.24	12.5	34.08
250	12.2	34.21	11.2	34.18	11.3	34.18
300	10.8	34.17	9.3	34.13	9.7	34.15
350	9.8	34.14	8.5	34.08	8.5	34.04
400	8.7	34.06	7.5	34.03	7.7	34.04
450	7.7	34.01	6.5	33.98	6.8	34.00
500	6.7	34.00	6.1	33.99	6.1	33.98
600	5.2	34.02	4.8	34.09	5.4	34.14
700	4.6	34.19	4.3	34.21	4.8	34.26
800	4.3	34.28	4.0	34.32	4.2	34.27
900	4.0	34.37	3.8	34.39	3.9	34.37
1000	3.8	34.42	3.6	34.44	3.6	34.43
1200	3.3	34.50	3.2	34.52	3.2	34.52
1500	2.7	34.56	2.7	34.57	2.6	34.58

Table 1. (Continued)

Depth	Station 7 Lat. 29°-23′.9N Long. 138°-05′.0W Jun. 11. 1976 Temp. (°C)	Salinity (‰)	Station 8 Lat. 28°-11′.1N Long. 137°-01′.3W Jul. 3. 1976 Temp. (°C)	Salinity (‰)	Station 9 Lat. 28°-25′.7N Long. 136°-02′.7W Jul. 3. 1976 Temp. (°C)	Salinity (‰)
0	19.3	34.89	19.8	35.05	19.3	34.62
10	19.3	34.90	19.7	35.04	19.1	34.59
20	19.3	34.91	19.7	35.04	19.1	34.59
30	19.0	34.90	19.7	35.04	19.0	34.55
50	18.4	34.79	19.4	34.99	18.2	34.49
70	18.2	34.69	18.9	35.00	17.3	34.46
100	17.8	34.76	18.8	35.07	17.1	34.50
130	17.7	34.73	18.6	35.05	17.0	34.51
150	15.8	34.67	18.5	35.06	16.0	34.32
200	12.2	34.05	15.1	34.39	12.5	33.96
250	10.7	34.03	12.1	34.12	10.5	34.00
300	9.5	34.10	10.5	34.13	9.3	34.05
350	8.3	34.05	9.4	34.05	8.2	34.01
400	7.4	34.01	8.0	33.99	7.2	33.98
450	6.5	33.99	7.0	33.95	6.2	33.98
500	5.7	33.98	6.1	34.01	5.6	34.01
600	4.8	34.08	5.2	34.08	4.9	34.12
700	4.5	34.20	4.6	34.21	4.5	34.25
800	4.2	34.30	4.2	34.31	4.2	34.34
900	4.0	34.39	3.9	34.40	3.9	34.40
1000	3.8	34.45	3.7	34.46	3.7	34.45
1200	3.3	34.52	3.3	34.52	3.2	34.51
1500	2.7	34.57	2.7	34.57	2.6	34.57

Depth	Station 10 Lat. 28°-46′.1N Long. 134°-59′.8W Jul. 3. 1976 Temp. (°C)	Salinity (‰)	Station 11 Lat. 29°-05′.5N Long. 133°-57′.0W Jul. 3. 1976 Temp. (°C)	Salinity (‰)	Station 12 Lat. 29°-24′.0N Long. 133°-00′.0W Jul. 2. 1976 Temp. (°C)	Salinity (‰)
0	19.5	34.83	19.7	34.78	18.7	34.22
10	19.4	34.82	19.3	34.77	18.7	34.21
20	19.4	34.82	19.3	34.78	18.6	34.41
30	19.2	34.76	19.3	34.78	18.6	34.57
50	19.1	34.93	19.2	34.98	18.5	34.65
70	18.7	34.89	18.9	34.96	17.7	34.53
100	18.3	34.88	18.3	34.94	17.3	34.54
130	18.2	34.92	18.3	35.00	17.0	34.53
150	17.4	34.72	18.4	35.04	16.2	34.43
200	13.6	34.17	15.2	34.32	11.8	33.90
250	11.6	34.09	11.4	34.01	10.0	33.90
300	10.1	34.07	9.0	33.92	8.9	34.02
350	8.6	34.03	8.5	34.02	7.8	33.98
400	7.6	33.99	7.9	34.06	7.1	33.97
450	6.7	33.99	7.4	34.10	6.3	33.98
500	5.9	34.03	6.9	34.13	5.6	34.00
600	5.1	34.13	5.5	34.15	5.0	34.16
700	4.6	34.24	4.9	34.26	4.6	34.27
800	4.2	34.33	4.4	34.33	4.3	34.35
900	3.9	34.41	4.0	34.40	4.0	34.41
1000	3.7	34.45	3.8	34.46	3.7	34.46
1200	3.2	34.52	3.3	34.52	3.3	34.52
1500	2.7	34.56	2.7	34.57	2.7	34.57

Table 1. (Continued)

Depth	Station 13 Lat. 29°-44′.0N Long. 132°-00′.0W Jul. 2. 1976 Temp. (°C)	Salinity (‰)	Station 14 Lat. 30°-03′.5N Long. 130°-58′.5W Jul. 2. 1976 Temp. (°C)	Salinity (‰)	Station 15 Lat. 30°-18′.8 Long. 130°-02′.3W Jul. 2. 1976 Temp. (°C)	Salinity (‰)
0	18.6	34.14	18.4	34.00	18.3	33.97
10	18.5	34.14	18.0	34.00	18.3	33.97
20	18.5	34.14	17.7	34.02	18.1	33.87
30	17.8	34.12	17.6	34.05	17.8	34.06
50	18.0	34.29	16.8	34.07	17.3	34.13
70	17.7	34.29	16.5	34.03	16.6	34.07
100	16.8	34.20	16.4	34.24	16.3	34.14
130	16.6	34.28	14.8	34.20	14.8	33.95
150	15.2	34.06	13.3	34.02	13.5	33.84
200	11.8	33.71	11.0	33.88	10.7	33.82
250	9.6	33.83	9.7	33.98	9.5	34.00
300	8.8	34.01	8.0	34.00	8.3	33.98
350	7.7	33.98	7.2	33.98	7.5	33.97
400	6.9	34.00	6.7	34.03	6.7	34.01
450	6.2	34.02	6.1	34.06	6.2	34.03
500	5.6	34.08	5.6	34.10	5.7	34.08
600	5.0	34.21	5.2	34.22	4.9	34.19
700	4.6	34.30	4.8	34.32	4.6	34.30
800	4.3	34.37	4.4	34.39	4.3	34.39
900	4.0	34.42	4.2	34.46	4.1	34.43
1000	3.7	34.46	3.9	34.49	3.8	34.47
1200	3.3	34.52	3.4	34.54	3.4	34.52
1500	2.7	34.57	2.8	34.58	2.9	34.56

Depth	Station 16 Lat. 30°-37′.0N Long. 129°-05′.5W Jul. 2. 1976 Temp. (°C)	Salinity (‰)	Station 17 Lat. 30°-58′.7N Long. 128°-00′.5W Jul. 1. 1976 Temp. (°C)	Salinity (‰)	Station 18 Lat. 31°-16′.0N Long. 127°-00′.0W Jul. 1. 1976 Temp. (°C)	Salinity (‰)
0	18.3	34.02	17.7	33.61	16.8	33.32
10	18.3	34.03	17.6	33.60	16.8	33.32
20	17.8	33.89	17.4	33.63	16.8	33.49
30	17.3	33.94	17.1	33.63	16.7	33.61
50	17.9	34.03	16.3	33.67	16.1	33.64
70	16.9	34.10	15.7	33.68	15.6	33.77
100	16.8	34.19	15.7	33.90	15.8	34.03
130	16.2	34.17	14.8	33.84	14.4	33.88
150	14.9	33.98	12.9	33.57	11.9	33.59
200	11.2	33.68	10.4	33.71	9.7	33.85
250	9.4	33.87	8.9	33.90	8.6	34.00
300	8.2	33.98	7.9	33.99	7.0	33.98
350	7.3	33.99	6.9	33.97	6.9	34.00
400	6.5	34.02	6.3	34.00	6.2	34.04
450	5.9	34.07	5.7	34.06	5.8	34.11
500	5.5	34.12	5.4	34.11	5.5	34.14
600	5.0	34.22	4.8	34.18	4.9	34.24
700	4.6	34.32	4.5	34.29	4.6	34.32
800	4.2	34.38	4.3	34.37	4.2	34.38
900	4.0	34.44	4.0	34.43	3.9	34.43
1000	3.7	34.48	3.8	34.47	3.7	34.47
1200	3.3	34.53	3.3	34.52	3.3	34.53
1500	2.7	34.57	2.7	34.57	2.7	34.57

Table 1. (Continued)

Depth	Station 19 Lat. 31°-34′.0N Long. 126°-02′.0W Jul. 1. 1976 Temp. (°C)	Salinity (‰)	Station 20 Lat. 31°-56′.0N Long. 125°-01′.0W Jul. 1. 1976 Temp. (°C)	Salinity (‰)	Station 21 Lat. 32°-14′.2N Long. 124°-01′.4W Jun. 30. 1976 Temp. (°C)	Salinity (‰)
0	16.8	33.36	16.1	33.12	15.8	33.11
10	16.5	33.36	16.0	33.12	15.7	33.10
20	16.0	33.36	15.8	33.25	15.0	33.05
30	15.8	33.29	15.7	33.29	14.9	33.06
50	14.9	33.31	14.5	33.24	13.8	33.06
70	14.2	33.30	14.3	33.32	12.8	33.01
100	13.0	33.26	13.6	33.28	11.6	33.06
130	11.8	33.31	11.9	33.30	10.5	33.18
150	10.9	33.35	11.1	33.42	9.8	33.42
200	9.5	33.63	9.1	33.78	8.8	33.82
250	8.4	33.92	8.3	33.96	7.9	33.95
300	7.8	34.03	7.6	33.99	7.0	33.99
350	7.2	34.07	6.9	34.01	6.6	34.02
400	6.7	34.11	6.5	34.07	6.0	34.06
450	6.3	34.14	5.8	34.10	5.7	34.10
500	6.0	34.18	5.6	34.14	5.7	34.23
600	5.4	34.26	5.1	34.27	5.1	34.27
700	5.0	34.36	4.5	34.30	4.5	34.33
800	4.6	34.41	4.2	34.37	4.2	34.40
900	4.1	34.44	4.0	34.44	3.9	34.45
1000	3.8	34.48	3.7	34.47	3.7	34.48
1200	3.3	34.52	3.2	34.52	3.3	34.52
1500	2.7	34.58	2.7	34.57	2.7	34.57

Depth	Station 22 Lat. 32°-32′.0N Long. 123°-00′.0W Jun. 30. 1976 Temp. (°C)	Salinity (‰)
0	15.8	33.27
10	15.8	33.25
20	15.1	33.25
30	14.9	33.25
50	14.3	33.17
70	12.8	33.24
100	11.9	33.38
130	11.1	33.50
150	10.5	33.63
200	9.0	33.87
250	8.1	33.99
300	7.5	34.07
350	7.1	34.10
400	6.9	34.20
450	6.3	34.20
500	5.9	34.19
600	5.4	34.30
700	5.0	34.36
800	4.6	34.40
900	4.3	34.45
1000	4.0	34.47
1200	3.5	34.51
1500	2.8	34.56

Table 2. Occurrence of zooplankton at each collecting station.

Date	Jun. 1, 1976	Jun. 2, 1976	Jun. 3, 1976	Jun. 4, 1976	Jun. 5, 1976
Station No.	1	2	3	4	5
Latitude	27°–26′.0N	27°–47′.5N	28°–22′.2N	28°–40′.0N	28°–48′.8N
Longitude	147°–07′.2W	145°–37′.4W	144°–11′.2W	142°–31′.8W	141°–01′.8W
Radiolaria	19	17	78	31	60
Ceratium	56	59	119	75	156
Chaetognatha	2	1	3	1	2
Polychaeta	1	1	1	1	4
Ostracoda	1	4	1		1
Copepoda	895	481	832	393	764
Appendicularia	74	66	111	34	68
Thaliacea	5	2	1	2	4
Unidentified Organisms		1			
Foraminifera	53	30	26	11	17
Total	1106	662	1172	548	1076

Date	Jun. 6, 1976	Jun. 11, 1976	Jul. 3, 1976	Jul. 3, 1976	Jul. 3, 1976
Station No.	6	7	8	9	10
Latitude	29°–22′.6N	29°–23′.9N	28°–11′.1N	28°–25′.7N	28°–46′.1N
Longitude	139°–34′.2W	138°–05′.0W	137°–01′.3W	136°–02′.7W	134°–59′.8W
Radiolaria	50	17	16	31	25
Ceratium	96	138	122	312	224
Chaetognatha	1	1	1	2	2
Polychaeta	1	1	6	4	4
Ostracoda		1	1	3	4
Copepoda	692	352	455	667	715
Appendicularia	79	34	68	106	96
Thaliacea	2	2	5	6	5
Unidentified Organisms	1				1
Foraminifera	17	4	16	19	20
Total	939	550	690	1150	1096

Date	Jul. 3, 1976	Jul. 2, 1976	Jul. 2, 1976	Jul. 2, 1976	Jul. 2, 1976
Station No.	11	12	13	14	15
Latitude	29°–05′.0N	29°–24′.0N	29°–44′.0N	30°–03′.5N	30°–18′.8N
Longitude	133°–57′.0W	133°–00′.0W	132°–00′.0W	130°–58′.5W	130°–02′.3W
Radiolaria	29	28	20	20	34
Ceratium	133	155	227	104	318
Chaetognatha	2	1	1	4	4
Polychaeta	2	2	1	1	1
Ostracoda	14	7	4	3	5
Copepoda	649	661	759	299	731
Appendicularia	92	39	47	27	83
Thaliacea	8	5	2	1	1
Unidentified Organisms	2	1		1	
Foraminifera	4	12	14	8	29
Total	935	911	1075	468	1206

Table 2. (Continued)

Date	Jul. 2, 1976	Jul. 1, 1976	Jul. 1, 1976	Jul. 1, 1976	Jul. 1, 1976
Station No.	16	17	18	19	20
Latitude	30°–37′.0N	30°–58′.7N	31°–16′.0N	31°–34′.0N	31°–56′.0N
Longitude	129°–05′.5W	128°–00′.5W	127°–00′.0W	126°–02′.0W	125°–01′.0W
Radiolaria	25	24	26	20	10
Ceratium	173	234	584	418	182
Chaetognatha	4	3	2	5	2
Polychaeta	2	5	1	10	4
Ostracoda	11	2	8	9	3
Copepoda	683	553	356	921	812
Appendicularia	49	25	28	60	
Thaliacea	2		1	4	1
Unidentified Organisms					
Foraminifera	8	7	11	15	25
Total	957	853	1017	1462	1039

Date	Jun. 30, 1976	Jun. 30, 1976
Station No.	21	22
Latitude	32°–14′.2N	32°–32′.0N
Longitude	124°–01′.4W	123°–00′.0W
Radiolaria	29	28
Ceratium	119	32
Chaetognatha	10	11
Polychaeta	9	7
Ostracoda	3	4
Copepoda	1268	732
Appendicularia	39	121
Thaliacea	13	14
Unidentified Organisms		
Foraminifera	6	16
Total	1496	965