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The Oceanographical Research in the Southern Region of the Hawaiian Islands-II

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Abstract

Oceanographical observations and biological research in the southern region of the Hawaiian Islands were carried out on board the Keiten Maru from May to June, 1978.

When the present results are compared with those obtained last year (1977), some differences are found in the oceanic characteristics and the distribution of zooplankton, which are summarized as follows.

1) The numerical values of the temperature of the surface water are ca 26.0°C at 15°N, ca 26.9°C at 12°N and ca 27.7°C at 08°N, respectively. Though the numerical value of the temperature of the surface water is almost equal to that of 1977, it becomes somewhat higher northward from 12°N.

2) The thermocline exists in a layer at a depth of about 80 m-200 m around 14°N, about 50 m-140 m around 09°-30′N but was shallower than that in 1977. The vertical gradients of temperature in the thermocline are ca 0.10°C/m at 14°N, ca 0.13°C/m at 08°N, and less than that in 1977.

3) The numerical value of surface salinity is ca 34.60‰, and ca 0.20‰ lower than that in 1977. The salinity maximum, which was found in a layer at a depth of about 100 m around 14°-30′N in 1977, extended to the south from the north as far as 09°N in a layer between 90 m-125 m in 1978.

4) The first salinity minimum is found at a depth of about 250 m at 15°N and is the same as our research reported in 1977. The depth of the salinity minimum becomes gradually shallower as approaching to the equator from the north. The second salinity minimum, showing the Equatorial Pacific Water, is found at a depth of about 800 m.

5) The boundary between the North Equatorial Current and the Equatorial Countercurrent is recognized around 09°N and it seems to have shifted to the south compared with that in 1977.

6) The current axies of the eastward and westward flow are around 08°-45′N and 09°-30′N. The axis of the eastward flow shifts to the south about 100 miles compared with that in 1977 but the axis of the westward flow is almost the same as that in 1977.

The numerical value of the maximum velocity of the eastward and westward flow are ca 23 cm/sec and ca 33 cm/sec. These are somewhat higher than that in 1977.

The total flux of the eastward and westward flow are ca 8.0×10^6 m^3/sec and ca 19.3×10^6 m^3/sec. The total flux of the eastward flow is far larger than that in 1977 but the total flux of the westward flow is smaller than that in 1977.

7) The maximum value of the occurrence of zooplankton per cubic meter is 461 individuals at 10°N and the minimum value is 140 individuals at 13°N. The rate of the occurrence of *Copepoda, Radioioria, Ceratium* and *Appendicularia* is 53%, 16%, 11% and 10%, respectively. The individual number and the rate of occurrence of each one are almost equal to that in 1977.

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1. Introduction

It is well known that the region of the Equatorial Current becomes the favorite fishing ground for species such as yellowfin tuna and marlin because the surface water is rich in nutrients-salt and supports a higher plankton production in an area where the upwelling, convection and vertical mixing of the water mass are well developed by the trade winds.

Studies have been published concerning this region by many oceanographers: Graham (1941), Sverdrup, Johnson and Fleming (1942), Cromwell (1953), Montgomery (1954), Yoshida (1959), Montgomery and Stroup (1962), Knauss (1963), Masuzawa (1964, 1967), Reid (1965), Yamanaka *et al* (1965).

Oceanographical observation and biological research of the tuna fishing ground in the southern region of the Hawaiian Islands were carried out on board the Keiten Maru of Kagoshima University in May, 1977.
Those results were presented in the previous paper. (Yuwaki and Henmi, I978)

Oceanographical observations and biological research were carried out again on board the Keiten Maru in the same area from May to June, 1978.

Some information was gained on the general features of the oceanic condition and the distribution of zooplankton by comparing the results obtained this year with those reported in the previous paper. The results are reported here.

2. Materials and Methods

Oceanographical observations and biological research were carried out on board the training ship Keiten Maru (G.T 860 tons) of Kagoshima University between 08°N and 15°N along the meridian of 158°W in the southern region of the Hawaiian Islands from May to June, 1978.
The observation points are shown in Fig. 1.

The oceanographical data was obtained by using a S.T.D. system (Plessy Model 9040). Zooplankton was collected with a Marutoku Net (45 cm in mouth diameter, 100 cm in length silk net G.G. 54).

The methods of oceanographical observation and of sampling zooplankton are quite similar to those reported in the previous paper (Henmi, 1976). The depth-temperature-salinity data at each station are tabulated in Appendix Table 1 and the individual number of zooplankton per cubic meter are tabulated in Appendix Table 2.

3. Results and Discussion

1) The vertical distribution of water temperature and salinity

The vertical distribution of water temperature and salinity between 08°N and

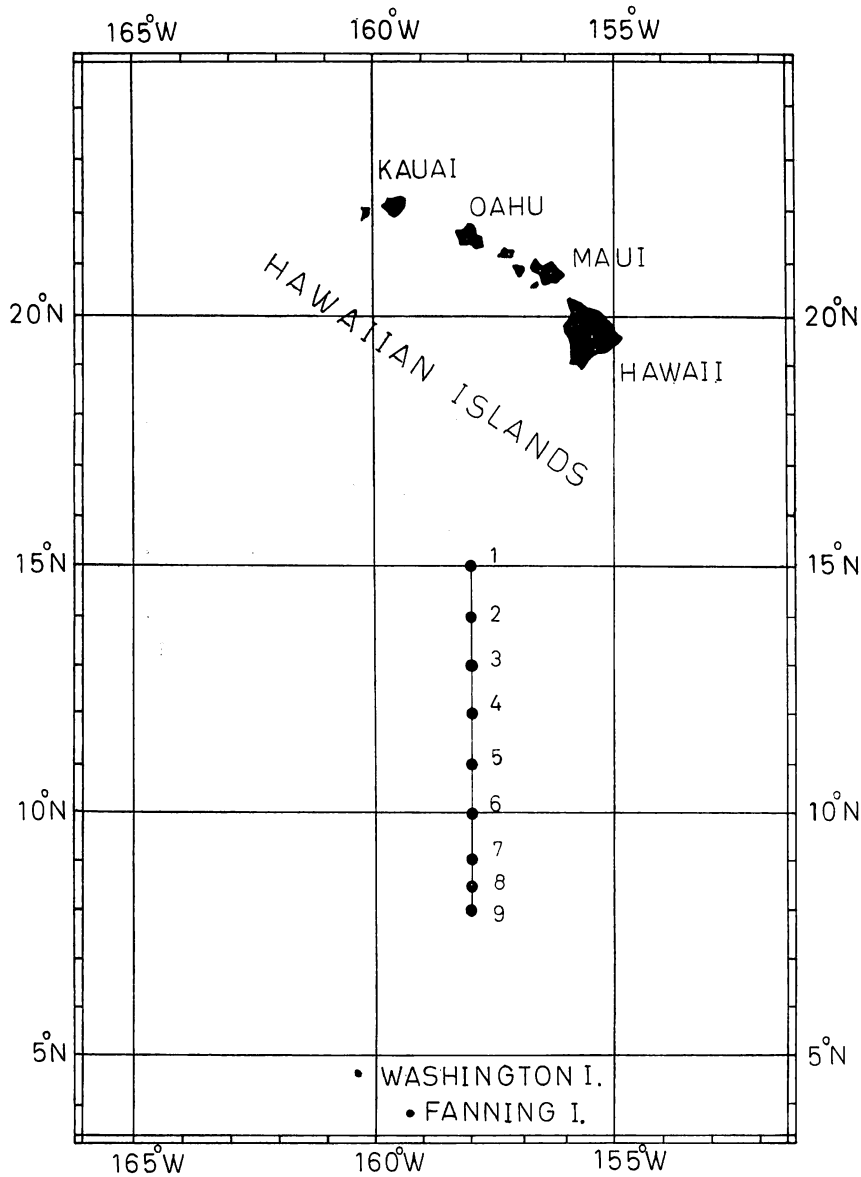


Fig. 1 Map showing the oceanographic stations of S.T.D observation and collection of plankton.

15°N along the meridian of 158°W in the southern region of the Hawaiian Isands are shown in Fig. 2 and Fig. 3, respectively.

Regarding the vertical distribution of water temperature (Fig. 2), the depth of the surface water is about 80 m around 14°N and about 40 m around 09°N.

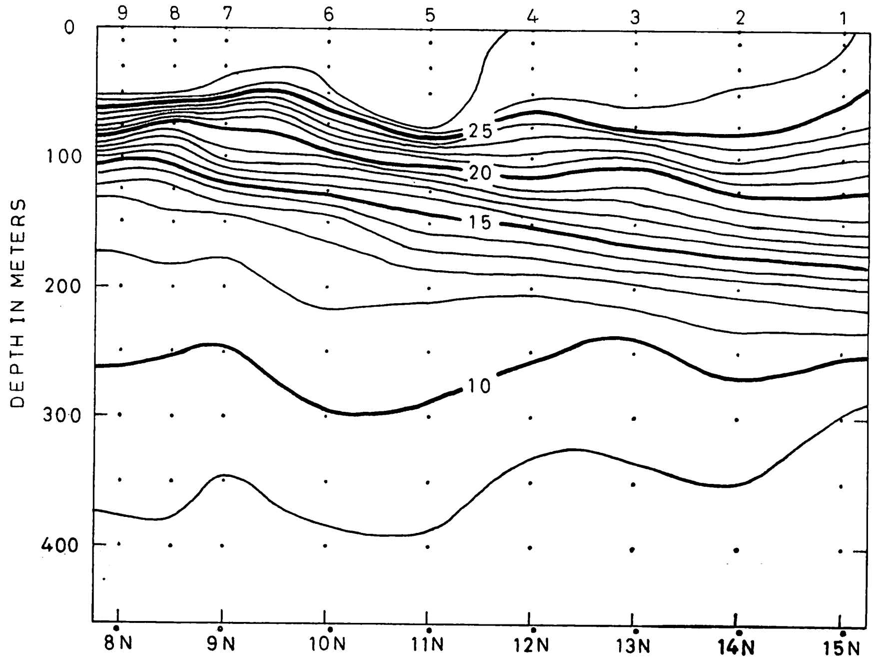


Fig. 2 Distribution of temperature (°C) in a vertical section along the meridian of 158°W.

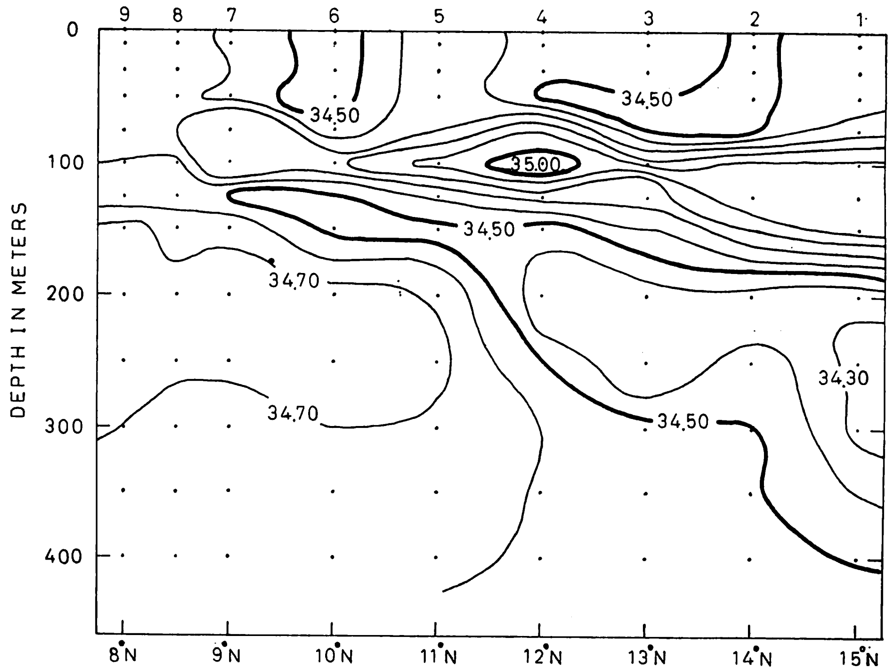


Fig. 3 Distribution of salinity (‰) in a vertical section along the meridian of 158°W.

The numerical values of the temperature of the surface water are ca 26.0°C at 15°N, ca 26.9°C at 12°N and ca 27.7°C at 08°N, respectively. The surface temperature increases gradually toward the south.

Below the surface layer, the thermocline (13°C - 25°C) is in a layer at a depth of about 80 m - 200 m around 14°N, and about 50 m - 140 m around 09°-30′N. The depth at the top of the thermocline is the shallowest around 09°-30′N and indicates a tendency to slope down toward the equator. Montgomery and Stroup (1962), Masuzawa (1964) reported that the depth at the top of the thermocline is most shallow near the boundary between the North Equatorial Current and the Equatorial Countercurrent, and the boundary of these Currents located at around 09°N.

In the present study, the boundary are assumed to be located around 09°-30′N. The vertical gradient of temperature in the thermocline is ca 0.10°C/m at 14°N, ca 0.13°C/m at 08°N and seems to be higher near the equator.

In the research in 1977, the numerical values of the temperature of the surface water were ca 25.1°C at 15°N, ca 26.4°C at 12°N and ca 27.7°C at 08°N, respectively, and the thermocline was in a layer at a depth of about 100 m - 190 m around 14°N and about 80 m - 130 m around 09°N.

The vertical gradient of the temperature in the thermocline was ca 0.13°C/m at 14°N, ca 0.20°C/m at 08°N, respectively.

Northward from 12°N the numerical value of the temperature of the surface water becomes somewhat high in 1978 study compared with that in 1977 and the depth of the thermocline is shallower in 1978 than in 1977. The vertical gradient of temperature in the thermocline was less in 1978 than in 1977.

In general, the thermocline is well developed where the annual variation of the water temperature in the surface layer is large.

Regarding the vertical distribution of salinity (Fig. 3), similar conditions have been seen in the vertical distribution of salinity shown by Cromwell (1953), Montgomery (1954), Montgomery and Stroup (1962). Surface water with a salinity of 34.50‰ is found above the 75 m depth. Below the surface water, the saline water with a salinity higher than 34.70‰ extends to the south from the north, and the protrusion of saline water reaches to around 08°-30′N. The depth of the center of the saline water is about 125 m around 15°N, about 100 m around 12°N and about 90 m around 09°N, and becomes shallow toward the south.

The core of the salinity maximum is found in a layer at a depth of 100 m around 12°N. According to Montgomery and Stroup (1962), the salinity maximum represents subtropical water that has originated in the central North Pacific with a surface salinity maximum of around 30°N.

A tongue of water with a salinity minimum lower than 34.50‰ extending to the south from the north in a layer between about 140 m and 270 m in depth reaches to around 09°N.

In general, it has been understood that the salinity minimum (ca 34.20‰) of the North Pacific flows southward with ascending motion. Masuzawa (1967) also described that the salinity minimum water is transported to the west with the southern part of the North Equatorial Current and flows to the east with the Equatorial Countercurrent. On the other hand, the salinity minimum in the North Pacific Ocean is formed by Intermediate Water originating in the subarctic North Pacific as reported by Reid (1965).

A tonguelike protuberance of salinity higher than 34.60‰ extending from the equator in a layer at a depth of about 200 m reaches to around 12° N.

Montgomery and Stroup (1962) reported that the high salinity extending from the south originates in the South Pacific and has a surface salinity maximum.

The numerical value of the surface salinity in 1978 is ca 0.20‰ lower than in 1977.

Below the surface water, water with a salinity of higher than 34.70‰ reached to around 09°N from the north to the south in 1978, but a lip of this salinity maximum was only seen around 14°-30′N in 1977.

Thus, it seems that the difference in protrusion of high salinity from year to year correlates to the shifting from the east to the west or from the west to the east of the North Pacific surface salinity maximum.

Also to stop the southward extension of the high salinity, there is a process of the vertical mixing with an upwelling near the equator. Water with a salinity of 34.60‰ extending from the south to the north in a layer between about 150 m and 400 m depth reached to around 13°-30′N in 1977, but it reached to around 12°N in 1978, i.e., it was observed that the salinity maximum extending from middle latitudes to the equator in a layer of about 100 m depth was stronger in 1978 than in 1977, and the protrusion of water with a salinity of 34.60‰ extending from the equator to the north in a layer between about 150 m and 400 m depth was weaker in 1978 compared with that in 1977.

2) Temperature and Salinity diagram

Figure 4 shows the temperature-salinity diagram at each station between 08°N and 15°N along the meridian of 158°W. The representative temperature-salinity curves of the Eastern North Pacific Water and the Equatorial Pacific Water (Sverdrup, Johnson and Fleming, 1942) are indicated by dotted bands.

As is evident in Fig. 4, the salinity maximum with a salinity of ca 35.00‰ is found between 15°N and 09°N, and the depths of the center of the salinity maximum are ca 125 m at 15°N, ca 75 m at 09°N and becomes shallower gradually toward the south.

It is considered that the salinity maximum found in the northeast region of the Hawaiian Islands around 29°N, 148°W sinks and spreads to this region (Yuwaki and Henmi, 1978). This salinity maximum disappears at 08°-30′N and

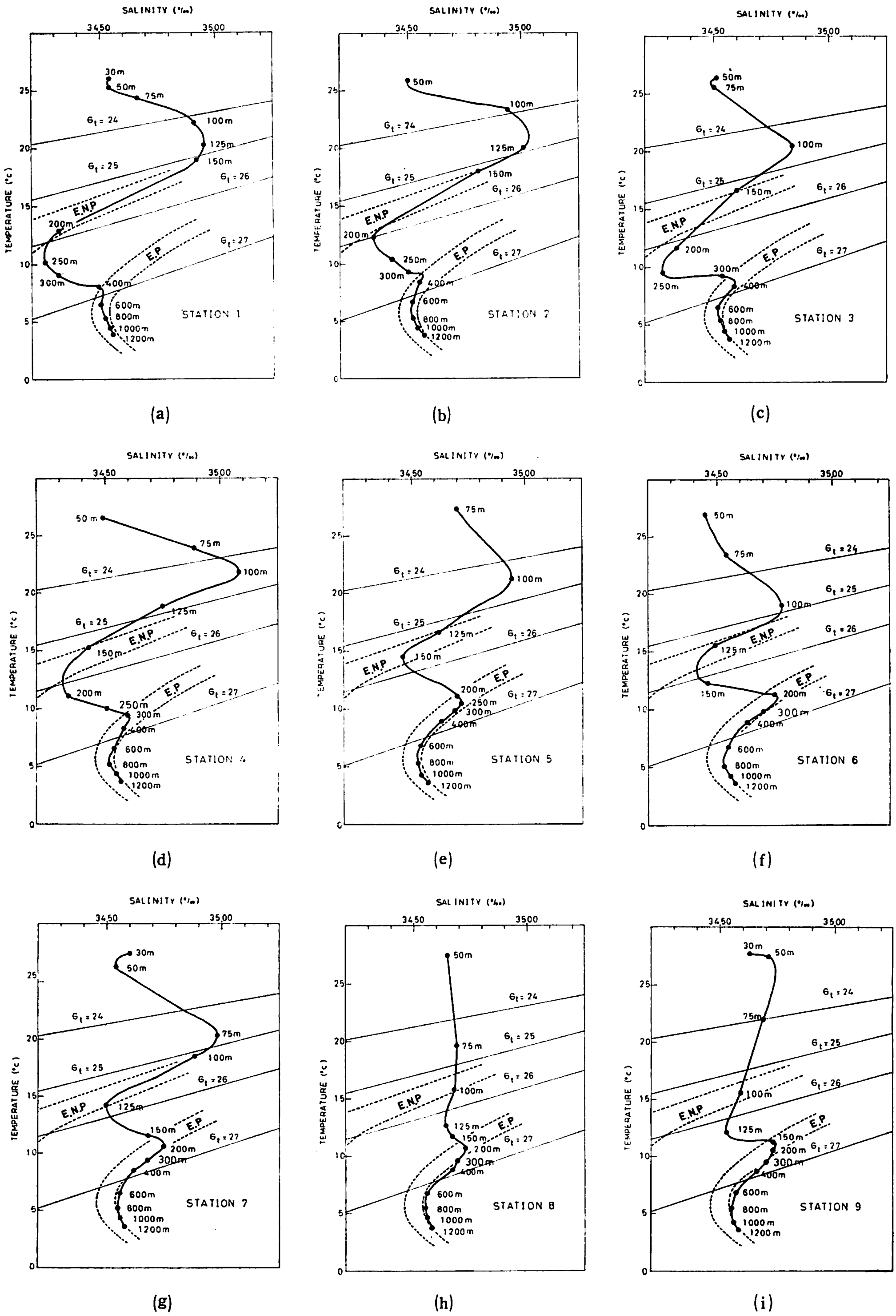


Fig. 4 Temperature-Salinity diagram at each stations between 8°N and 15°N along the meridian of 158°W. Number of stations and the observing depth are indicated.

08°N. (Fig. 4, h, i)

The first minimum of salinity is found at a depth of about 250 m at 15°N. The numerical value of the salinity minimum is ca 34.25‰ and increases gradually toward the south, indicating the admixture of the surrounding water and it is ca 34.50‰ at a depth of about 125 m at 09°N. This salinity minimum obscures at 08°N and 08°-30′N.

The origin of the salinity minimum is not clear, but as reported by Montgomery and Stroup (1962), this water is thought to be formed in the northeast region of the Hawaiian Islands around 38°N, 140°W (Eastern North Pacific). As reported by the authors (1978), it is thought that this salinity minimum is a water mass from the Subarctic Pacific Water in the eastern North Pacific Ocean, which has been mixed with waters of the tropical region, making an invasion below the surface layer in this region.

The second minimum with a salinity of ca 34.50‰ is found at a depth of about 800 m. As reported by Sverdrup *et al* (1942), this salinity minimum is part of the Intermediate Water in the South Pacific which originates at the surface in high latitude, and as it sinks and spreads northward and mixes with the waters above and below, this water mass is gradually transformed and extends along the equator between 10°S and 15°N in the east. This water mass is called the Equatorial Pacific Water.

Though conspicuous differences are not recognized in the temperature-salinity curve in the research in 1978 compared with that in 1977, as mentioned before (Chapter 1), there is a difference in that the southward extension of the salinity maximum with a salinity of ca 35.00‰ at a depth of about 100 m reached to around 15°N in 1977, and around 09°N in 1978.

3) Eastward and Westward flow

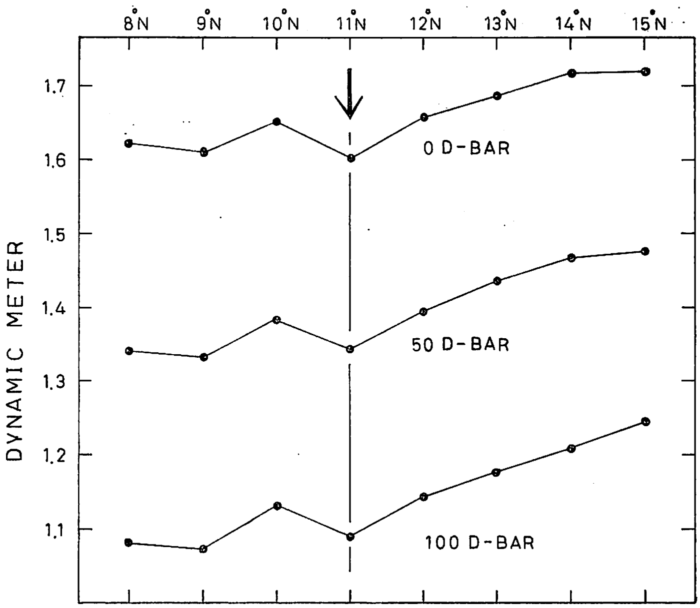
Geopotential profiles referred to 1,000 db surface between 08°N and 15°N along the meridian of 158°W in 1977 and 1978 are shown in Fig. 5, (a) and (b), respectively.

The distribution of the east-west component of the geostrophic current referred to 1,200 m depth between 08°N and 15°N along the meridian of 158°W is shown in Fig. 6 and the fluxes are listed in Table 1.

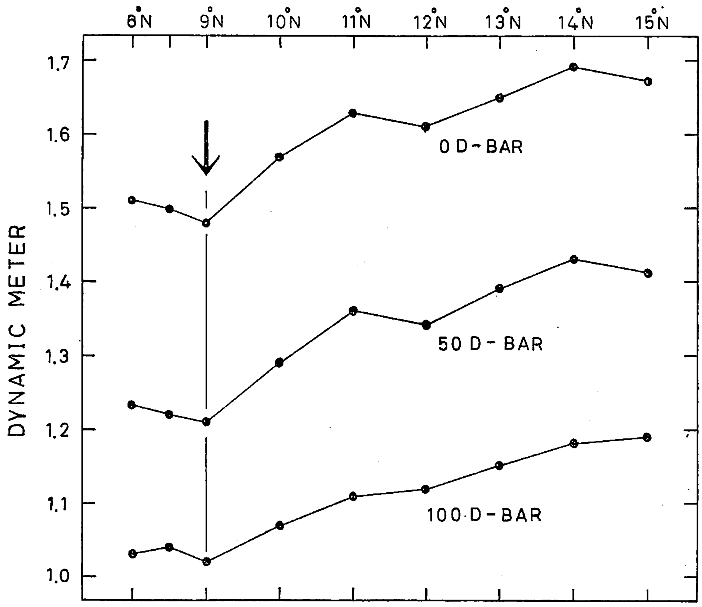
Though it is not easy to define the southern and northern limits of the current, the southern limit of the North Equatorial Current is assumed to lie at a station where the geopotential is at a minimum in the present study.

As is seen in Fig. 5 (a) and (b), the southern limit of the North Equatorial Current in 1978 was around 09°N, in contrast with around 11°N in 1977 and had shifted to the south about 120 miles.

In the report by Masuzawa (1964), the boundary between the North Equatorial Current and the Equatorial Countercurrent at 158°W is around 09°N. Montgomery and Stroup (1962) also described the boundary is 09°N, in agreement



(a)



(b)

Fig. 5 Profiles of isobaric surfaces referred to 1000-decibar surface. Arrows show the southern limit of the North Equatorial Current. (a) 1977 (b) 1978

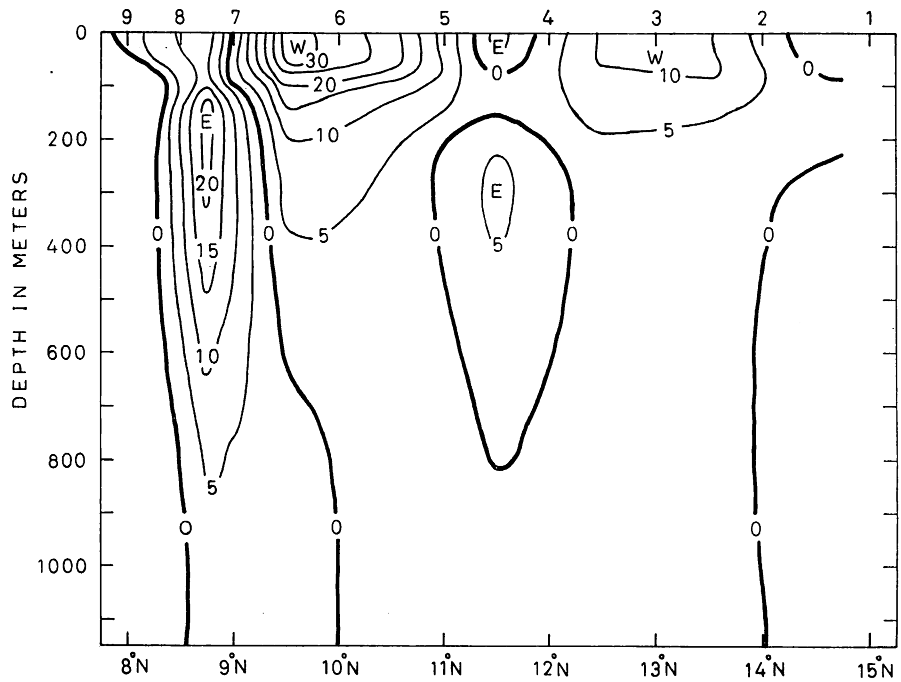


Fig. 6 The east-west compoment (cm/sec) of calculated relative current velocity across 158°W referred to 1, 200 m.

with the present study. But the location of the northern and southern limits of the Equatorial Countercurrent vary very much according to the season and year. This was also reported by Yamanaka *et al* (1965).

According to Fig. 6, the vertical section of the east-west component shows the alternate distribution of the velocity components: east, west east and west from the south to the north. The conspicous boundary between the eastward and westward flow is found around 09°N. The North Equatorial Current is divided into two portions, the northern and southern halves, and each portion is frequently subdivided into two or three portions and there are cyclonic or anticyclonic vortexes. (Yamanaka, Anraku and Morita, 1965. Masuzawa, 1967).

The eastward flow, having the maximum velocity of 23 cm/sec, is located at around 08°-45′N. The current axis of eastward flow shifted to the south about 100 miles compared with that in 1977 and the maximum velocity of eastward flow is somewhat higher than that in 1977. The eastward flow located around 11° - 30′N, having a velocity of 07 cm/sec, may be a part of the vortexes.
The westward flow, having a maximum velocity of 33 cm/sec, is located around 09° - 30′N. In the research in 1977, the westward flow was divided into two portions, which are located around 09°-30′N and 11°-30′N. The velocity of each portion is less than that in the present study.

Table 1. Values of the current velocity and the transport of component of geostrophic current

Year	Position of current axis	West-East component	Current velocity (cm/sec)	Transport (10^6 m^3/sec)
	11°-30′N	W	20	12.3
1977	10°-30′N	E	20	4.7
	09°-30′N	W	21	15.3
	13°-00′N	W	11	6.6
1978	11°-30′N	E	7	2.5
	09°-30′N	W	33	12.7
	08°-45′N	E	23	5.5

The maximum velocity of eastward flow was almost equal to that of westward flow in the research in 1977, but the maximum velocity of eastward flow is less than that of westward flow in the present study.

The fluxes of eastward and westward flow between 08°N and 15°N are ca 8.0×10^6 m^3/sec and 19.3×10^6 m^3/sec, respectively.

The eastward flux was far larger in 1978 than in 1977 and the westward flux was smaller in 1978 than in 1977. It is considered that the differences of the current velocity and the geostrophic flux are caused by the vicissitude of the wind system excelling in the eastern North Pacific.

The flux of the Equatorial Countercurrent (eastward flow) estimated by Montgomery and Stroup (1962), Sverdrup (1942) is 20.6×10^6 m^3/sec (5°N to 9°N) and 25×10^6 m^3/sec (entire Equatorial Counter-current), respectively, but these are far larger compared with that (8°N to 15°N) in the present study.

On the other hand, Montgomery and Stroup (1962), Sverdrup et al (1942) and Masuzawa (1964) estimated the flux of the North Equatorial Current (westward flow) to be 6.7×10^6 m^3/sec (8°N to 12°N), 40×10^6 m^3/sec (entire North Equatorial Current) and 21.4×10^6 m^3/sec, respectively. The westward flux (08°N to 15°N) in the present study is far larger than that reported by Montgomery and Stroup (1962), and far smaller than that reported by Sverdrup *et al* (1942), but nearly equal to that reported by Masuzawa (1964).

Though the differences of these geostrophic flux, as a matter of course, are caused by the distance of the observed station compared to the flux, the variation of the flux with season and with longitude remains unknown. There may be a strong influence on the choice of the motionless surface in the dynamic calculation.

4) Zooplankton

The distribution of the zooplankton between 08°N and 15°N along the meridian of 158°W is shown in Fig. 7.

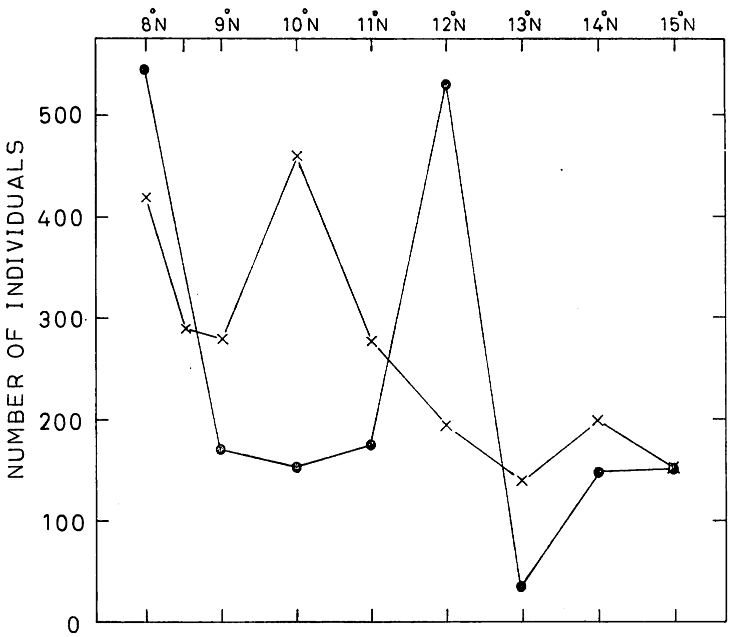


Fig. 7 Distribution of zooplankton per cubic meter along the meridian of 158°W. Symbols: bots, 1977; crosses, 1978.

The zooplankton communities in this region are represented by *Copepoda, Radiolaria, Ceratium* and *Appendicularia.*
Pteropoda, Thaliacea, Ostracoda, Chaetognatha, Foraminifera and *Polychaeta* also occur, though the number of the individuals is very small.
Copepoda occupies the greater percentage of zooplankton. The rate of occurrence of *Copepoda, Radiolaria, Ceratium* and *Appendicularia* is 53 %, 16 %, 11 % and 10 %, respectively. These figures are almost equal to those in 1977. The maximum value of the number of individuals per cubic meter is 461 individuals at 10°N and the minimum value is 140 individuals at 13°N in 1978, though the maximum was 545 individuals at 08°N and the minimum was 37 individuals at 13°N in 1977. The average rate of occurrence of zooplankton per cubic meter is almost equal to that in 1977. The distribution of zooplankton which changes with the latitudes shows a tendency for the number to increase from high latitude to low latitude.

Graham (1941) described a distinctly greater production of plankton in the tropics than in high latitudes. That marine productivity becomes greater in tropics is probably dependent upon unstable tropical water. Sverdrup *et al* (1942) also described that there are vertical water movements in the Equatorial Current. The divergence appears at the northern limit of the Equatorial Countercurrent and the convergence appears at the southern boundary of the Equatorial Countercurrent. The divergence may be expected to be a region of high productivity.

The eastward flow of the geostrophic current around 08°-45′N is assumed to be the Equatorial Countercurrent. The divergence appears around 09°N and the convergence appears around 08°N in the present study.

As is evident in Fig. 7, the total number of zooplankton is the greatest around 10°N in the northern part of the divergence at the northern limit of the Equatorial Countercurrent. It may be recognized that the divergences caused by an upwelling has clear relation to the greater production of zooplankton.

4. Summary

Oceanographical research in the southern region of the Hawaiian Islands was carried out in May, 1977 and again from May to June, 1978. The results obtained are summarized as follows;

1) The numerical values of the temperature of the surface water are ca 26.0°C at 15°N, ca 26.9°C at 12°N and ca 27.7°C at 08°N, respectively.

Though the numerical value of the temperature of the surface water is almost equal to that reported in 1977, it becomes somewhat higher northward from 12°N.

2) The thermocline exists in a layer at a depth of about 80 m - 200 m around 14°N and about 50 m - 140 m around 09°-30′N, which is most shallow in this region. The depth of the thermocline was shallower in 1978 than in 1977.

The variation range of the numerical value of temperature between the thermocline is ca 12.0°C and the vertical gradient of temperature in the thermocline are ca 0.10°C/m at 14°N, ca 0.13°C/m at 08°N, respectively. The vertical gradient of temperature in the thermocline is less in 1978 than in 1977.

3) The numerical value of surface salinity is ca 34.50 ‰ and ca 0.20 ‰ lower than that in 1977. A tongue of saline water with a salinity of 34.90 ‰ extending to the south from the north in a layer between about 90 m and 125 m depth reaches to around 09°N.

The core of the salinity maximum is found in a layer at a depth of about 100 m around 12°N.

In research in 1977, a lip of the salinity maximum was only seen in a layer at a depth of about 100 m around 14°-30′N.

4) The first minimum with a salinity of ca 34.26 ‰ is found at a depth of about 250 m at 15°N. The research in 1977 produced the same results. The depth of the salinity minimum becomes shallower gradually as approaching to the equator from the north and the numerical value of the salinity minimum increases toward the south. The second minimum with a salinity of ca 34.55‰ is found at a depth of about 800 m.

5) The boundary between the North Equatorial Current and the Equatorial Countercurrent is recognized around 09°N and it seems to have shifted to the

south compared with that in 1977.

6) The current axies of the eastward and westward flows are around 08°-45'N and 09°-30'N. The axis of the eastward flow shifts to the south about 100 miles compared with that in 1977 but the axis of the westward flow is almost the same as that in 1977.

The numerical value of the maximum velocity of the eastward and westward flow are ca 23 cm/sec and ca 33 cm/sec. These are somewhat higher than those reported in 1977. The total flux of the eastward and westward flow is ca $8.0\times 10^6\,m^3/sec$ and ca $19.3\times 10^6\,m^3/sec$. The total flux of the eastward flow is far larger than that in 1977 but the total flux of the westward flow is smaller than that in 1977.

7) The zooplankton communities are represented by *Copepoda, Radiolaria, Ceratium* and *Appendicularia*. The rate of occurrence of each one is 53 %, 16 %, 11 % and 10 %, respectively.

The maximum value of occurrence of zooplankton per cubic meter is 461 individuals at 10°N and the minimum value is 140 individuals at 13°N. The rates and the average value of occurrence of zooplankton are almost equal to those in 1977.

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Appendix

Appendix 1. S.T.D. data

Depth	Station 1 Lat. 14°-59.′8N Long. 157°-59.′5W May. 31, 1978 Temp. (°C)	 Salinity (‰)	Station 2 Lat. 13°-59.′9N Long. 157°-59.′8W Jun. 1, 1978 Temp. (°C)	 Salinity (‰)	Station 3 Lat. 12°-59.′8N Long. 158°-02.′5W Jun. 1, 1978 Temp. (°C)	 Salinity (‰)	Station 4 Lat. 11°-59.′8N Long. 157°-59.′7W Jun. 1, 1978 Temp. (°C)	 Salinity (‰)
0	26.00	34.54	26.39	34.50	26.37	34.51	26.89	34.51
10	26.00	34.54	26.32	34.50	26.37	34.51	26.68	34.51
30	25.92	34.54	26.24	34.50	26.37	34.51	26.65	34.51
50	25.30	34.54	25.90	34.50	26.30	34.50	26.53	34.49
75	24.34	34.66	25.52	34.50	25.58	34.50	23.92	34.89
100	22.17	34.94	23.35	34.94	20.63	34.84	21.81	35.08
125	20.19	34.95	20.22	35.01	18.67	34.75	18.78	34.75
150	18.80	34.94	18.00	34.81	16.65	34.60	15.31	34.43
200	12.79	34.32	12.28	34.35	11.74	34.34	11.10	34.34
250	10.14	34.26	10.45	34.48	9.48	34.28	10.10	34.51
300	8.96	34.32	9.28	34.50	9.30	34.54	9.36	34.60
350	8.16	34.40	9.00	34.58	8.87	34.59	8.81	34.59
400	8.01	34.49	8.38	34.55	8.35	34.59	8.28	34.58
450	7.69	34.51	7.95	34.55	7.87	34.57	7.80	34.57
500	7.25	34.51	7.42	34.53	7.37	34.55	7.39	34.56
600	6.40	34.50	6.68	34.52	6.49	34.52	6.55	34.54
700	5.70	34.51	5.83	34.51	5.19	34.52	5.75	34.53
800	5.18	34.52	5.26	34.52	5.37	34.53	5.16	34.52
1000	4.33	34.54	4.39	34.54	4.42	34.55	4.37	34.55
1200	3.74	34.55	3.76	34.57	3.71	34.57	3.68	34.57

Appendix 1. (Continued)

Depth	Station 5 Lat. 10°-57.'4N Long. 158°-06.'8W Jun. 1, 1978 Temp. (C°)	Salinity (‰)	Station 6 Lat. 09°-59.'6N Long. 158°-00.'3W Jun. 2, 1978 Temp. (°C)	Salinity (‰)	Station 7 Lat. 08°-57.'3N Long. 158°-01.'0W Jun. 3, 1978 Temp. (°C)	Salinity (‰)	Station 8 Lat. 08°-30.'7N Long. 158°-00.'4W Jun. 5, 1978 Temp. (°C)	Salinity (‰)
0	27.41	34.70	26.98	34.44	27.45	34.58	27.63	34.65
10	27.40	34.70	26.99	34.44	27.45	34.58	27.63	34.65
30	27.36	34.69	26.99	34.44	27.44	34.60	27.63	34.65
50	27.33	34.70	26.96	34.45	26.22	34.54	27.43	34.65
75	27.31	34.70	23.40	34.54	20.29	34.88	19.61	34.69
100	21.32	34.94	19.04	34.78	18.52	34.88	15.81	34.58
125	16.56	34.62	15.56	34.49	14.24	34.50	12.67	34.54
150	14.53	34.46	12.31	34.46	11.57	34.68	11.71	34.67
200	11.14	34.70	11.28	34.75	10.57	34.75	10.66	34.73
250	10.46	34.72	10.48	34.72	9.98	34.71	10.06	34.71
300	9.85	34.69	9.95	34.70	9.45	34.68	9.48	34.68
350	9.42	34.66	9.38	34.65	8.97	34.67	9.17	34.68
400	8.87	34.63	8.80	34.63	8.51	34.62	8.85	34.67
450	8.38	34.60	8.31	34.59	7.90	34.61	8.47	34.64
500	7.81	34.57	7.79	34.58	7.46	34.58	7.93	34.61
600	6.80	34.54	6.75	34.55	6.54	34.56	6.77	34.56
700	5.97	34.52	5.98	34.53	5.74	34.55	6.02	34.55
800	5.32	34.53	5.11	34.53	5.25	34.55	5.44	34.55
1000	4.33	34.54	4.23	34.56	4.37	34.56	4.56	34.56
1200	3.59	34.57	3.58	34.58	3.67	34.58	3.69	34.58

Appendix 1. (Continued)

Depth	Station 9 Lat. 07°-58.'8N Long. 158°-01.'3W Jun. 4, 1978 Temp. (°C)	Salinity (‰)
0	27.69	34.63
10	27.69	34.63
30	27.67	34.63
50	27.47	34.71
75	22.14	34.69
100	15.65	34.59
125	12.26	34.53
150	11.42	34.73
200	10.60	34.73
250	10.11	34.72
300	9.64	34.70
350	9.22	34.67

400	8.82	34.66
450	8.30	34.63
500	7.93	34.61
600	6.93	34.57
700	6.22	34.56
800	5.47	34.55
1000	4.34	34.56
1200	3.62	34.58

Appendix 2. Individual number of zooplankton per cubic meter

Date Station No. Latitude Longitude	May 31, 1978 1 14°-59′.8 N 157°-59′.5W	Jun. 1, 1978 2 13°-59′.9N 157°-59′.8W	Jun. 1, 1978 3 12°-59′.8N 158°-02′.5W	Jun. 1, 1978 4 11°-59′.8N 157°-59′.7W	Jun. 1, 1978 5 10°-57′.4N 158°-06′.8W
Copepoda	89	100	58	91	178
Radiolaria	17	55	39	47	23
Appendicularia	17	13	18	22	20
Pteropoda	3	2	1	2	6
Thaliacea	7	5	5	1	3
Ceratium	7	11	10	22	29
Ostracoda	7	6	5	2	11
Chaetognatha	3	3	2	2	5
Foraminifera	1	3		4	9
Polychaeta	1	2	1	1	
Decapoda larva	3	3	1		4
Total	155	203	140	194	288

Appendix 2. (Continued)

Date Station No. Latitude Longitude	Jun. 2, 1978 6 09°-59′.6N 158°-00′.3W	Jun. 3, 1978 7 08°-57′.3N 158°-01′.0W	Jun. 5, 1978 8 08°-30′.7N 158°-00′.4W	Jun. 4, 1978 9 07°-58′.8N 158°-01′.3W
Copepoda	263	136	161	214
Radiolaria	52	52	62	46
Appendicularia	32	49	26	51
Pteropoda	8	2	4	7
Thaliacea	5	2	1	2
Ceratium	64	22	26	79
Ostracoda	10	7	1	8
Chaetognatha	7	3	2	5
Foraminifera	14	5	4	3
Polychaeta	1	1		3
Decapoda larva	5	1	2	2
Total	461	280	289	420