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(de l'exercice des années de 1994 et 1995)

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The western boundary current east of the Ryukyu Islands[*1]

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Abstract: With hydrographic data in Sept. 1992 and moored current meter records from Nov. 1991 to Sept. 1992, a modified inverse method is used for computing the western boundary current east of the Ryukyu Islands (WBCE) and the Kuroshio in the East China Sea. The WBCE has two cores, of which the depths vary seasonally. There is a southwestward abyssal boundary current under it throughout the year. Through a transect southeast of Okinawa, the volume transport (VT) of the WBCE is $30.8\times10^6 m^3/s$ and the VT of the southwestward current is $6.0\times10^6 m^3/s$, so that the net northward VT is $24.8\times10^6 m^3/s$. Through a transect northwest of Okinawa the total VT of the Kuroshio and Taiwan Warm Current is $32.1\times10^6 m^3/s$ and the VT of a southwestward countercurrent is $3.7\times10^6 m^3/s$, so that the net northeastward VT is $28.4\times10^6 m^3/s$, slightly larger than the VT southeast of Okinawa. The amount of water exchanged between the east and west sides of the Ryukyu Islands is discussed. The salinity minimum water in the mid-layer flows northwestward from the east of the Ryukyu Islands to the East China Sea through a gap of the Ryukyu Ridge. Its VT west of Okinawa is about $2.4\times10^6 m^3/s$.

1. Introduction

The current east of the Ryukyu Islands, sometimes called the Ryukyu Current (WANG and SUN, 1990), was first discussed by NITANI (1972). He pointed out that a narrow countercurrent flows just southeast of the Ryukyu Islands, on the offshore side of which flows a northeasterly current. However, so far there have been few studies on it.

YUAN *et al.* (1991*a*, *b*) first showed the subsurface core structure of the Ryukyu Current, a southward undercurrent below it and a southward countercurrent to its east, which is often associated with a mesoscale anticyclonic eddy. The volume transport (hereafter abbreviated to VT) of the Ryukyu Current was computed with the inverse method (YUAN *et al.*, 1991*a*, *b*) and the modified inverse method (YUAN *et al.*, 1992, 1993*a*, *b*, *c*).

The study on the Ryukyu Current is of primary importance for understanding the western boundary current system in the northwestern Pacific Ocean, especially because it is one of the principal sources of the Kuroshio transport southeast of Kyushu (YUAN *et al.*, 1991; YUAN *et al.*, 1993*b*). Previous studies were based on hydrographic, GEK and/or onboard ADCP data which are confined into surface layers. Very few direct current measurements have been done with moored meters in this region. CHAEN *et al.* (1993) made deep and bottom current measurements at three mooring sites southeast of Okinawa from Nov. 1987 to May 1989.

In the framework of a China-Japan cooperative study, long term current measurements with moored current meters were made southeast of Okinawa (TAKANO *et al.*, in preparation). Hydrographic data were obtained during two cruises by the R/V Shijian, one for the deployment of the moorings in Oct. to Nov. 1991 and the other for recovery in Sept. 1992. The current velocity and the volume transport are obtained with the modified inverse method together with the current meter data.

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2. Calculation

Figure 1a shows hydrographic sections in Oct. to Nov. 1991 with mooring stations OA, OB and OC and isobaths, and Fig. 1b hydrographic sections in Sept. 1992. The modified inverse method is applied to boxes (1) to (4). The result for Oct. to Nov. 1991 is presented in another paper (YUAN *et al.*, 1994). The computation points (hereafter abbreviated to Cp) are at the middle of nearby two hydrographic stations. The boundary sections of each computation box are divided into five layers according to $\sigma_{t,p}$-iso-

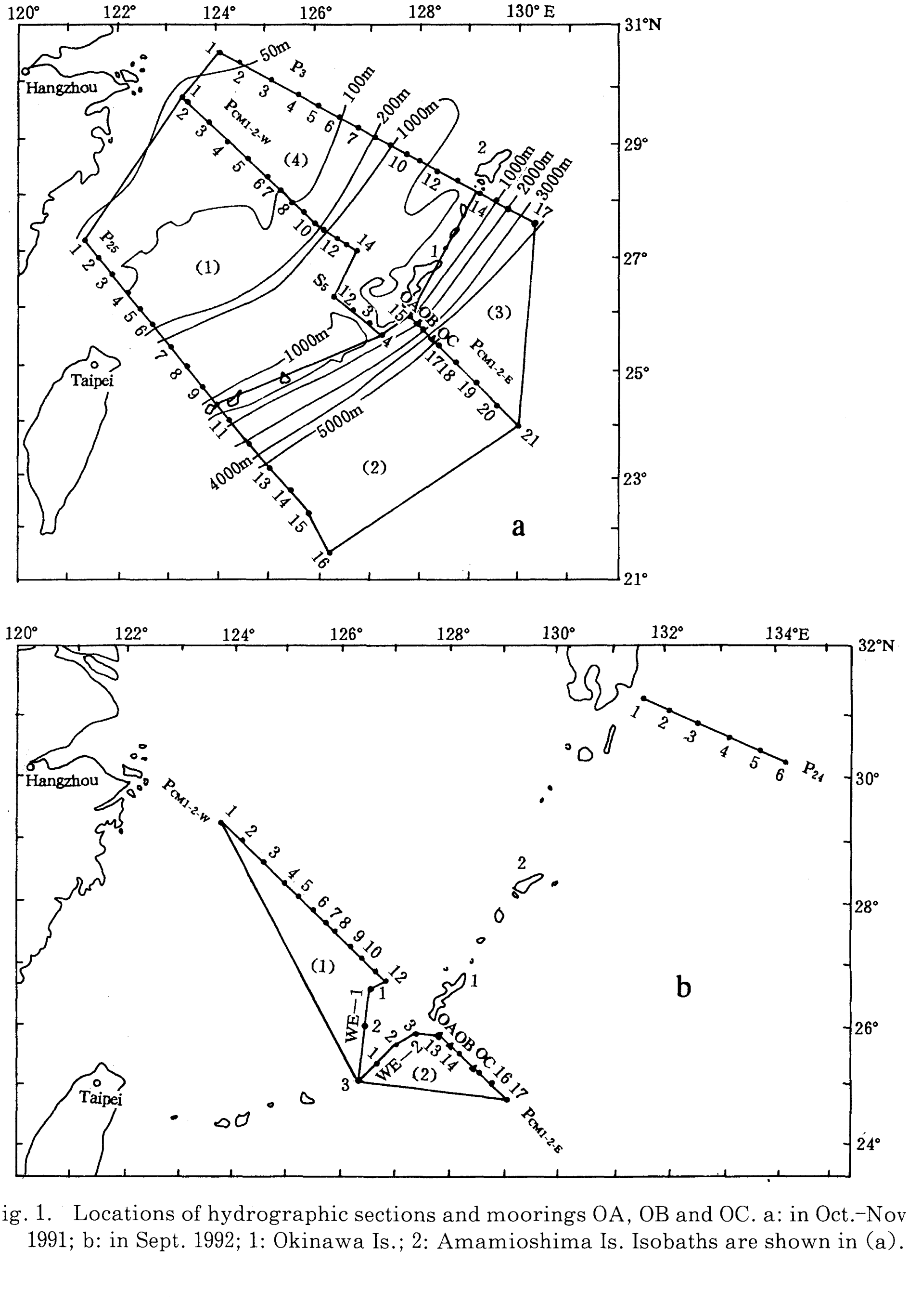

Fig. 1. Locations of hydrographic sections and moorings OA, OB and OC. a: in Oct.-Nov. 1991; b: in Sept. 1992; 1: Okinawa Is.; 2: Amamioshima Is. Isobaths are shown in (a).

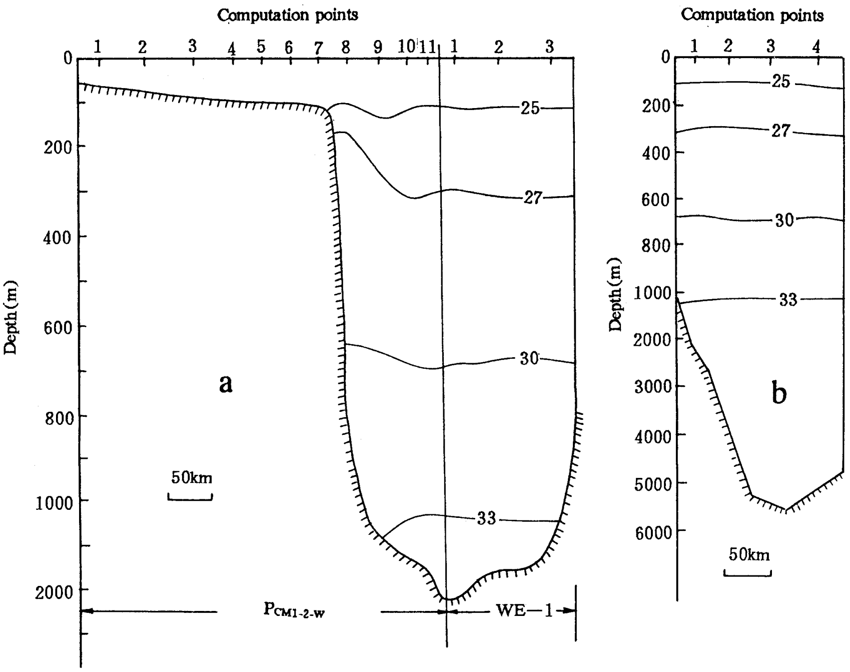

Fig. 2. Isopycnal surfaces in Sept. 1992. a: along PCM 1-2-W and WE-1; b: along PCM 1-2-E.

pycnal values of 25, 27, 30 and 33. At Sections PCM1-2-W and WE-1 in Sept. 1992, depths of $\sigma_{t,p}$ = 25, 27, 30 and 33 lie between 60m and 136m, 177m and 315m, 646m and 696m, 1231m and 1409m, respectively (Fig 2a). At PCM 1-2-E they lie between 102m and 120m, 313m and 328m, 690m and 700m, 1193m and 1206m, respectively (Fig. 2b).

The average wind speed and direction observed aboard the R/V Shijian are 2.3m/s and 335° in Sept. 1992. Because no reliable wind data are available over the whole survey region, this average wind is assumed as the wind forcing which is constant in time and space. The minimum and maximum upward surface heat fluxes are prescribed to be -1.05×10^7J/(m^2 day) and 1.26 $\times$ 10^7 J / (m^{2}day) according to 10-year long climatological data for September (Institute of Oceanography and Geography, 1977). The computation is done in such a way that the calculated surface heat flux comes between these two bounds. The vertical eddy diffusion coefficient is 10^{-2}m^2/s for momentum and 10^{-3}m^2/s for heat and salinity. The horizontal eddy diffusion is neglected because it is very small with the diffusion coefficient of the order of 10^4m^2/s or less. Hydrographic and current meter data in Sept. 1992 are used. The mooring stations OA, OB and OC are located along PCM 1-2-E.

Usable data are obtained at a depth of 1980m at OB, and depths of 2000m and 4500m at OC. The low-passed current velocities averaged over 1 to 6 Sept. 1992 are listed in Table 1. Figures 3a, b, c show progressive vector diagrams for Nov. 1991 to Sept. 1992. The low-passed currents are fairly steady in Sept. 1992.

As shown in Fig. 1, Stn OC is not exactly located on any Cp but Stn OB is on Cp 1 at PCM 1-2-E, so that the average velocity at 1890m depth at OB is used as a known value for the computation. The velocity at 2000m depth of Cp 2 is interpolated from the average velocities at 1890m depth of OB and 2000m depth of OC, and used as a known value.

The depth of the reference level is determined as 2500m with a method by FIADEIRO and VERONIS (1982). It is assumed to be the water depth if the bottom is shallower than 2500m.

Table 1. Low-passed current velocities averaged over 1 to 6 Sept. 1992.

Mooring station	Location	Water depth(m)	meter depth(m)	v* (cm/s)	θ** (°)	v′*** (cm/s)
OB	25°48′N, 128°03′E	2020	1890	3.6	263	−2.8
OC	25°34′N, 128°20′E	4630	2000	3.1	193	−2.7
OC			4500	2.0	200	−1.9

* Speed. ** measured clockwise from the due north.

*** velocity component normal to section PCM 1-2-E. negative: southward.

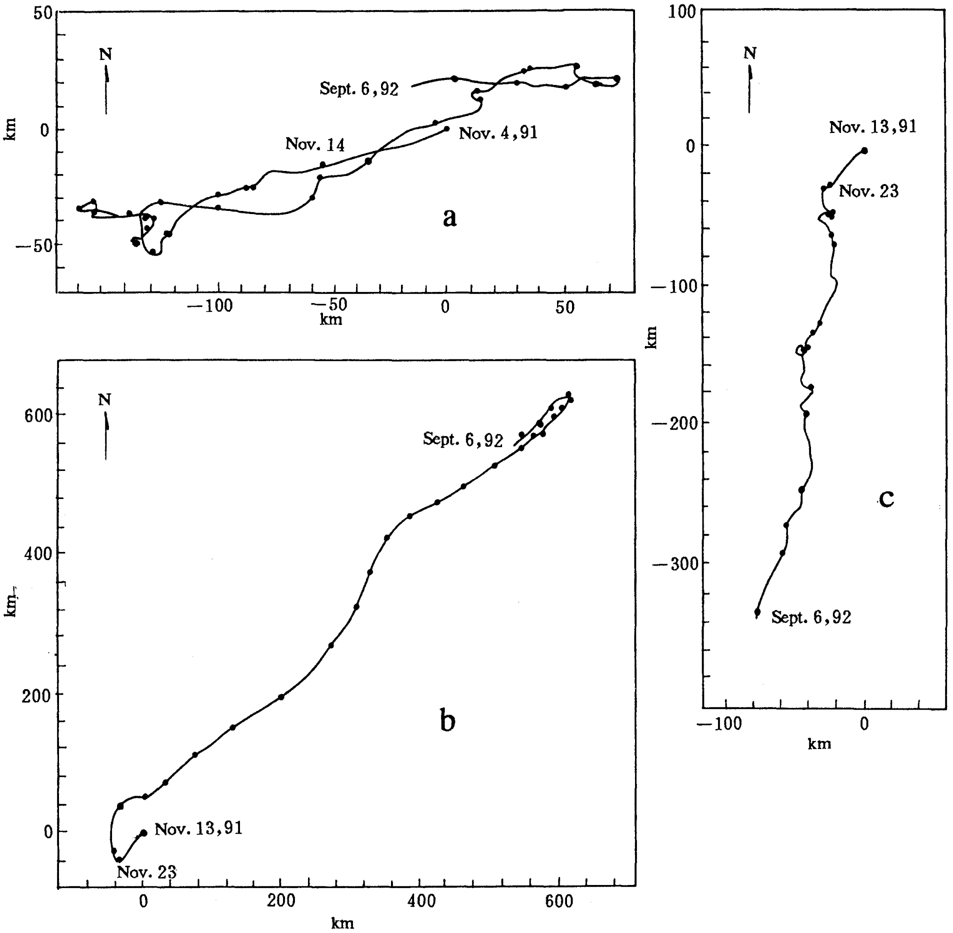

Fig. 3 Progressive vector diagrams of the observed currents. a: 1890m depth at Stn OB; b: 2000m depth at OC; c: 4500m at OC. Time interval between two dots: 10 days.

3. Result in September 1992

(1) *Velocity distribution*

(a) Sections PCM 1-2-W and WE-1

The Kuroshio flows northeastward through PCM 1-2-W. Its core is located above the continental slope (Fig. 4). The velocities are greater than 100cm/s in the upper 200m at Cp 8. The maximum velocity is 172cm/s at 50m depth. There is a weak southward countercurrent in deeper layers below the Kuroshio. There is another southward countercurrent east of the Kuroshio with maximum velocity of 31cm/s at 150m depth at Cp 11.

Section WE-1 is mostly occupied by an almost

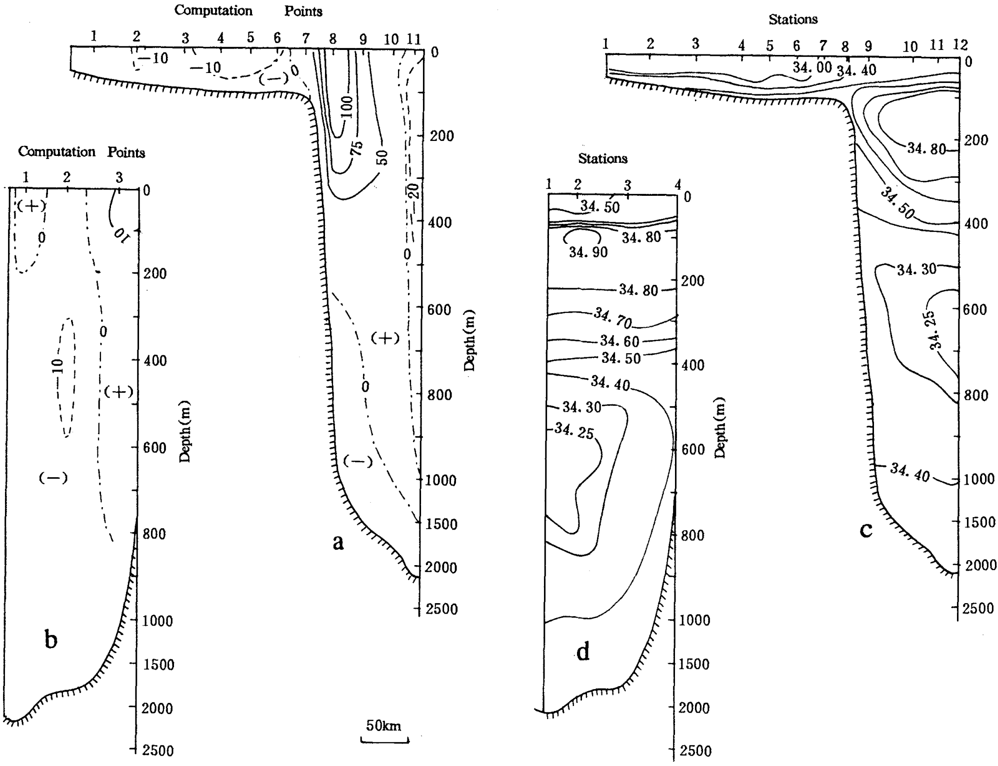

Fig. 4. Velocity (a, b, cm/s) and salinity (c, d, ‰) distribution. a: at PCM 1-2-W (positive: northward); b: at WE-1 (positive: eastward); c: at PCM 1-2-W, d: at WE-1.

westward flow coming into box 1 except in the upper 200m at the northern end (Cp 1) and the upper 800m at the southern end (Cp 3).

Figures 4c, d show the salinity distribution. In the upper 350m there is a salinity maximum tongue (S>34.60‰), which extends to the shelf break. The salinity minimum water (S<34.30 ‰) appears in the mid-layer between 500 and 800m depths as pointed out by Yu *et al.*(1994). The flow below 500m depth at WE-1 is mostly westward as mentioned above. Salinity minimum water in the mid-layer flows westward through WE-1 (Figs. 4b, d).

(b) Sections PCM 1-2-E and WE-2

Figure 5b shows that the greater part of PCM 1-2-E is occupied by a northeastward current with two cores, as in Oct.–Nov. 1991 (Yuan *et al.*, 1994). One of the two cores lies between 200m and 700m depths above the maximum slope of the bottom, where the velocity is 23.0 cm/s at 400m depth and 22.6cm/s at 500m depth. The other is located above 200m depth further to the east, where the maximum velocity is 32.5cm/s at the surface. Below the northeastward flowing Ryukyu Current, there is a southwestward flow with the maximum velocity of 5.1cm/s at 2500m depth. This is compatible with the result of the current measurement at OC showing that the average velocity component normal to PCM 1-2-E is 2.7cm/s at 2000m depth and 1.9cm/s at 4500m depth, both southwestward (Table 1). At the eastern part of PCM 1-2-E there is another southward flow between 50m and 750m depths.

In short, these current features are similar to those in Oct.–Nov. 1991 (Yuan *et al.*, 1994).

Section WE-2 crosses a gap of the Ryukyu Ridge between Cp 2 and Cp 3 (Fig.5a). While northward and southward flows alternate in the upper 400m, it is occupied mostly by a northward flow in the mid-layer between 400m and 800m, especially over the Ridge.

Figures 5c, d show the salinity distribution. The salinity maximum (34.50<S<34.93 ‰)

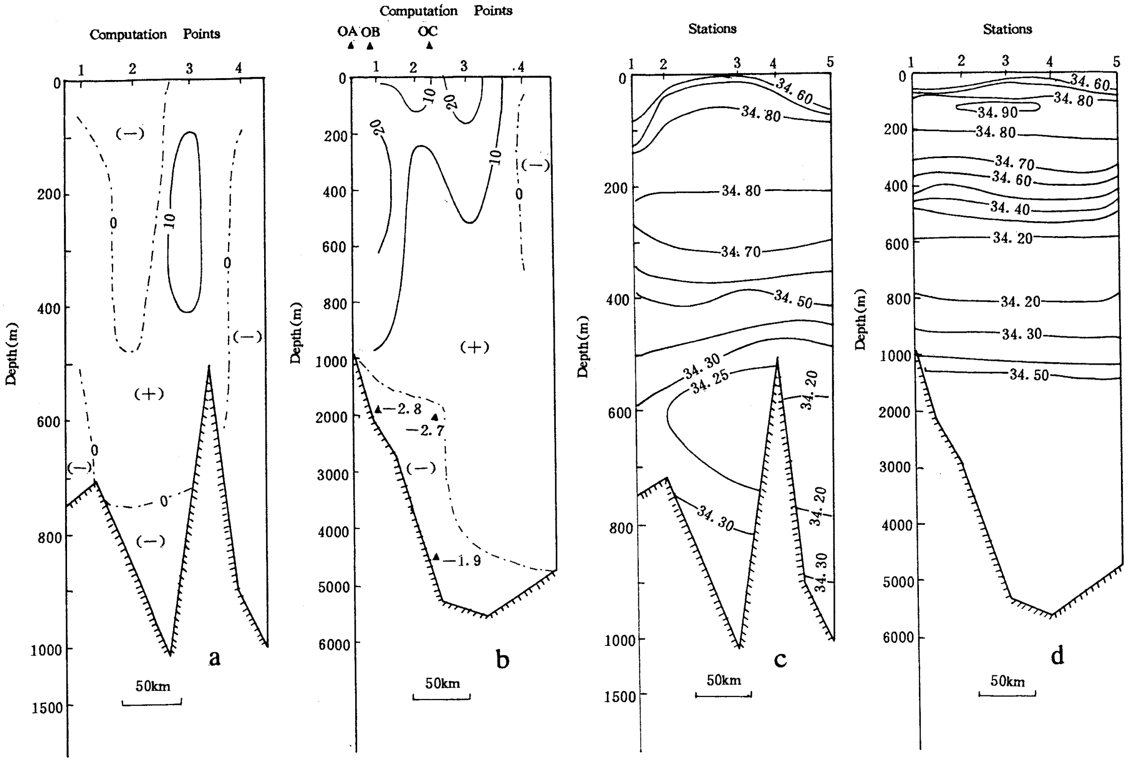

Fig. 5. Velocity (a, b, cm/s) and salinity (c, d, ‰) distribution. a: at WE-2 (positive: northwestward); b: at PCM 1-2-E (positive: northeastward); c: at WE-2; d: at PCM 1-2-E.

water lies in the upper 400m. The salinity minimum (34.14<S<34.50‰) water lying between 400m and 1000m depths extends into the gap at WE-2 with slightly higher minimum value. The salinity is higher than 34.50‰ in the deep layer below 1000m depth. These salinity features were also reported by Yu *et al.*(1993).

An important point follows from the above result: a part of the salinity minimum water in the mid-layer east of the Ryukyu Islands flows northwestward through the gap of the Ryukyu Ridge, then westward through WE-1, probably merging into the Kuroshio afterwards. With a hydrograhic data analysis Yu *et al.*(1994) also pointed out that a part of the salinity minimum water of the Kuroshio in the East China Sea is related to the intrusion of the salinity minimum water east of the Ryukyu Islands through the gap. Here we draw a similar conclusion from the velocity distribution computed with the modified inverse method.

(c) Section P_{24}

Section P_{24} is located southeast of Kyushu (Fig. 1b). Because there are no other sections nearby, the modified inverse method cannot be used. The velocity distribution across the section is obtained as the sum of the surface Ekman drift and the geostrophic current calculated with an assumed reference level 2500m deep. The wind stress is calculated with wind data collected aboard the R/V Shijian at Section P_{24}. Figure 6a shows the most part of the section is occupied by a northward flow with a core above the maximum slope of the bottom. There is a southward flow at its eastern end.

Figure 6b shows the salinity distribution. The salinity maximum (34.50<S<34.93‰) water occupies the most part of P_{24} in the upper 400m. There is the salinity minimum (34.14<S<34.50‰) water in the mid-layer between 400m and 1200m. The salinity is higher than 34.50‰ in the deep layer below 1200m depth. Comparison of Fig. 6b with Figs. 4c and 5d shows that the

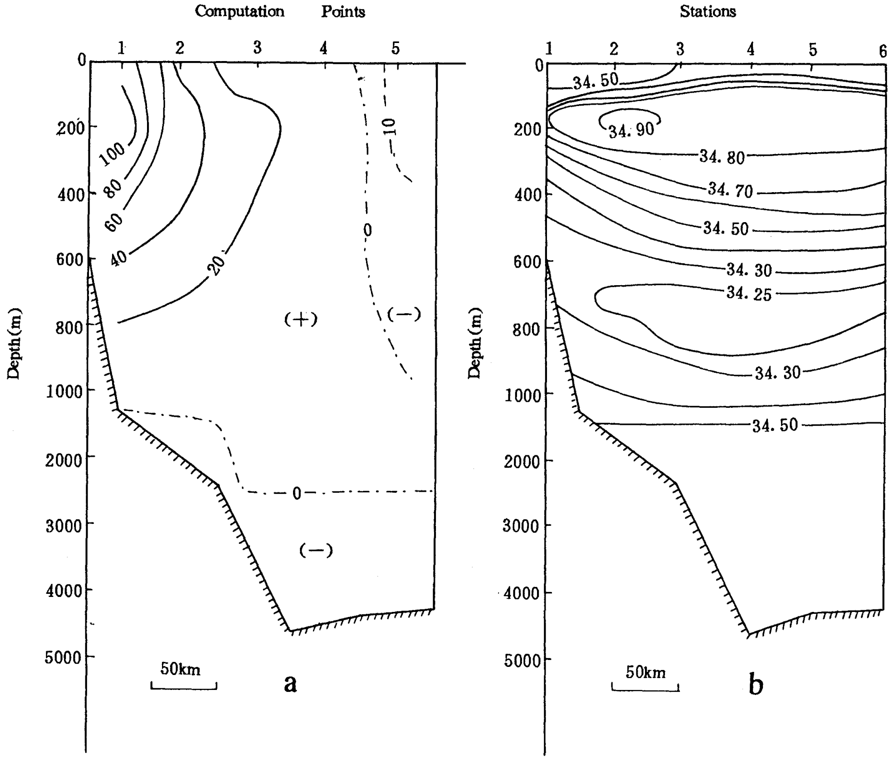

Fig. 6. Velocity (a, cm/s, positive: northeastward) and salinity (b, ‰) at P_{24}.

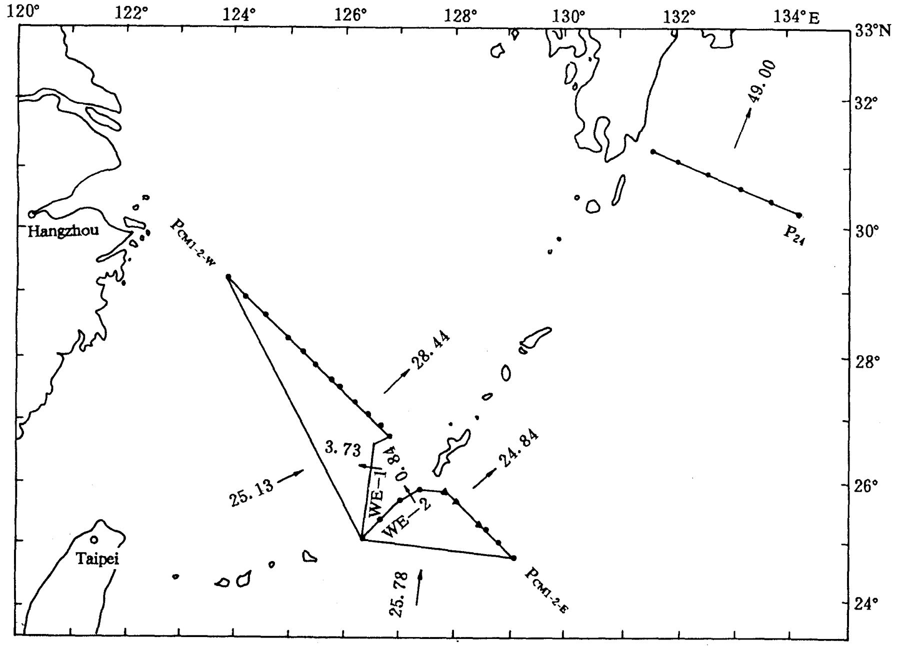

Fig. 7. Total volume transports. units: 10^6m/s.

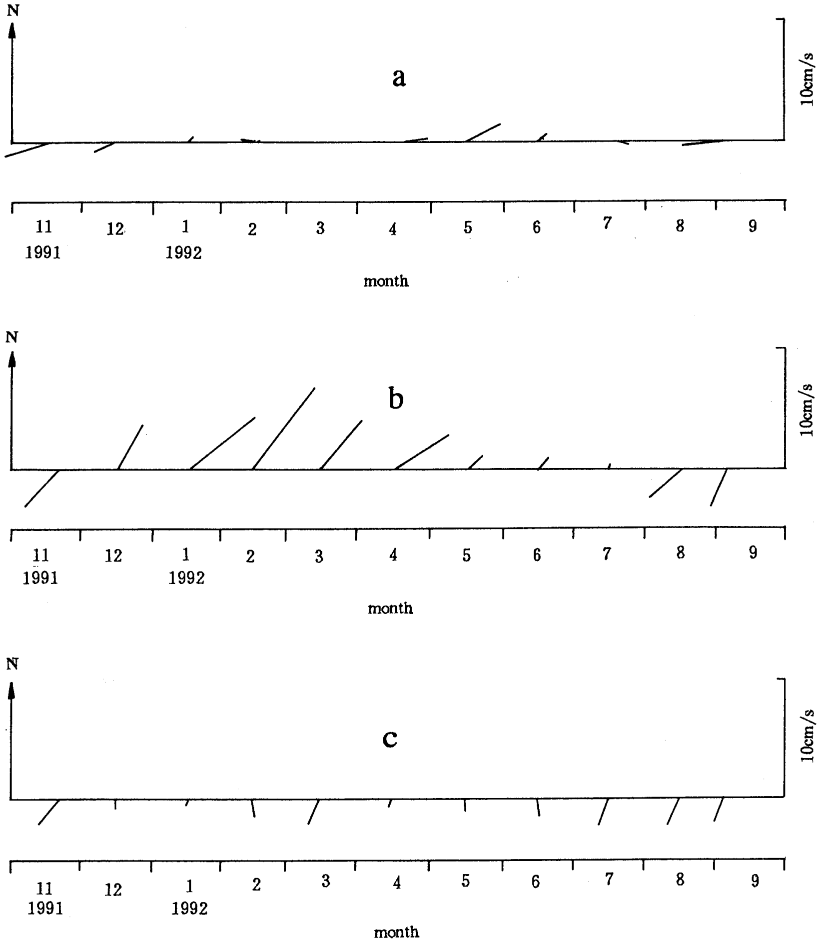

Fig. 8. Monthly averages of the low-passed current velocities. a: at 1890m depth at OB; b: at 2000m depth at OC; c: 4500m depth at OC.

salinity distribution at P_{24} is similar to that at PCM 1-2-E and PCM 1-2-W. However, the salinity minimum water area at P_{24} is much wider than that at PCM 1-2-E and 1-2-W, suggesting that the salinity minimum water in the mid-layer of P_{24} comes from both PCM 1-2-E and 1-2-W. This point will be discussed later with the volume transport.

(2) *Volume transport*

Figure 7 shows the total VT across each section. The total VT of the Kuroshio and Taiwan Warm Current across PCM 1-2-W is 32.1×10^6 m^3/s. The VT of the sothwestward countercurrents below, and east of, the Kuroshio is $3.7 \times 10^6 m^3/s$, so that the net northeastward VT across PCM 1-2-W is $28.4 \times 10^6 m^3/s$. The northeastward VT of the Ryukyu Current, 30.8×10^6 m^3/s, and the southwestward VT, $6.0 \times 10^6 m^3/s$, through PCM 1-2-E make a net northeastward VT of $24.8 \times 10^6 m^3/s$, so that the transport of the Kuroshio is almost equal to that of the western boundary current east of the Ryukyu Islands (hereafter referred to as WBCE). A numerical simulation shows the annual average VT is $22.8 \times 10^6 m^3/s$ to the west of Okinawa and about $30 \times 10^6 m^3/s$ to its east (H. ISHIZAKI, personal communication). The model ocean is driven by an annual average wind stress and seasonally varying surface temperature and salinity. Since the grid size, 1°×1°, is not fine, the coefficient of eddy viscosity is large ($10^4 m^2/s$), which broadens the western boundary current

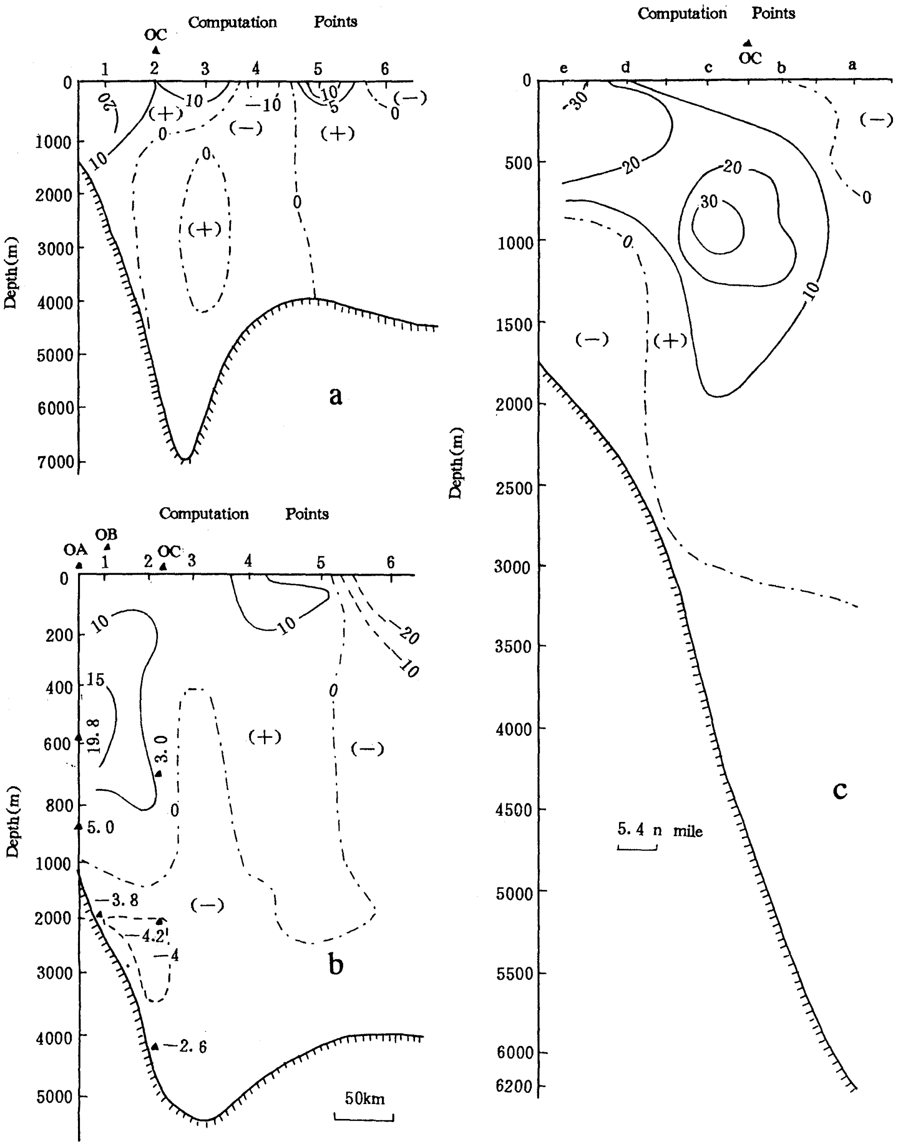

Fig. 9. Velocity distribution at PCM 1-2-E (cm/s, positive: northeastward). a: in Sept. to Oct. 1987 (YUAN *et al.*, 1991a); b: in Oct. to Nov. 1991 (YUAN *et al.*, 1994); c: in April 1988 (YUAN *et al.*, 1993c). Measured velocities are shown beside solid triangles in (b). The horizontal and vertical scales are different from each other.

and turns out that the VT west of Okinawa decreases and the VT of the WBCE increases. Therefore, the observed result appears consistent with the simulated one. The total northwestward VT through WE-2 is $2.9\times10^6 m^3/s$, of which the first layer about 100m thick transports $0.5\times10^6 m^3/s$ and the deeper layer $2.4\times10^6 m^3/s$. This indicates that a significant amount of the salinity minimum water flows from the east of the Ryukyu Islands to the East China Sea through the gap. The total northwestward VT through WE-2 is $0.8\times10^6 m^3/s$.

The total westward and eastward VT through WE-1 are $8.0\times10^6 m^3/s$ and $4.3\times10^6 m^3/s$, resulting in a net westward VT of $3.7\times10^6 m^3/s$.

The total northeastward and southwestward

Table 2. Two core depths (m) and maximum speeds (cm/s).

Cruise	depth	speed	depth	speed
Sept.-Oct. 1987	125～900	20<	0～200	10<
Oct.-Nov. 1991	390～700	15<	0～200	10<
Sept. 1992	200～700	20<	0～200	20<
Apr. 1988	550～1300	30<	0～620	30<

VT through P_{24} are $52.8\times10^6 m^3/s$ and $3.8\times10^6 m^3/s$, resulting in a net northeastward VT of $49.0\times10^6 m^3/s$.

4. Seasonal variability

Figure 8 shows the monthly average of the low-passed currents obtained with the three moored meters. At 2000m depth of OC, the flow is northeastward from Dec. 1991 to June 1992 and southwestward in Dec. 1991, Aug. and Sept. 1992, which suggests a seasonal change in the vertical extent of the WBCE.

The flow at OB is northeastward in May and June 1992 and southwestward in Nov. and Dec. 1991. The flow at 4500m depth of OC is southward for all the months. The maxima of the 10-day and monthly averages are 4.5cm/s and 2.6 cm/s, respectively, which indicated the presence of a fairly steady southward flow under the Ryukyu Current. This is also reported by CHAEN *et al.* (1993). They showed an abyssal boundary current of depths greater than 3000m in the Ryukyu Trench southeast of Okinawa. The observed velocity averaged over Nov. 1987 to April 1989 at 4170m at their Stn RT_3 (25°24′N, 128°18′E, water depth: 4570m) located 18.8 km apart from OC was 4.3cm/s and southwestward in agreement with our result.

Features over the whole section PCM 1-2-E common to the three fall cruises in Sept. to Oct. 1987, Oct. to Nov. 1991 and Sept. 1992 are as follows (Figs. 5b, 9a, b). (i) The greater part of the section is occupied by a northward flow with two cores. One is in the mid-layer above the maximum slope of the bottom. The maximum core velocity is about 20cm/s or greater. The other is located above 200m depth further to the east. (ii) There is a southward flow at 2000m depth around OC, which agrees with the direct current measurement.

The spring cruise in April 1988 gives following results (Fig. 9c). (i) The Ryukyu Current has also two cores, of which the locations are variable with time. One is located in the layer from the surface to 620m depth above the maximum slope of the bottom. The maximum velocity is at the surface layer, and an isotach of 20cm/s reaches from the surface to 600m depth, while in fall the maximum velocity is at the mid-layer. The other core is located in the layer from 550m to 1300m furtehr to the east. The core depths and maximum speeds are summarized in Table 2. The cores are deeper and speeds are faster in spring than in fall. (ii) There is a northward flow at 200m depth around OC. The velocities at two Cp nearest to OC (c and d in Fig. 9c) is 9.2cm/s and 3.0cm/s, giving an average of about 6cm/s, which agrees with the monthly average, 5.5cm/s, of the observed velocities at 2000m depth of OC in April 1992.

5. Summary

The modified inverse method is applied to hydrographic data in Sept. 1992 together with moored current meter records from Nov. 1991 to Sept. 1992 for computing the western boundary current east of the Ryukyu Islands and the Kuroshio in the East China Sea.

Following results are obtained.

(1) The WBCE has two cores. One is above the maximum slope of the ocean bottom, and the other is located further to the east.

(2) There is a seasonal change in the vertical extent of the WBCE. It is deeper in winter and spring than in fall.

(3) Under the Ryukyu Current there is a southward abyssal boundary current which is fairly steady for all the months.

(4) The VTs of the Ryukyu Current and deep southward countercurrent through PCM 1-2-E are $30.8\times10^6 m^3/s$ and $6.0\times10^6 m^3/s$, resulting in a net northeastward VT of $24.8\times10^6 m^3/s$.

The total VT of the Kuroshio and Taiwan

Warm Current through PCM 1-2-W is $32.1\times 10^6 m^3/s$, and the VT of the southwestward undercurrent is $3.7\times 10^6 m^3/s$, so that the net northeastward VT is $28.4\times 10^6 m^3/s$.

The northeastward VT through P_{24} is $52.8\times 10^6 m^3/s$, and the southwestward VT is $3.8\times 10^6 m^3/s$, so that the net northeastward VT is $49.0\times 10^6 m^3/s$.

(5) The salinity minimum water in the mid-layer flows northwestward through a gap of the Ryukyu ridge from the east of the Ryukyu Islands to the East China Sea. Its northwestward VT at WE-2 is $2.4\times 10^6 m^3/s$. The westward and eastward VT through WE-1 are $8.0\times 10^6 m^3/s$ and $4.3\times 10^6 m^3/s$, making a net westward VT of $3.7\times 10^6 m^3/s$.

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琉球諸島東側の西岸境界流

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要旨：1992年９月の海洋観測データと1991年11月から1992年９月までの流速データに改訂インバース法を使い，琉球諸島東側の西岸境界流と西側の黒潮を計算した。琉球諸島東側の境界流には２つのコアがあり，その深さは季節によって変わる。その下には南西に向かう深層境界流がつねに存在する。沖縄の南東では，北東向きの流量は$30.8\times 10^6 m^3/s$であり，南西向きの流量は$6.0\times 10^6 m^3/s$なので，正味の北東向き流量は$24.8\times 10^6 m^3/s$となる。沖縄の北西では，黒潮と台湾海流の流量の和は$32.1\times 10^6 m^3/s$であり，南西向きの反流の流量は$3.7\times 10^6 m^3/s$なので，正味の北東向き流量は$28.4\times 10^6 m^3/s$となり，南東側の流量よりもすこし大きい。中層を塩分極小水が琉球諸島の東側から琉球海嶺の割れ目を通って北西に流れる。その流量は沖縄の西側で$2.4\times 10^6 m^3/s$である。

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Société franco-japonaise d'océanographie, Tokyo

Temperature-salinity frequency distribution of the upper 10 m water of the Japan Sea*

Hideo SUDO**

Abstract: The Japan Sea except the northwestern part is divided into four areas according to seasonal variation pattern of sea surface temperature and salinity. Monthly temperature-salinity characteristics at the sea surface and at 10 m depth are examined by use of relative frequency distribution in bivariate class of 1℃×0.2 (‰ or psu) in salinity for each of four areas and for the whole study area. Two modes are seen in the frequency distributions nearly through a year because a frontal zone exists in the central area where cold, low salinity water of the north contacts warm, high salinity water of the south. The eastern part of the frontal zone occasionally extends northeastward along the Japan coast and there occurs another weak mode representing a little warm water in the southeast of the zone or in the west of northern Japan. The most frequently occurring water at 10 m through a year has characteristics of 5–13℃, 34.0–34.2, partly 33.8–34.0 or 34.2–34.4 seen in the south of the frontal zone mostly during January to May. Other significant waters are the coldest water centered at the class of 2–3℃, 33.8–34.0 occurring during December to April and the warm water of 17–21℃, 33.8–34.2 appearing mostly during July to December.

1. Introduction

The Japan Sea is a mid-latitude marginal sea located in the northwest of the North Pacific; large annual variations of sea surface temperature (SST) (exceeding 15℃) occur in the sea. Besides, sea surface salinity (SSS) shows wide variations, both annually and interannually, according to the salinity value of the Tsushima Warm Current water entering from the East China Sea and to fresh water amounts supplied by river discharges from the surrounding land. If sufficient hydrographic data are provided, we can estimate monthly means of both SST and SSS with their standard deviations for every unit area, e. g. 1 degree square. Their annual variations are given by monthly means through the year; their standard deviations show composites of spatial and interannual variations. Mapping of monthly mean SST and SSS of the Japan Sea with their variations (hereafter referred to as SUDO's Mapping) are now under way to be published. Temperatures and salinities are separately presented in the mapping.

The only dominant surface water of the Japan Sea is the warm, saline Tsushima Warm Current water; colder, lower salinity waters occupy a great portion of the surface of the sea and occasionally extremely low surface salinities are found not only near mouths of rivers but also far offshore. Low sea surface salinities affect SST values because of high vertical stabilities. In the open sea surface waters with low salinities are liable to be warmer or colder according to heating by inflow of solar energy or cooling by long wave radiation, conduction and evaporation; coastal waters show great variations in temperature through land heating or cooling and in autumn to spring waters discharged from rivers are colder than ambient sea surface waters. Therefore, SSS and SST are not always independent in the Japan Sea.

In order to show variation of SST and SSS, bivariate distributions are more useful. Volumetric potential temperature (θ)-salinity diagrams of the Japan Sea have been already provided for each of four seasons and through year (YASUI *et al.*, 1967). Since surface waters are small in absolute volume and show a wide variation, volumetric analysis is not always adequate for description of surface water

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characteristics. This report uses relative presentation of *T-S* distributions of the surface water for every calendar month. The oceanic domain of the sea with enough observations in divided into four areas according to sea surface water characteristics; the distributions are examined for each of areas and for the whole domain. Frequencies at 10 m depth as well as at the sea surface are made to examine the structure of the surface mixed layer.

2. Data and analysis

I have tried to use all available historical data, but about 15,000 stations taken at least before and during the World War II are not adequate because of bad quality. Almost all of the stations taken during 1952–1988 (including partly in 1989 and 1990) are provided for the present analysis; more than 400 stations, about 2600 to 4400 stations since 1966, have been occupied in the Japan Sea including the Tsushima Strait region every year during the period. About 74,000 out of more than 110,000 stations taken since 1924 in the Japan Sea including the Tsushima Strait region are used for the present analysis. Details of data sources will be described in SUDO'S Mapping.

The northwestern part off the North Korean and the Russian coasts north of 38°30'N, where few available data have been taken since the end of the World War II, is excluded from the area for the analysis. The coastal areas from 135°E to 44°N, the Wakasa Bay and further northeast, are excluded as well, because surface water characteristics are seriously affected by river discharges. Some districts bounded by coastal lines and every half degree meridians and/or longitude lines are also excluded, because fewness of observations or locality of water characteristics. Hereafter, the area for the analysis, bordered with heavy solid lines in Fig. 1, is referred to as the whole area or the whole study area.

The whole area is divided into four areas by characteristics of annual variations of SST and SSS (Fig. 1). The whole area does not include the southwestern half of the Area I, west of 129°30′E and south of 34°30′N. For some portions of other three areas in which insufficient hydrographic data have been obtained, *T-S* frequency distribution analysis is excluded from the areas and included for the whole area. Some near-coast districts along the Japan Islansd, still showing coastal water characteristics (Fig. 1, hatched portions), cannot be applied to any of four areas; *T-S* frequency distributions for these districts are used only for the analysis for the whole study area.

For each calendar month, *T-S* frequency distributions at the sea surface and at 10 m depth are determined for the unit area, every 1° square, partly 30' square or 1°×30' rectangle. It is assumed that the relative *T-S* frequency distribution based on the samples taken through the month for each of years has an equal weight, a reciprocal of number of observation years, regardless of number of samples. *T-S* values observed are classified into every 1℃×0.2 (‰ or psu) bivariate classes and their relative frequencies are accumulated in their corresponding classes for each of calendar months for each of unit areas. Then, the relative frequencies for each of four areas are obtained by averaging the relative frequencies for unit areas according to area size. In the same way, the *T-S* frequency distributions for the whole area are yielded from the distributions for four areas including insufficient data portions and for near-coast districts excluded for four area analyses and excluding the southwest of the Tsushima Strait.

The class intervals of 1℃ and 0.2 (‰ or psu) are adequate because standard deviations of temperatures and salinities of the water entering the Tsushima Strait are mostly about 1℃ and 0.2‰ for the monthly means (OGAWA, 1983). These standard deviations must include time variations among the month and interannual variations besides spatial variations as frequency distributions will show in section 4. At about 10℃, an increase in σ_t with a temperature decrease of 1℃ is equivalent to that with a salinity increase of 0.2 psu; therefore this *T-S* class interval ratio is reasonable in density variation.

3. Division of the sea area

The oceanic domain of the sea with enough observations is divided into four areas according to sea surface water characteristics of unit areas (1 degree squares or half degree squares) (Fig. 1).

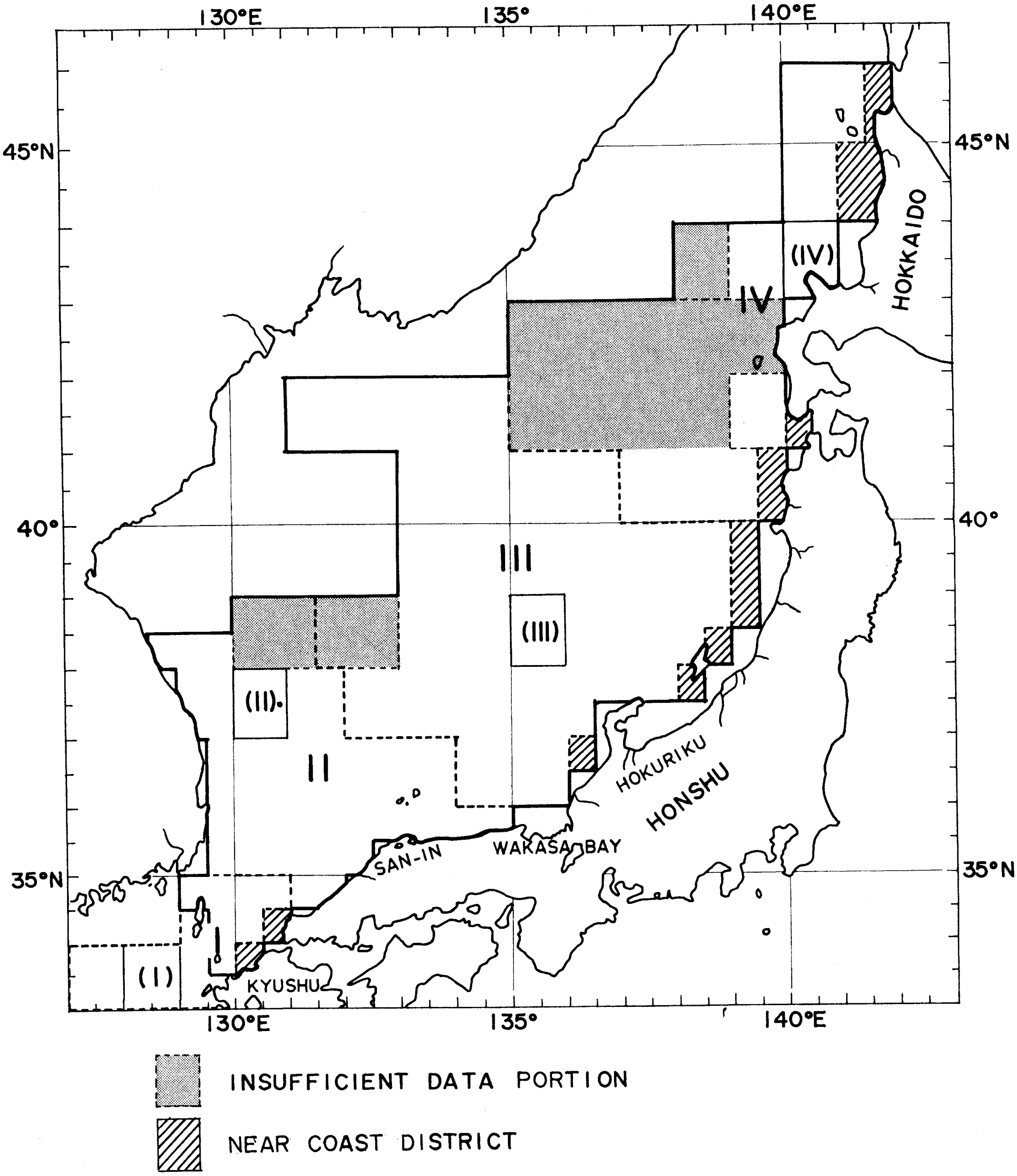


Fig. 1. The area for calculation of temperature-salinity frequency distribution. The area bordered with heavy solid lines is the whole study area, for which a northwestern part of the Japan Sea is excluded. Each of four areas I–IV are bounded by heavy dashed lines and some heavy solid lines. For one degree squares with parenthesized area numbers, annual variations of *T-S* relations at the sea surface and at 10 m depth are shown in Fig. 2. The *T-S* frequency distribution analysis for shaded portions with insufficient data is not made for each of Areas II, III and IV. Hatched portions are not included in any of four areas. *T-S* relations for shaded and hatched portions are used for the analysis of the whole area analysis.

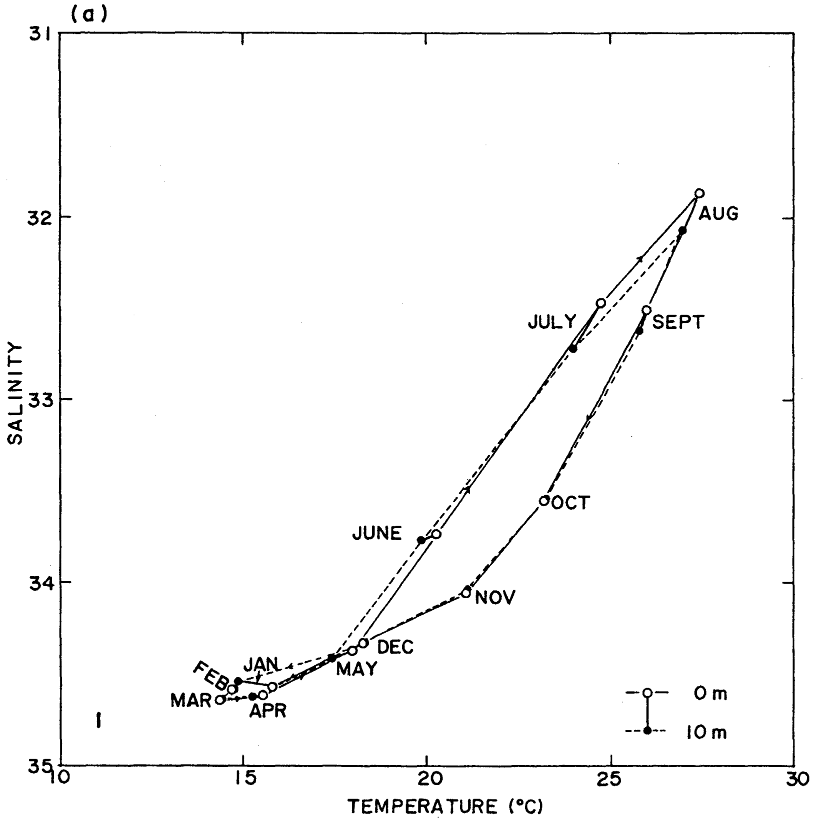


Fig. 2. Annual variations of monthly mean temperature-salinity relations at the sea surface and at 10 m depth for 1° squares selected for (a) Area I, (b) Area II, (c) Area III and (d) Area IV. The 1° squares are shown in Fig. 1.

Examples of annual variations in the *T-S* relation at the sea surface and 10 m depth for the four areas are shown in Fig. 2. This division is purely tentative and would not be applied to the remainder of the Japan Sea.

Area I, the Tsushima Strait (Korea Strait) region, is defined as the area in which monthly mean SST is 13.0℃ or more and monthly mean SSS is 34.5 or more both in February and in March (Fig. 2a). Variations during December to May are small; the ranges are 4–5℃ in temperature and less than 0.4 in salinity. In particular, the mean SST and SSS show little variation in January to April. Long winter and small winter variations are common features of surface water characteristics of the Japan Sea. In other seasons, in June to November, monthly mean SSS decreases rapidly with monthly mean SST.

Area II is the southwestern part of the Japan Sea, a fan-like area between the San-in coast and the Korean coast. It is defined as the area in which the monthly mean SSS shows 34.2 or more in April or May and decreases to less than 33.0 in any or both of August and September (Fig. 2b). Basically, the pattern of the annual variation of surface water characteristics is not different from that in Area I except that the water is fresher in the cooling season than in the warming season for a specified temperature.

Area III is the central part of the sea, a vast area ranging from off the eastern San-in coast and north of the Wakasa Bay to 42°N off the shelf of Primorye (Enkai). It is defined as the area in which the monthly mean SSS with annual range of 0.5 or more shows 34.0 or more at least in one of April to June and 33.0 or more both in August and in September (Fig. 2c). The annual range of the monthly mean SST amounting to 15℃ or more is the largest of the four areas.

Fig. 2b.

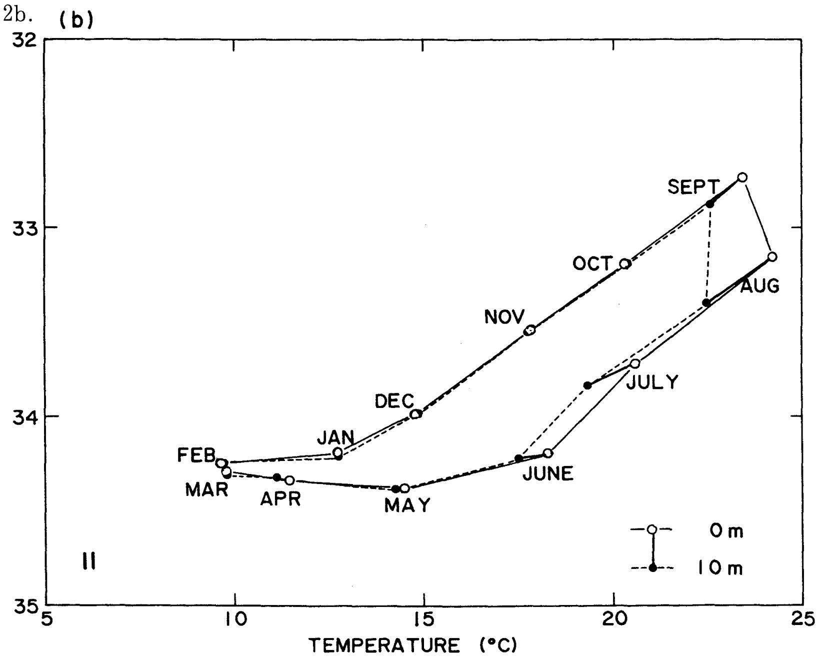


Fig. 2c.

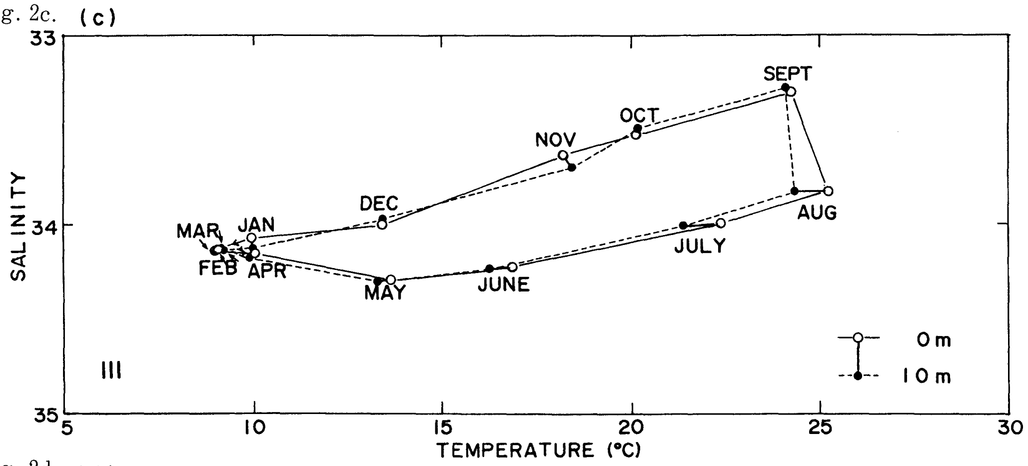


Fig. 2d.

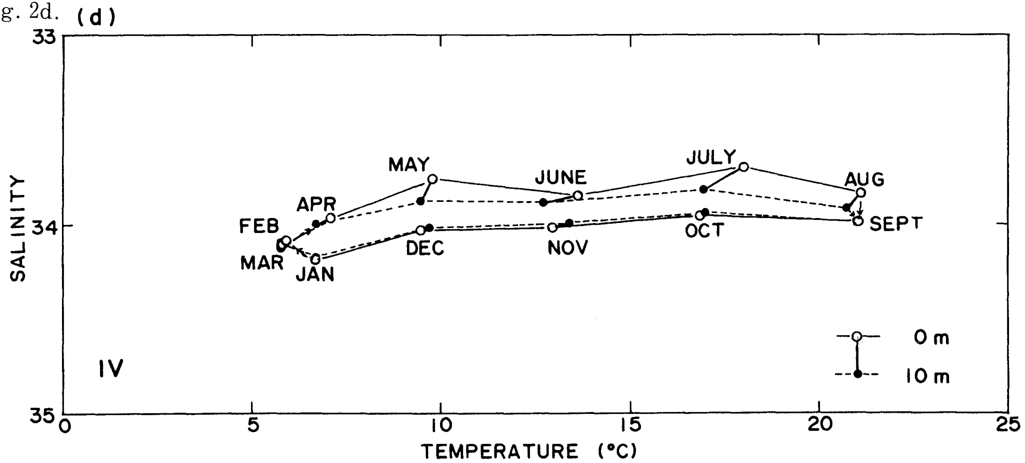


Table 1. Figure numbers of temperature-salinity frequency distributions shown in the present paper.

	Whole Area		Area I		Area II		Area III		Area IV	
	0 m	10 m	0 m	10 m	0 m	10 m	0 m	10 m	0 m	10 m
January	-	-	-	-	-	-	-	-	-	-
February	Fig. 3a	-	-	-	-	-	Fig. 3b	-	-	-
March	Fig. 6a	-	Fig. 6b	-	-	-	-	-	-	-
April	Fig. 7a	-	-	-	-	-	Fig. 7b	Fig. 7c	-	-
May	Fig. 8a	-	-	-	-	-	Fig. 8b	Fig. 8c	Fig. 8d	-
June	Fig. 9a	-	-	-	-	-	-	-	Fig. 9b	-
July	Fig. 10	-	-	-	-	-	-	-	-	-
August	Fig. 11a	-	-	-	Fig. 11b	Fig. 11c	-	-	Fig. 11d	-
September	Fig. 12	-	-	-	-	-	-	-	-	-
October	Fig. 13	-	-	-	-	-	-	-	-	-
November	Fig. 14	-	-	-	Fig. 18	-	-	-	-	-
December	Fig. 15	-	-	-	-	-	-	-	-	-

(a)

Whole Area February 0 m 5064 stations

	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17 (°C)	Total
-32.0								0													0
32.0-32.2	1																				1
32.2-32.4	1										0		0								1
32.4-32.6							0							0							0
32.6-32.8												0									0
32.8-33.0		0																			0
33.0-33.2		1											0								1
33.2-33.4		0		0							0		0			0					1
33.4-33.6			0			0			0		1	0									2
33.6-33.8			5	2	0		0	0	1	1	2	2	0	1							15
33.8-34.0			11	13	24	5	5	4	0	6	11	17	10	6	1	0					*113*
34.0-34.2			*70*	*43*	*35*	*47*	*52*	21	21	*27*	*37*	*64*	*49*	26	8	2	0				*502*
34.2-34.4			1	4	0	5	2	8	16	*34*	32	*45*	*51*	29	18	5	2	0			*251*
34.4-34.6						1		1	1	1	4	4	9	12	21	17	5	1			*76*
34.6-34.8											0	0	1	4	9	10	6	2	0		32
34.8-35.0													0	2	1	1	1	0			5
Total	1	1	*87*	*62*	*60*	*57*	*60*	34	*39*	*68*	*87*	*132*	*119*	*81*	*58*	36	14	3	0		1000

(b)

Area III February 0 m 1884 stations

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 (°C)	Total
33.0-33.2											0							0
33.2-33.4																		-
33.4-33.6							0		0									0
33.6-33.8		0	0			0	2		2	2	0	2						9
33.8-34.0	15	14	40	2	1	4		5	5	28	17	12	1	0				*143*
34.0-34.2	*77*	*52*	26	37	36	26	33	*42*	*43*	*92*	*81*	40	10	0				*596*
34.2-34.4	2	2	1	1	1	4	7	27	*40*	*56*	*51*	19	18	0				*229*
34.4-34.6				2			0	0	4	4	4	2	3					19
34.6-34.8												2	0					2
34.8-35.0												1				0		1
Total	*94*	*68*	*68*	*42*	*38*	34	*42*	*75*	*94*	*182*	*153*	*77*	32	1	-	0		1000

Fig. 3. Temperature-salinity frequency distributions at the sea surface in February (a) for the whole area and (b) for Area Ⅲ. Relative frequencies in per mille are shown in bivariate class intervals of 1℃×0.2 (‰ or psu). The range for which summed frequencies are not less than 75% is shown in shaded areas and constituents of the range of not less than 50% in italics. Italics of total frequencies for each of temperature and salinity denote constituents of the range of not less than 90%. The frequency '0' means a frequency of less than 0.5 per mille (0.05 per cent).

The pattern of the annual variation of the *T-S* relation can be identical with that in Area Ⅱ except for smaller salinity range.

Area Ⅳ is the northeastern part of the sea, west of the northernmost Honshu and Hokkaido. It is defined as the area in which the monthly mean SSS shows the maximum 34.0 or more in winter and its annual range is less than 0.5 (Fig. 2d). Observations have been sparse in the western half portion. The example is taken from the near-coast district with sufficient data.

The features described above are nothing but the results based on the monthly mean characteristics. Fluctuations among the month and the area and interannual variations are not shown. They can be shown in the *T-S* frequency distribution as overall variations.

4. Seasonal variation of temperature-salinity frequency distributions

A total of 120 *T-S* frequency distribution figures are provided; significant ones of them are shown in the following (Table 1).

Because of lack of data in most parts, temperature-salinity frequency distributions for January are not presented in this paper.

The frequency distribution for the whole area in February clearly shows two modes (Fig. 3a, [0-1℃, 34.0-34.2], 7.0% and [9-10℃, 34.0-34.2], 6.4%). These two modes are more noticeable at 10 m (7.5% and 6.8%). This is due to the existence of the polar front indicated by a sharp meridional gradient in SST found between 39° and 42°N (Isoda *et al.*, 1991). The value of the cold mode is only 7.7% in Area Ⅲ (Fig. 3b), the central part, because a smaller portion of the area occupies the north of the polar front. The warm mode is conspicuous in Area Ⅲ (9.2%). The mean SST distribution in February (Sudo's Mapping) shows that four every one degree isotherms of 9-12℃, extending roughly zonally from the Korean coast to the Japan coast between 36° and 39°N, make a little broad zones between meighboring isotherms. The distance between east and west coasts or zonal width of the Japan Sea increases with latitude; therefore, the northernmost zone between 9 and 10℃ is the largest area. In Area Ⅱ, the southwestern part, the distribution has the mode [11-12℃, 34.2-34.4] (10.1%). The mean SSS in February decreases northeastward from the Tsushima Strait and an isohaline of 34.2 runs with an arc shape from 38°N at the eastern coast of Korea to the west of the Wakasa Bay. In the whole study area the mean SSS in February is more than 34.0 except the northwestern part and near the Japan coast east of 135° E. A water with a salinity of 34.0-34.2 exceeds 50% of the whole surface water (Fig. 3a, the rightmost row) and amounts 60% in the central parts (Fig. 3b). The mode in Area Ⅰ, the Tsushima Strait area, is [14-15℃, 34.6-34.8] (14.4%) in February as expected from Fig. 2a. A weak mode [4-5℃, 34.0-34.2] (5.2%) in Fig. 3a corresponds to the mode at the same class in Area Ⅳ (22.4%), the northeastern part. Probably this represents the Tsushima Warm Corrent water at the sea surface west of Hokkaido, but the relation between the water and the polar front is not clear.

The bivariate classes containing at least 50% and 75% of the surface water of the whole area are 11 and 21 in number, respectively (Fig. 3a). The 75% range is about twice the 50% range in class number regardless of area, month and depth; however, the number of classes for the sea surface is about the same or a little more

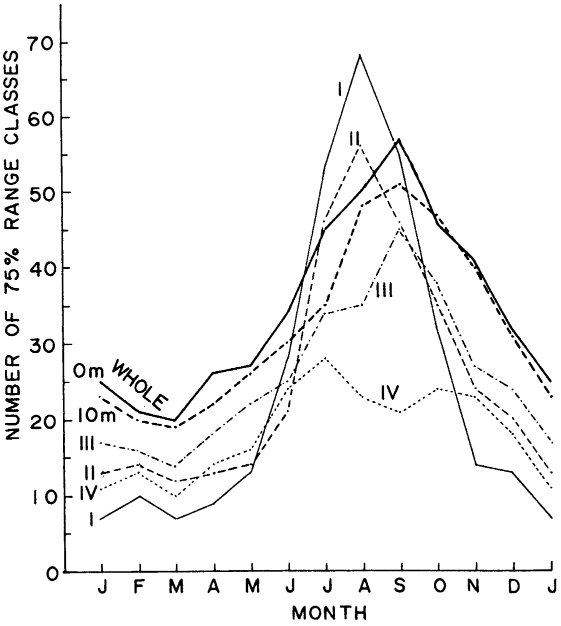


Fig. 4. Numbers of *T-S* frequency classes constituting the range of not less than 75% at the sea surface.

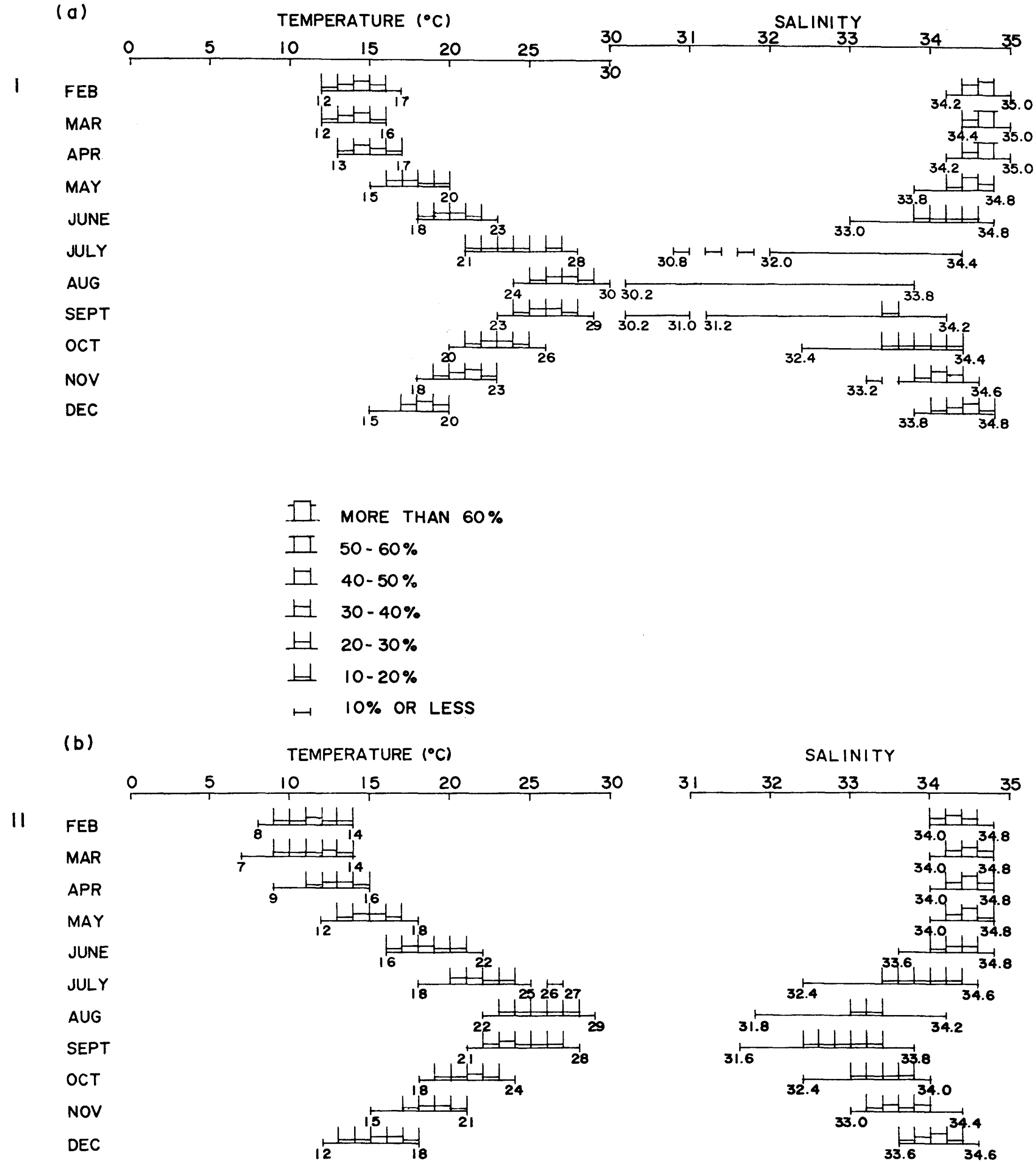
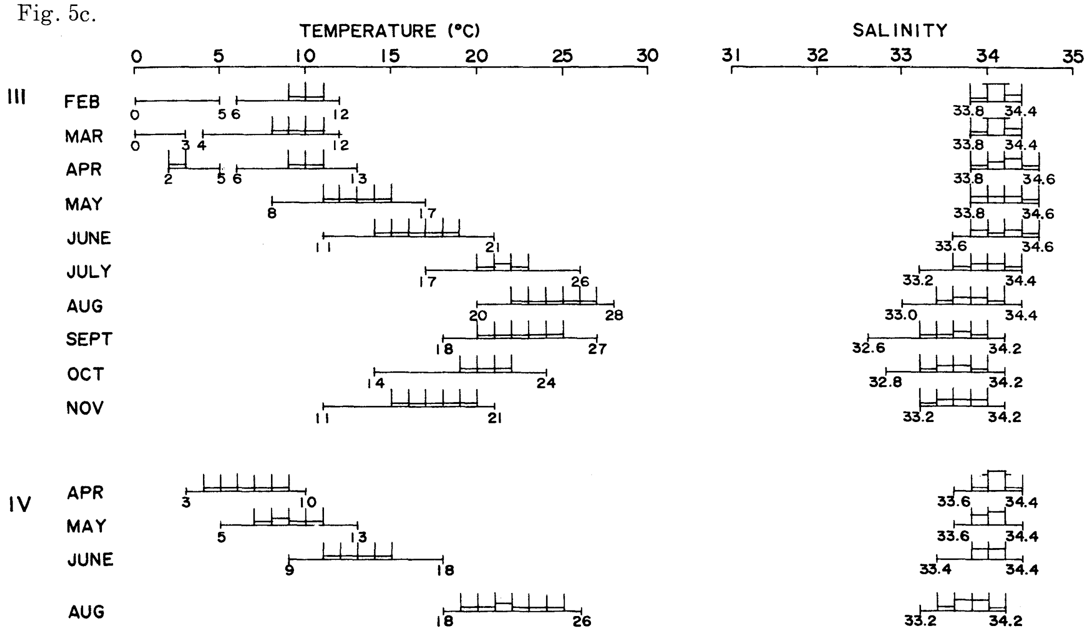


Fig. 5. Not less than 90% frequency ranges of SST and SSS (a) for Area I, (b) for Area II and (c) for Areas III and IV. The ranges for months in which less than 800 stations are taken are omitted.

than that for 10 m depth except for Area II in August (Fig. 11b-c). These numbers indicate scattering or variation of water properties (Fig. 4). For the sake of simplicity, separated frequency distributions of SST and SSS for 90% range are shown instead of bivariate distributions for each of four areas (Fig. 5).

T-S frequency distributions in March are slightly different from those in February. Winter convection derived from strong surface cooling and evaporation lasts until February or March; therefore, SST minimum in the Japan

Fig. 5c.



(a)

Whole Area March 0 m 4903 stations

	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 (°C)	Total
-32.0											0									0
32.0-32.2										0			0							0
32.2-32.4		0								0										0
32.4-32.6		0								0	0		0							0
32.6-32.8	0										0	0								1
32.8-33.0										0		0								0
33.0-33.2									0		0	0		0						1
33.2-33.4		0							0	0	0	0				0				1
33.4-33.6					0	0	0		0	1	1	1	1	0						4
33.6-33.8				0	0				1	1	4	3	3	0	0					12
33.8-34.0			26	10	6	8	2	5	2	5	17	15	6	1		0	0			*103*
34.0-34.2			21	*78*	*46*	*46*	*57*	*45*	*41*	38	*43*	*43*	25	8	1	0				*490*
34.2-34.4			1		1	2	3	10	14	12	*39*	*49*	*43*	19	3	2	1	0		*198*
34.4-34.6							0	0	1	0	4	8	22	28	29	12	2	0		*105*
34.6-34.8									0		0	3	5	13	25	22	4	0		*74*
34.8-35.0												0	1	3	1	2	1	1		9
35.0-35.2													0	0			0	0		1
Total	1	0	48	*88*	*53*	*56*	*63*	*59*	*59*	*58*	*108*	*122*	*104*	*72*	*59*	38	8	2		1000

(b)

Area I Mar 0 m 1134 stations

	10	11	12	13	14	15	16	17 (°C)	Total
33.6-33.8			1						1
33.8-34.0									0
34.0-34.2		0		0					1
34.2-34.4	0	2	7	6	16	12			43
34.4-34.6	1	6	49	*109*	91	30	3		*288*
34.6-34.8	1	34	71	*158*	*201*	*102*	2		*569*
34.8-35.0	1	17	5	25	17	22	7		*94*
35.0-35.2		1				3			5
Total	3	61	*133*	*298*	*324*	*169*	12		1000

Fig. 6. As in Fig. 3 but in March (a) for the whole area and (b) for Area I.

(a)

Whole Area April 0 m 6277 stations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19(°C)	Total
-31.0				0	0	0	0	0	0	0	0		0			0				2
31.0-31.2							0			0										0
31.2-31.4				0	0	0	0			0	0		0							1
31.4-31.6				0									0							0
31.6-31.8					0	0	0	0	0			0	0							1
31.8-32.0						0	0		0	0										0
32.0-32.2					0		0		0	0	0	0								0
32.2-32.4					0	0	0	0	0	0		0	0							1
32.4-32.6					0	0	0	0	0	0		0	0							1
32.6-32.8						0	0	0	0	0	0	0	0							1
32.8-33.0					0	0	0	0	0	0	0	0					0			1
33.0-33.2				0	1	0	0	0	0	0	0	0	0			0				3
33.2-33.4			0	0	0	0	0	1	1	0	0	0	0							4
33.4-33.6	13	0	1	5	0	1	1	3	1	1	1	0	0		0					28
33.6-33.8	0	0	1	1	1	1	3	3	2	2	2	1	0	0		0	0			18
33.8-34.0	16	*38*	14	11	5	5	5	7	9	7	4	1	0	0	0	0	0			*124*
34.0-34.2	5	23	21	*35*	*43*	*40*	*38*	*45*	*31*	23	10	3	2	1	1	0	0	0		*322*
34.2-34.4	10	2	0	1	2	5	*34*	19	*65*	*46*	*27*	15	8	3	1	0	0			*239*
34.4-34.6	10	1			0	0	0	4	7	20	*33*	*34*	25	19	7	1	0	0		*162*
34.6-34.8							1	2	2	4	9	17	22	17	6	1	0			*79*
34.8-35.0							1	0	0		1	2	2	5	1	0				12
35.0-35.2							0	0					0	0	0					1
Total	*54*	*65*	38	*55*	*54*	*54*	*86*	*86*	*120*	*104*	*87*	*75*	*61*	*44*	16	3	1	0		1000

(b)

Area III April 0 m 1331 stations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19(°C)	Total
31.2-31.4													0							0
31.4-31.6																				-
31.6-31.8													0							0
31.8-32.0																				-
32.0-32.2												0								0
32.2-32.4																				-
32.4-32.6										0			0							1
32.6-32.8													0							0
32.8-33.0									0			0					0			0
33.0-33.2									0	0		0				0				1
33.2-33.4								0	0	0	0	0								1
33.4-33.6	9		3	12				2	0	1	2	0	0							29
33.6-33.8						1	2	1	1	2	3	1	0	0		0				12
33.8-34.0		*91*	31	15	1	3	6	4	10	9	8	2	0	0	0	0	0			*181*
34.0-34.2		13	21	*46*	20	*35*	24	34	*44*	*34*	15	6	4	0	0	0	1	0		*298*
34.2-34.4		2	1	1	1	10	*48*	30	*122*	*68*	22	13	3	2	0	0	0			*324*
34.4-34.6		2			0		1	5	9	*37*	32	13	5	5	0	1	0	0		*112*
34.6-34.8							3	3	3	4	4	9	4	1	0					32
34.8-35.0							3	1			1	1	0	1						7
35.0-35.2							0	1												1
Total	9	*109*	*57*	*74*	23	*49*	*86*	*81*	*189*	*156*	*87*	*47*	17	9	1	1	2	0		1000

(c)

Area III April 10 m 1101 stations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15 (°C)	Total
32.4-32.6									0							0
32.6-32.8																-
32.8-33.0											0					0
33.0-33.2												1				1
33.2-33.4									0	1						1
33.4-33.6								0	0	0	0	1				2
33.6-33.8							2	1	2	5	1					10
33.8-34.0	0	*114*	40	19	1	8	3	2	10	9	8	1	0			*216*
34.0-34.2		9	1	32	39	9	31	*58*	*67*	*40*	15	4	0	0		*307*
34.2-34.4	5	0	0	7	1	9	18	26	*116*	*82*	26	10	2	1		*302*
34.4-34.6							3	6	21	29	*45*	14	8	5		*131*
34.6-34.8							4	3	2	3	2	3	5	0		22
34.8-35.0							3	2				1				6
35.0-35.2							0	1								2
Total	5	*124*	*42*	*57*	*41*	25	*65*	*98*	*219*	*169*	*98*	36	15	6		1000

Fig. 7. As in Fig. 3 but in April (a) for the whole area and for Area Ⅲ (b) at the sea surface and (c) at 10 m.

Sea occurs in February or March. In March the cold mode shifts to 1℃ warmer class, [1–2℃, 34.0–34.2] (7.8% for the whole area (Fig. 6a); 8.0% for Area Ⅲ), and the warm one to 0.2 higher salinity class [9–10℃, 34.2-34.4] for the whole area (Fig. 6a, 4.9%) and the same as in February for Area Ⅲ (8.0%).

Areal and time variations of surface water characteristics in March are smaller than those in any other month; 50% and 75% frequency ranges show fewest classes for all of the areas (Fig.4). In particular, 50% and 75% of the surface of Area I are characterized by only four and seven *T-S* bivariate classes with a mode [14–15℃, 34.6–34,8] (Fig. 6b, 20.1%). In Area Ⅳ the frequency of salinity range 34.0 - 34.2 amounts to 69% (at the sea surface) and 80% (at 10 m).

There is not much difference in surface water characteristics between in March and in April (Figs. 2 and 5). On the whole, the surface water is a little warmed and its salinity distribution is slightly diffused (Fig. 7a). A cold water of less than 1℃ completely disappears. The cold mode is weaken shifting to a lower salinity class [2–3℃, 33.8–34.0] and its frequency (3.8%) is less than that of the middle mode [5–6℃, 34.0–34.2] (4.3%). The salinity mode of 34.0–34.2 is less than that in March by 16.8%; 6.2% of this decrease is diffused to lower classes and 10.6% to higher classes. On the average the monthly mean SSS in April is the highest in a year. In particular, in Area Ⅱ, the southwestern part, there is an alternation of 8.2% from low salinity water (<34.4) to high salinity water (>34.4) (Fig. 5b). On the contrary, in the Tsushima Strait region, surface water freshening already starts in the month; 7.5% of the sea surface is altered from high salinity water (>34.4) to low salinity water (<34.4) during March to April. Salinity dispersion in Area Ⅲ is noticeable (Fig. 7b). The water with a salinity of 34.0–34.2 occupying more than a half in March shows a decrease by 24.0%. This decrease is replaced by increases of lower one by 6.4% and higher one by 17.6%. The cold mode shifts to 0.2 lower class [2-3℃, 33.8-34.0] (9.1%) and the warm mode to 0.2 higher class

(a)

Whole Area May 0 m 7185 stations

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23 (°C)	Total
-30.0						0	0	0	0	0	0	0										1
30.0-30.2				0									0									0
30.2-30.4									0	0		0				0						0
30.4-30.6								0	0	0	0	0										0
30.6-30.8							0	0		0	0	0										0
30.8-31.0									0	0	0	0	0	0								1
31.0-31.2								0	0	0	0		0		0							1
31.2-31.4							0	0	0	0	0	0		0	0							0
31.4-31.6						0	0	0			0	0		0								0
31.6-31.8					0		0		0	0	0			0	0	0						1
31.8-32.0				0			0	0	0	0	0	0	0									1
32.0-32.2					0	0		0	0		0	0	0			0						1
32.2-32.4				0		0		0	0	0	0	0	0		0							2
32.4-32.6			0			0		0	0	0	0		0	0	0							2
32.6-32.8							0	0	0	0	0	0	1	0	0	0						3
32.8-33.0				0		0	0	0	1	0	1	0	1	0	0	0						4
33.0-33.2			0	0	0	0	2	0	0	1	0	0	0	0	0			0				5
33.2-33.4					0	0	2	2	1	1	1	1	0	0	0	0						9
33.4-33.6	0	0	0		0	2	2	1	1	2	2	1	0	2	0							13
33.6-33.8	0		0	1	1	6	4	4	5	2	3	3	2	0	0	0						31
33.8-34.0	3	1	8	16	22	40	40	26	18	9	5	6	4	3	1		0					203
34.0-34.2		5	5	15	31	34	43	36	26	30	25	18	8	4	2	1	0					284
34.2-34.4					0	5	6	15	23	38	32	33	22	11	7	2	1	0	0			196
34.4-34.6							0	1	4	7	31	35	43	36	18	5	1	1	0	0		182
34.6-34.8										0	2	10	17	14	9	3	0	0	0	0		57
34.8-35.0									0	0	0	0	1	1		0						3
35.0-35.2													0									0
Total	4	7	14	32	55	88	99	88	81	93	103	108	102	73	37	12	3	1	0	0		1000

Fig. 8. As in Fig. 3 but in May (a) for the whole area, for Area Ⅲ (b) at the sea surface and (c) at 10 m and (d) for Area Ⅳ.

Fig. 8b.

Area III May 0 m 2824 stations

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23 (°C)	Total
30.8-31.0													0									0
31.0-31.2											0											0
31.2-31.4														0								0
31.4-31.6														0								0
31.6-31.8										0												0
31.8-32.0																						-
32.0-32.2																						-
32.2-32.4										0												0
32.4-32.6										0	0		0									0
32.6-32.8										0												0
32.8-33.0								1		0	0	0				0						1
33.0-33.2										2			0		0							2
33.2-33.4								0	1	1	1	1	1	1	0	0						5
33.4-33.6						3		1	1	2	3	1	0	1								11
33.6-33.8						9	2	3	9	2	3	5	3	0	0	0		0				37
33.8-34.0	8		8	1	21	40	56	30	23	17	8	7	6	3								228
34.0-34.2		0	1	2	15	24	21	40	40	46	35	24	12	3	2	0	0					265
34.2-34.4					0	5	8	19	44	60	45	42	23	12	6	1	1					268
34.4-34.6							0	3	7	12	38	33	32	20	8	0	0	1		0		156
34.6-34.8										1	1	8	6	8	2	0						27
34.8-35.0									1	0						0						1
Total	8	0	9	2	36	82	87	97	126	143	134	121	84	47	18	3	2	1	-	0		1000

Fig. 8c.

Area III May 10 m 1751 stations

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22 (°C)	Total
31.0-31.2											0										0
31.2-31.4													0								0
31.4-31.6													0								0
31.6-31.8													0								0
31.8-32.6																					-
32.6-32.8									0	0											0
32.8-33.0										0	0		0								0
33.0-33.2										1		0		0							1
33.2-33.4								2	1	1	2	1	1								7
33.4-33.6						4		0	3	2	0	1	1	1							12
33.6-33.8						11	1	1	13	4	4	2	1		0						36
33.8-34.0	8	0	5	1	34	63	22	52	13	15	11	11	2	1							238
34.0-34.2		0	4	0	0	42	23	41	47	45	30	18	15	2	1	0					268
34.2-34.4				0	0	13	8	22	48	51	42	37	23	10	3	0	0		1		258
34.4-34.6								3	10	10	38	33	37	16	7	1					155
34.6-34.8										1	1	7	5	7							21
34.8-35.0									1	0			1	0							3
Total	8	1	9	2	35	133	54	121	135	130	127	111	86	36	11	2	0		1		1000

[9-10℃, 34.2-34.4] (12.2%). Both modes are strengthened, especially the former at 10 m (Fig. 7c, 11.4%). This indicates that the polar front appears in the surface water most clearly in April. In Area Ⅳ, the northeastern part, a little freshening is seen, but the salinity mode (34.0-34.2) still exceeds 60% (Fig. 5c). The salinity increase of the sea is due to a northeastward transport of the high salinity Tsushima Warm Current water. The freshening observed in the central and northern parts is likely due to the discharge of the snow melted fresh water from the land, mainly northern Japan.

In May frequency distributions in 50% and 75% ranges are flattened in the whole area; all of the 14 classes included in the 50% range at the sea surface show relative frequencies of 3.0% to 4.3% (Fig. 8a). Three modes are still distinguished ([9-10℃, 34.0-34.2], 4.3%, [12-13℃, 34.2-34.4], 3.8% and [15-16℃, 34.4-34.6], 4.3%). At 10 m the middle mode disappears. Unlike in February to April, the cold mode corresponds to a single mode in Area Ⅳ (Fig. 8d, [8-9℃, 34.0-34.2], 9.6%). In Area Ⅲ, frequency values of modes are flattened and temperature differences between modes are diminished both at 0 m and 10 m. Four modes including two middle modes (Fig. 7b, [4-5℃, 34.0-34.2], 4.6% and [7-8℃,

Fig. 8d.

Area IV May 0 m 966 stations

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18 (°C)	Total
30.2-30.4										0			0				1
30.4-30.6																	-
30.6-30.8								0	1								1
30.8-31.0																	-
31.0-31.2																	-
31.2-31.4								0	0	0			0				1
31.4-31.6								0									0
31.6-31.8								0									0
31.8-32.0													0				0
32.0-32.2									0	0							1
32.2-32.4							0		1								1
32.4-32.6							1		1	1		1					4
32.6-32.8								0	0	0				6			7
32.8-33.0								0	0	4	1						6
33.0-33.2				1	0		1	0	1	2	0	1					8
33.2-33.4							0	1	11	4	1	0	1	0			20
33.4-33.6			1	1		1	4	5	4	3	4	2	0			1	25
33.6-33.8				1	2	2	8	14	8	5	1	7	0				47
33.8-34.0		1	4	19	28	44	73	72	37	28	11	0	4	2			323
34.0-34.2			31	21	38	76	96	84	46	40	24	14	3	3	3		480
34.2-34.4						2	17	14	9	12	11	3	1	1			71
34.4-34.6														1	3		5
Total		1	36	43	68	125	201	192	120	99	55	29	11	13	7	1	1000

(a)

Whole Area June 0 m 7605 stations

	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26(°C)	Total
-31.0										0		0	0	0			0		0					1
31.0-31.2													0	0	0									0
31.2-31.4												0	0	0	0									0
31.4-31.6							1	0					0	0	0									2
31.6-31.8												0	0	0	0		0	0						1
31.8-32.0											0	0	0	0	0	0	0							1
32.0-32.2								0	0	0	0	0	0	0	0	0	0	0	0					2
32.2-32.4										0		0	0	0	0	0	0	0	0					1
32.4-32.6								0		0	0	0	0	0	0	0	0	0	0					2
32.6-32.8							0	0	0	0	0	1	1	0	0	0	0	0	0					3
32.8-33.0							0	0	0	0	0	0	1	0	1	0	0	0	0					5
33.0-33.2						0	0	0	0	0	0	1	0	1	1	1	0	0	0					7
33.2-33.4						0	0	1	1	1	1	1	2	2	2	1	1	0	0					13
33.4-33.6				1	0	0	2	1	1	1	1	1	4	4	5	2	1	0	0	0				26
33.6-33.8	0		1	1	3	5	8	8	10	12	16	5	6	6	5	5	3	1	0					94
33.8-34.0				0	5	17	24	44	26	32	24	16	9	12	11	8	4	2	0	1	1			235
34.0-34.2			0	1	3	6	10	14	10	23	33	23	27	22	16	8	4	1	2	0	0			203
34.2-34.4						0	3	5	5	6	14	21	37	43	37	26	14	5	4	1	0			220
34.4-34.6						1	1		1	0	2	14	23	33	37	25	12	3	2	1				155
34.6-34.8							0	0	0	1	1	2	3	6	3	4	5	1	0	0		0		26
34.8-35.0								1			0	0	0		0	1	0	0		0				3
35.0-35.2															0	0								0
Total	0	-	1	4	11	29	49	74	53	77	94	88	114	131	120	82	45	15	9	4	1	0		1000

Fig. 9. As in Fig. 3 but in June (a) for the whole area and (b) for Area Ⅳ.

34.2–34.4], 4.8%) found at the sea surface in April are reduced to two in May (Fig. 8b); the two colder modes in April must be merged into the cold one ([9–10℃, 33.8–34.0], 5.6%) in May and the two warmer ones into the warmer one ([12–13℃, 34.2–34.4], 6.0%). At 10 m there is a weak middle mode in April (Fig. 7c, [5–6℃, 34.0–34.2], 3.9%) and in May three modes still exist two degrees apart for each neighboring two (Fig. 8c, [8–9℃, 33.8–34.0], 6.3%, [10–11℃, 33.8–34.0], 5.2% and [12-13℃, 34.2–34.4], 5.1%). Apparently the cold mode in Area Ⅲ corresponds to the mode in Area Ⅳ as in the whole area though the former is 0.2 lower in salinity

Fig. 9b.

Area IV June 0 m 1365 stations

	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21 (°C)	Total
31.2-31.4											0						0
31.4-31.6													0				0
31.6-31.8													1				1
31.8-32.0									0	1	1						2
32.0-32.2							0	1		0	1	1					3
32.2-32.4								0		1		0	0				2
32.4-32.6										1							1
32.6-32.8							0		0	4	2	1	0				7
32.8-33.0							2	2	1	1	4			0			9
33.0-33.2					1	3	1	1	3	5		0	1				15
33.2-33.4				1	1	0	3	4	1	1	4	0	2				17
33.4-33.6				2	9	2	2	5	5	1	3	3	3	1			35
33.6-33.8			2	1	4	19	22	14	17	5	5	6	1	0			93
33.8-34.0		3	8	31	39	71	53	57	38	27	17	13	2	5			363
34.0-34.2	3	8	16	34	22	30	25	58	52	30	35	9	7	1	0		330
34.2-34.4				0	15	19	9	5	12	14	7	5	4	1			93
34.4-34.6								0	1	8	4	1	10	3			27
34.6-34.8										1			2				3
Total	3	10	26	68	90	143	117	147	132	98	82	38	33	12	0		1000

Whole Area July 0 m 5581 stations

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31 (°C)	Total
-29.0									0	1	0		0				0					1
29.0-30.0									0	0	0			0	0		0					1
30.0-30.2									0	0	0			0								0
30.2-30.4														0								0
30.4-30.6												0		0			0					0
30.6-30.8											0	0		0	0	0	0					1
30.8-31.0										0	0			0		0	0					1
31.0-31.2									0	1	0	0		0		0						1
31.2-31.4									0	1	0		0	0	0	0	0		0			2
31.4-31.6									0	0	0	0	0	0		0	0	0				2
31.6-31.8									0	0		0	0	1	0	1	0	0				3
31.8-32.0								0	0	0	0	1	1	1	0	1	1	0				6
32.0-32.2			0		0			0		1	0	0	2	2	0	0	0	0				6
32.2-32.4				0				0	0	1	0	1	1	1	1	0	1	0	0			7
32.4-32.6							1	0	0	1	1	1	2	2	0	1	1	1	0			10
32.6-32.8				0		0	1	0	1	1	1	2	2	1	2	0	1	0				12
32.8-33.0					0	1	1	0	2	2	1	2	3	2	1	0	0					15
33.0-33.2					0	0	0	2	1	2	4	4	4	4	1	1	1	0				24
33.2-33.4				0	5	1	2	5	2	4	9	7	7	6	4	1	1	0				54
33.4-33.6	0	0	0	1	2	3	7	8	9	10	17	15	9	6	3	2	2	0	0			92
33.6-33.8		1	3	9	16	16	22	22	17	24	25	17	10	10	4	2	1	0	0			199
33.8-34.0	1	5	6	6	9	18	29	21	18	24	31	26	21	17	7	4	2	0		0		244
34.0-34.2	0		4	4	7	7	9	17	19	33	43	22	11	8	5	4	1	0				194
34.2-34.4		0		3	1	0	0	2	9	25	26	16	6	3	3	2	0	0				98
34.4-34.6					1	1	0	1	1	6	4	6	4	1	0	0						25
34.6-34.8							0	0	0	0	0	0										1
34.8-35.0							0	1														1
Total	1	6	14	23	42	47	72	81	79	136	164	121	83	66	31	19	11	4	1	0		1000

Fig. 10. As in Fig. 3 but in July for whole area.

than the latter at the sea surface. These mode characteristics imply that the polar front is weakened and the surface water north of the front is warmed by 6–7℃ during April to May except for the northeastern part. Whether this rapid warming is due to only solar radiation absorption or partly current pattern variation cannot be explained owing to insufficient data. Though the cold mode is concealed in total temperature frequency distribution (the bottom line) in Fig. 8b, it is discernible at 9–10℃ (9.9%) in Fig. 8a and clearly seen at 8-9℃ at 10 m in Area Ⅲ (Fig. 8c, 13.3%) as well as in the whole area (11.3%).

Overall freshening of the surface water continues. The water of salinity >34.0 decreases by 9.3% compared with in April, but high salinity water (>34.4) decrease is only 1.2% (Fig. 8a). In Area I the water >34.4 decreases by 17.9% (Fig 5a) and the lower limit shifts from 33.0 to 31.0. This saline water (>34.4) decrease is 4.6% ia Area Ⅱ (Fig. 5b); on the contrary in Area Ⅲ the saline water increases by 3.2% (Fig. 8b).

Salinity dispersion and overall freshening continue until September and northeastward transport of high salinity water continues at least until June. Cold modes are common to upper 10 m depths ([11–12℃, 33.8–34.0], 4.4% at 0 m (Fig. 9a); 4.7% at 10 m) and warm modes shift to 0.2 lower salinity class ([17–18℃, 34.2–34.4], 4.3% at 0 m (Fig. 9a); [16–17℃, 34.2–34.4] 4.9% at 10 m). In Area Ⅲ both modes being the same as in the whole area are clearly seen at 10 m (cold 6.0% and warm 7.3%), but the cold mode is indiscernible through total temperature frequencies in upper 10 m depths. In Area Ⅳ two cold modes are clearly seen at the sea surface (Fig. 9b, [11–12℃, 33.8–34.0] 7.1% and [13–14℃, 34.0–34.2] 5.8%). The saline water (>34.4) shows a sudden decrease in Area I (46.8%) and in Area Ⅱ (29.2%) and a slight increase in Area Ⅲ (0.6%) on the frequency of the previous month; in the whole area it decreases by 5.8%.

A marked warming and freshening occur during June and July for all of the areas. Areas I and Ⅱ are remarkable for salinity decrease and dispersion (Fig. 5a-b). *T-S* bivariate classes of 50% and 75% ranges in both areas in July are about twice in June (Fig. 4). High salinity water (>34.4) decreases to less than 1.0% Area I and to 2.4–3.7% in Areas Ⅱ-Ⅳ. The cold modes in the whole area and Area Ⅲ are still discernible in salinity range 33.8–34.0 (17–18℃, 2.9% at 0 m (Fig. 10) and 16–17℃, 3.3% at 10 m in the whole area; 18–19℃, 2.7% at 0 m and 17–18℃, 2.5% at 10 m in Area Ⅲ), though they are weakened and corresponding total temperature frequencies are flattened.

A further salinity decrease in the sea continues until September. The water of more than salinity 33.8 at the sea surface in August de-

(a)

Whole Area August 0 m 7483 stations

	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31 (°C)	Total
-29.0												0	0	0		0				1
29.0-30.0													0	0	0	0	0			1
30.0-30.2													0	0	0	0	0			0
30.2-30.4														0	0	0	0			1
30.4-30.6														0	0	0	0			1
30.6-30.8													0	0	0	0	0	0		1
30.8-31.0											0	0	0	0	1	1	0			3
31.0-31.2										0		0	0	0	1	0	0			2
31.2-31.4												0	0	0	1	1	1			3
31.4-31.6									0		0	0	0	1	1	1	1	0		5
31.6-31.8						0			0		0	0	1	1	3	1	1	0		7
31.8-32.0										0	0	1	2	3	2	2	1	0		11
32.0-32.2									0	0	0	1	3	2	4	2	1	0	0	13
32.2-32.4							0	0	0	0	1	2	3	3	4	3	1	0		18
32.4-32.6						0		0	1	0	1	2	5	3	4	4	3	0	0	23
32.6-32.8								0	1	1	2	5	5	4	5	6	3	0		32
32.8-33.0			4					0	0	1	2	4	7	10	8	6	3	0		45
33.0-33.2		1			0			2	1	4	4	5	11	9	11	7	3	0		58
33.2-33.4							0	2	7	7	6	15	16	17	12	6	3	0		92
33.4-33.6						5	3	12	23	16	16	13	23	14	13	12	4	0		153
33.6-33.8				1	1	6	7	12	22	40	38	32	23	18	16	10	2	0	0	227
33.8-34.0				0	3	2	7	12	16	21	20	28	23	20	15	8	2	1		177
34.0-34.2			0		0	1	3	1	6	12	15	15	18	10	10	6	1			97
34.2-34.4							0	1	1	0	3	5	4	2	4	2	1			23
34.4-34.6						0	0	0	1	1	0	1	0	1	1	0	0	0		4
34.6-34.8								0	0					0	0	0	0			1
34.8-35.0																				-
Total		1	4	1	4	14	21	41	79	104	108	129	145	119	116	80	31	3	0	

Fig. 11. As in Fig. 3 but in August (a) for the whole area and for Area Ⅱ (b) at the sea surface and (c) at 10 m and (d) for Area Ⅳ.

Fig. 11b.

Area II August 0 m 2458 stations

	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30 (°C)	Total
-29.0											1				0			1
29.0-30.0														0	0			1
30.0-30.2															0			0
30.2-30.4													1	0	1			2
30.4-30.6													1		1	0		2
30.6-30.8													0	1	1	0	0	2
30.8-31.0												1	1		6			8
31.0-31.2									0		1	0	1	2	2	2		8
31.2-31.4											1	1	2	2	2	3		11
31.4-31.6										1	1	1	4	5	3	0	0	16
31.6-31.8					0			0		1	2	2	3	9	3	1	0	21
31.8-32.0									0	2	3	5	11	4	8	1		34
32.0-32.2								0	2	2	3	12	7	13	3	2		43
32.2-32.4						0	1	1	2	3	8	16	10	11	8	3		61
32.4-32.6					0		0	1	1	3	9	18	12	14	12	9	1	81
32.6-32.8							0	2	3	7	11	20	11	13	16	10	1	95
32.8-33.0							1	1	3	2	12	17	20	15	14	8	1	94
33.0-33.2				0			1	1	5	12	16	22	14	17	17	3		108
33.2-33.4							0	2	9	12	16	26	22	22	12	6	2	130
33.4-33.6						1	2	2	4	9	13	22	20	9	11	3	1	97
33.6-33.8					1	1	2	4	7	7	18	19	10	15	10	1		95
33.8-34.0					0		1	0	4	4	13	10	5	4	4	1	0	48
34.0-34.2		0		1	0		1	0	2	1	7	3	4	3	3			25
34.2-34.4						0	0	0		2	3	5	0	3	1			15
34.4-34.6					0		0	1	1		1				0			3
34.6-34.8							0	0								0		1
Total		0		1	2	2	10	17	42	67	137	199	157	162	139	56	7	1000

Fig. 11c.

Area II August 10 m 2365 stations

	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30 (°C)	Total
30.0-30.2																	1					1
30.2-30.4																	0	1	1			2
30.4-30.6																			0	0		0
30.6-30.8																1	1	0	0			2
30.8-31.0															0	0		0	1	0		1
31.0-31.2												0			1	0	0		2			3
31.2-31.4														1		1	1	2	7			11
31.4-31.6															1	0	1	2	2			6
31.6-31.8												0			0	2	4	4	0	1		12
31.8-32.0													2	4	1	3	11	5	5	4		34
32.0-32.2											0	0	1	2	2	13	6	4	4			33
32.2-32.4							1				0	1	2	3	7	12	9	12	2	2		50
32.4-32.6								0	1	1		1	2	2	13	15	15	10	7	4		71
32.6-32.8								0	0	0	1	2	3	4	12	10	14	8	10	3		67
32.8-33.0							0	2	0	4	2	4	4	7	10	17	15	19	7	0		91
33.0-33.2						1	0	3	3	4	2	2	4	6	13	23	9	18	9	2		98
33.2-33.4				1	1	1	1	1	4	3	5	7	8	11	8	16	20	13	15	2		118
33.4-33.6				0	0	2	4	1	5	5	4	7	17	15	19	15	21	12	7	0	0	136
33.6-33.8				0	1	1	1	3	3	4	5	9	10	10	24	11	8	8	10	0		111
33.8-34.0			1		2	2	2	3	2	4	2	5	10	4	21	12	2	1	4			77
34.0-34.2			1	0	1	2	3	2	2	2	1	4	5	5	8	8	2	2	1			48
34.2-34.4		1		1	1	1	1		0	1	1	1	3	1	5	6						23
34.4-34.6								0		1	0	1		0	0	0						3
34.6-34.8										1												1
34.8-35.0									0													0
Total		1	2	3	6	10	15	15	21	28	23	46	72	77	144	164	137	123	94	19	0	1000

creases by 26.1% compared with July (Figs. 10 and 11a). In the Tsushima Strait region, SSS decreases to the minimum of the year and the T-S bivariate distribution shows the maximum number of 50% and 75% classes (36 and 68) that the analysis has yielded for the surface (Fig. 4). The high salinity water (>34.4) completely disappears and warm water of 27–29℃ is scattered over the large salinity range of 28.0–34.4 at the sea surface in Area Ⅰ. In Area Ⅱ 50% range

Fig. 11d.

Area IV August 0 m 927 stations

	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29 (°C)	Total
30.6-30.8										1						1
32.4-32.6						3										3
32.6-32.8										1		1				2
32.8-33.0								0	0		1					2
33.0-33.2						2	2			3	1	4				12
33.2-33.4				4	8	1	9	10	4	12	9	0				58
33.4-33.6				4	6	10	46	18	9	14	8	5	1			122
33.6-33.8		2	11	15	38	29	74	34	42	13	18	5	2			283
33.8-34.0	0	22	16	27	60	36	47	32	32	32	10	5	1			322
34.0-34.2			1	22	2	31	29	16	20	29	7	5	2	1		164
34.2-34.4				1	1	2		6	3	3	1	6	2	2		26
34.4-34.6									5					1		6
Total	0	25	28	74	115	114	207	116	115	107	56	33	7	4		1000

Whole Area September 0 m 5425 stations

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30 (°C)	Total
-29.0												0	0	0							1
29.0-29.2																					-
29.2-29.4												0					0				1
29.4-29.6																	0				0
29.6-29.8																0	0	0			1
29.8-30.0																0	0	0			0
30.0-30.2															0		1				1
30.2-30.4													0	0	0	0	0				1
30.4-30.6														0	0		0				1
30.6-30.8												0		0	0	0	0	0			1
30.8-31.0														1	0	0	2	0			4
31.0-31.2														0	0	0	1	0			2
31.2-31.4										0		0	0	0	2	2	1				6
31.4-31.6												1	1	2	1	1	0	0			5
31.6-31.8											0	0	1	2	2	2	1	0			8
31.8-32.0										0	1	2	4	1	2	4	1	0			15
32.0-32.2										0	0	3	5	4	3	3	2	0			20
32.2-32.4								0			1	4	4	6	5	4	1	0	0		26
32.4-32.6								0	0	2	5	7	8	6	7	4	1	1			40
32.6-32.8			0						0	2	6	6	7	10	10	3	1	1			48
32.8-33.0							0	3	1	6	7	10	8	9	11	7	4	1	1		67
33.0-33.2			0					0	1	5	9	7	10	14	11	4	4	1	0		66
33.2-33.4						0	1	4	3	5	10	12	13	20	14	9	4	0	0		96
33.4-33.6						11	6	2	8	8	14	24	19	16	12	9	1	0			130
33.6-33.8	0		0	1	2	5	4	25	32	27	29	21	18	15	10	8	2		0		198
33.8-34.0					0	7	3	10	14	20	24	24	18	10	5	3	1	0	0		138
34.0-34.2					0	1	1	3	14	17	18	12	9	7	4	1	1				88
34.2-34.4								3	4	10	4	3	2	3	1	1					30
34.4-34.6									1	2	1	1	1	1	0	0					6
34.6-34.8											0	1	1								2
34.8-35.0														0	0						0
Total	0	-	1	1	2	24	16	49	77	104	130	138	127	127	102	65	30	5	1		1000

Fig. 12. As in Fig. 3 but in September for the whole area.

amounts to 69 in bivariate class number at 10 m, because a great vertical temperature gradient in the surface water yields a wider temperature range below the sea surface, while the number reduces to 56 at the sea surface (Figs. 4 and 11b-c). The mode in the area must lie around 25℃, 33.4 at the sea surface and at a little colder side at 10 m, though the distribution evens out.

There is no mode other than [21–22℃, 33.6–33.8] (4.0%) at the sea surface in the whole area (Fig. 11a); however, it seems to deviate slightly towards a colder, fresher side from the midpoint. In Area Ⅲ, a weak mode [19–20℃, 33.4–33.6] (1.8%) is formed at the sea surface besides the first mode [23–24℃, 33.8–34.0] (4.6%).

Double modes are clear at the sea surface in Area Ⅳ (Fig. 11d, [21–22℃, 33.6–33.8], 7.4%

Whole Area October 0 m 8155 stations

	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28 (°C)	Total
-31.0													0		0	0						0
31.0-31.2															0	0						0
31.2-31.4											0	0	0		0							0
31.4-31.6													0		0							0
31.6-31.8														0	0	0	0					1
31.8-32.0													0	1	1	0						2
32.0-32.2											0	0	1	2	1	1	2	0				6
32.2-32.4										0	0	2	1	2	4	0	1	1				11
32.4-32.6											0	2	2	3	5	3	3	1	0			21
32.6-32.8									0	0	1	4	6	4	5	5	2	0	0			28
32.8-33.0								0	0	1	2	5	8	8	9	5	3	1	0			43
33.0-33.2								0	0	2	2	7	11	11	15	9	4	1	0			65
33.2-33.4						0	1	1	1	2	3	9	19	28	22	11	6	1		0		105
33.4-33.6					0	2	2	9	7	6	19	13	20	25	28	16	8	3	1		0	158
33.6-33.8					4	14	14	12	25	16	19	14	17	21	20	14	9	2	1	0		201
33.8-34.0			2	2	2	5	8	11	14	26	34	24	22	17	13	6	5	2	1			195
34.0-34.2				1	6	5	3	18	20	18	21	10	7	7	3	4	2	1	0			126
34.2-34.4							4	2	2	0	9	8	3	1	1	2	1	1	0			34
34.4-34.6								1			1	1		1	1	0	0	0				4
34.6-34.8														0	0	0	0					0
34.8-35.0																	0					0
Total			2	3	13	25	31	54	70	71	113	99	116	133	128	76	46	15	3	0	0	1000

Fig. 13. As in Fig. 3 but in October for the whole area.

Whole Area November 0 m 3958 stations

	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 (°C)	Total
-32.0									0						0	0	0					1
32.0-32.2																0	0					0
32.2-32.4								0	0				0	0		0		1				2
32.4-32.6												0			1	1						1
32.6-32.8											0			1	2	2	0					5
32.8-33.0									0			0	0	5	6	4	3	0				19
33.0-33.2								0	4	4		1	4	9	7	6	7	2				45
33.2-33.4						1					3	5	15	19	17	19	14	5	0			99
33.4-33.6						2	0		15	2	5	19	24	18	22	32	24	8	0			170
33.6-33.8						2		8	4	5	19	23	20	16	31	23	21	14	2			189
33.8-34.0		11			31	6	10	18	23	37	2	12	14	13	22	23	19	17	6	1		265
34.0-34.2				8	3	1	4	10	15	8	13	11	5	7	4	8	9	12	5	1		124
34.2-34.4			1	15	1	6	2	4	4	4	4	4	1	2	3	3	4	7	4	0	0	69
34.4-34.6									0		1	1	0	2	1	1	2	1	1	0	0	10
34.6-34.8														1	0	0	1	0	0		0	2
34.8-35.0																						
Total		11	1	23	35	16	17	41	66	59	47	76	83	93	117	123	104	67	18	2	0	1000

Fig. 14. As in Fig. 3 but in November for the whole area.

and [19–20℃, 33.8–34.0], 6.0%), but the latter disappears at 10 m.

In September SSS in the sea shows the minimum of the year and 50% and 75% ranges occupy 28 and 57 classes, maxima of the year, at the sea surface (Fig. 12). The upper 10 m water of Area I shows an increase of total salinity frequency of every class of more than 32.8 over those in August. On the contrary, total salinity frequencies in Area II decrease in classes of more than 33.2 at the sea surface and of more than 33.4 at 10 m. In Area III, the salinity frequency decrease is limited to classes of more than 33.8 through upper 10 m. The surface water of the northeastern part, Area IV, shows a weak salinity maximum in September (Fig. 2d). The saline water (>34.0) increases by 17.8% in September and decreases by 2.0% in October. The mode at the sea surface in the whole area shifts to two degrees lower class (Fig. 12, [19–20℃, 33.6–33.8], 3.2%), deviating towards a colder, lower salinity side as in August. The weak second mode of high temperature is seem at [24–25℃, 33.2–33.4] (2.0%). Two modes are discernible at both depths in Area III ([19–20℃, 33.6–33.8] 3.7% at 0 m and 3.3% at 10 m; [23–24℃, 33.4–33.6] 3.1% at 0 m and [24–25℃, 33.6–33.8] 3.1% at 10 m) as well, Whole Area December 0 m 3429 station

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21 (°C)	Total
-32.0														0							0
32.0-32.2												0									0
32.2-32.4				0												0					0
32.4-32.6			0								0	0				0					1
32.6-32.8								0	0						0						1
32.8-33.0						1	0							0	0						1
33.0-33.2					0					2	0	0	2	2	4	1	0				10
33.2-33.4											0	1	6	9	2	2	0				20
33.4-33.6		0	0	0				0		3	0	4	2	10	7	8	0			0	35
33.6-33.8			0	0		0	0	3	2	1	6	6	13	20	19	18	5	0			94
33.8-34.0		59	24	4	0	14	9	7	11	7	19	43	33	34	38	25	13	2	0		342
34.0-34.2			5	14	4	44	39	17	22	13	12	10	28	25	35	23	11	3	0		304
34.2-34.4					0	4	8	4	12	2	9	26	16	13	14	16	11	4	2		142
34.4-34.6								3			1	1	5	3	5	7	7	5	1		37
34.6-34.8														1	2	3	3	2	1		10
34.8-35.0													1			0	0	0	0		2
35.0-35.2																	0	0			0
Total		59	29	18	5	62	56	35	47	27	48	91	106	117	127	103	50	16	4	0	1000

Fig. 15. As in Fig. 3 but in December for the whole area.

(a)

Whole Area Year 0 m 66,263 stations

	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31 (°C)	Total
-30.0																																			1
30.0-31.0																																			2
31.0-31.2																																			1
31.2-31.4																																			1
31.4-31.6																																			1
31.6-31.8																																			2
31.8-32.0																														1					3
32.0-32.2																											1	1		1					4
32.2-32.4																											1	1	1	1					6
32.4-32.6																								1	1	1	1	1	1	1					8
32.6-32.8																						1	1	1	1	1	1	1	1	1	1				11
32.8-33.0																				1	1	1	1	1	1	2	1	2	2	1	1				17
33.0-33.2																			1	1	1	1	2	2	3	2	2	3	2	1	1				24
33.2-33.4																	1	1	2	2	2	3	3	4	4	3	3	4	3	2	1				41
33.4-33.6					1							1		1	2	1	1	3	4	4	5	5	6	6	6	6	4	4	2	2	1				68
33.6-33.8											1	2	2	2	3	3	6	7	8	7	8	8	9	9	10	8	6	4	3	2	1				109
33.8-34.0				3	3	12	5	3	4	3	7	8	11	11	13	12	8	10	9	9	10	8	8	8	8	6	6	4	3	2	1				195
34.0-34.2				8	12	11	11	16	12	16	17	16	20	22	18	10	11	11	8	7	6	5	5	7	7	5	3	3	2	1	1				269
34.2-34.4					2	1	1	1	3	6	8	9	16	15	10	11	8	7	6	6	6	5	4	5	3	2	1	1	1	1					139
34.4-34.6					1							1	2	5	7	8	9	7	8	6	5	4	2	2	1	1	1								70
34.6-34.8														1	2	5	5	4	3	2	2	1	1												26
34.8-35.0															1		1	1																	3
35.0-35.2																																			0
Total		0	0	11	19	24	17	21	19	26	34	38	53	57	55	51	51	52	49	45	46	43	42	47	47	38	32	29	21	17	10	3	0	0	1000

Fig. 16. As in Fig. 3 but yearly mean for the whole area (a) at the sea surface and (b) at 10 m. The frequency '0' (less than 0.5 per mille (0.05 per cent)) for bivariate classes is omitted. Solid lines in (b) denotes the same limits as inner limits in Fig. 17.

though total temperature frequency shows a single mode at the sea surface.

After September the surface water of the sea steadily decreases in temperature and increases in salinity; *T-S* bivariate classes of 50% and 75% ranges decrease until winter or early spring. Available stations in the whole area in October make up the greatest number of the year. Figure 13 shows that classes of 2.0% or more spreads widely over the range of 15–22℃, 33.2–34.2 at the sea surface. The mode [17–18 ℃, 33.8–34.0] (3.4%) deviates towards a colder, more saline class from the center; the second mode seems to be around 21℃, 33.5. On the contrary, the first mode is warmer one at 10 m ([17-18℃, 33.8–34.0], 2.9% and [20–21℃, 33.2–

Fig. 16b.

Whole Area Year 10 m 53,343 stations

	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29 30(° C)	Total
-30.0																																	0
30.0-31.0																																	1
31.0-31.2																																	0
31.2-31.4																																	1
31.4-31.6																																	1
31.6-31.8																																	1
31.8-32.0																																	2
32.0-32.2																										1	1	1					4
32.2-32.4																								1	1	1	1	1	1				5
32.4-32.6																						1	1	1	1	1	1	1					7
32.6-32.8																				1	1	1	1	1	1	1	1	1	1				11
32.8-33.0																				1	1	1	2	1	2	2	2	1	1	1			17
33.0-33.2															1		1	1	2	1	2	2	2	2	2	1	2	2	1				24
33.2-33.4																1	2	2	2	2	4	4	5	4	4	3	3	2	1	1			40
33.4-33.6											1	1		2	1	2	4	4	4	5	5	6	7	5	6	5	4	2	2	1			66
33.6-33.8										3	2	2	3	3	4	7	7	8	8	7	8	9	10	9	7	6	4	2	2				113
33.8-34.0				3	13	5	2	4	4	7	12	12	12	8	12	9	10	11	10	9	8	8	8	9	8	5	3	2	1	1			197
34.0-34.2			8	10	10	9	14	13	18	20	19	21	23	17	14	10	11	7	7	5	5	6	7	8	5	3	2	1	1				275
34.2-34.4				4	1	1	1	2	2	6	9	16	15	14	8	7	8	6	8	6	5	4	5	3	1	1	1						135
34.4-34.6												2	5	7	9	8	9	9	7	6	4	2	1	1									72
34.6-34.8													1	1	4	5	4	3	2	1	1	1											23
34.8-35.0																	1																2
35.0-35.2																																	0
Total	0	0	9	17	24	16	17	19	25	37	43	53	60	54	53	50	57	52	51	45	43	46	50	46	40	30	26	18	12	6	1	0	1000

33.4], 3.4%). In addition, a cold mode [15–16 ℃, 33.6–33.8] (4.5% at 0 m and 3.9% at 10 m) appears in Area Ⅲ forming a clear second mode in total temperature frequencies. In Area Ⅳ, two modes are clearly ([15–16℃, 34.0–34.2] 9.4% at 0 m and [16–17℃, 34.0–34.2] 7.3% at 10 m; [18–19℃, 33.8–34.0] 7.4% at 0 m and 10.1% at 10 m).

As total temperature frequencies show in Figs. 14 and 15, three modes are formed in November and December ([7–8℃, 33.8–34.0] 3.1%, [12–13℃, 33.8–34.0] 3.7% and [18–19℃, 33.4–33.6] 3.2% in November; [2–3℃, 33.8–34.0] 5.9%, [6–7℃, 34.0–34.2] 4.4% and [12–13℃, 33.8–34.0] 4.3% in December). The coldest mode must be formed rapidly after October and grows until March.

5. Overall characteristics of *T-S* frequency distributions

The yearly mean *T-S* frequency distributions for the whole study area are obtained with the averages of relative distributions in January through December for the area (Fig. 16). According to a previous analysis, mostly *T-S* relation points for more than 5℃ at the sea surface fall on the lower salinity sides of the line connecting (17℃, 34.7), (13℃, 34.7) and (5℃, 34.1) and of the salinity 34.1 line for less than 5℃ in winter to spring; the upper limit of salinity for more than 17℃ decreases with temperature in spring to summer. This generally agrees with Fig. 16 except that the upper limit of salinity for low temperatures is about 34.4. Figure 16 shows that the highest salinity of more than 34.8 occurs at about 13℃ or a little warmer temperatures. The limit does not depend on temperature for the cold water of less than 8-9℃.

There are five to six modes or large frequency class groups in Fig. 16. They nearly correspond to the class groups of 1.0% or more during five months or more shown in Fig.17. The group centered at the class [10–11℃, 34.0–34.2] (W_2) is conspicuous among them. As stated in section 3 or shown in Fig. 2, little variation during long winter is one of the outstanding characteristics of the surface water of the sea. This group (W_2) shows frequency of 1.0% or more mostly during January to May partly in November, December, or June. The period of the frequency (1.0% or more) for the centered class [10–11℃, 34.0–34.2] covers eight months. The W_2 group mainly denotes *T-S* relations south of the polar front, but probably its colder portion includes the surface water west of northern Japan. The W_1, the only class [2–3℃, 33.8–34.0], definitely shows a water characteristic north of the polar front. These two groups of waters must keep lying on the proper sea areas almost during the period.

Since temperature and salinity values of the

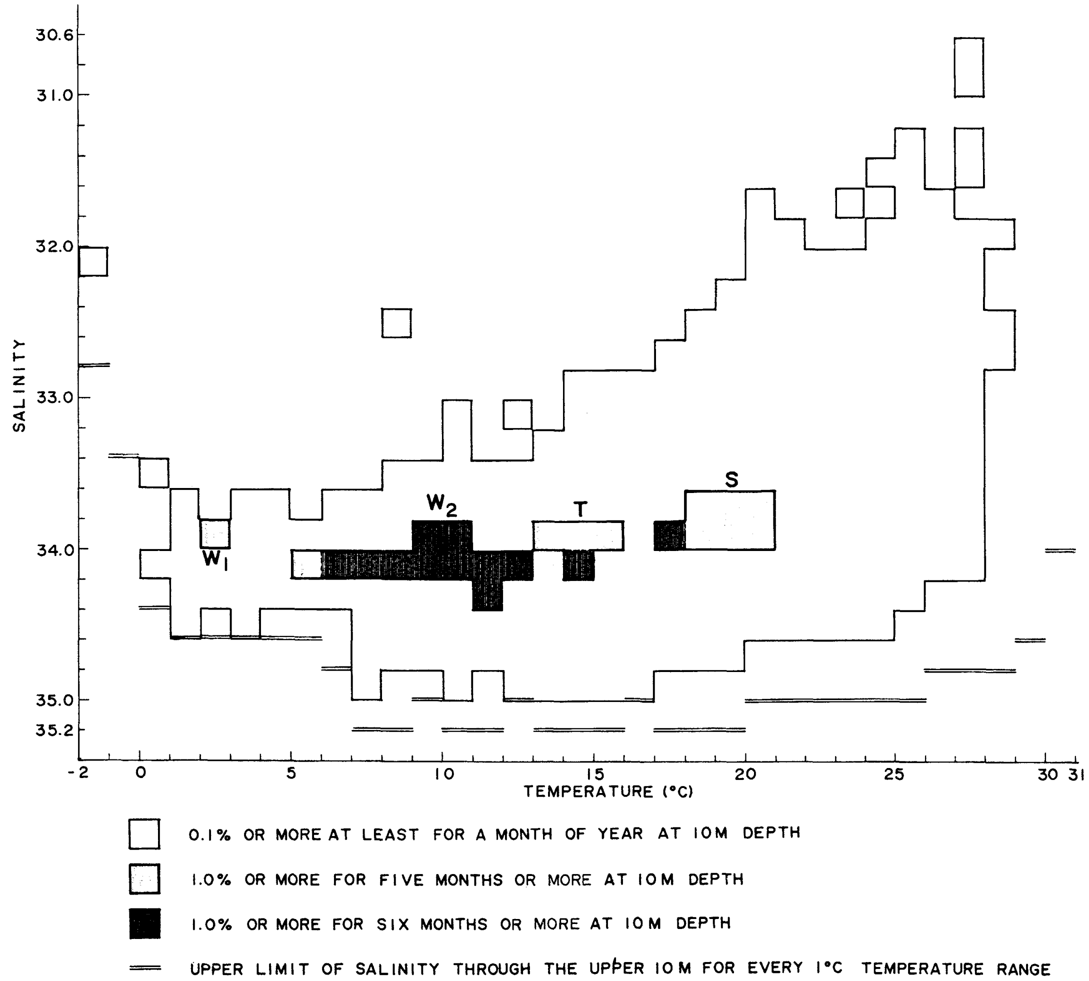


Fig. 17. Overall characteristics of *T-S* frequency distributions of the surface water of the whole study area. Outer solid lines denote the limits within which *T-S* values of 1℃×0.2 (‰ or psu) bivariate classes show frequencies of 0.1% or more at least for a month of year at 10 m depth. Inner solid lines denote the limits within which *T-S* values of the classes show frequencies of 1.0% or more for five months or more of year at 10 m and shaded areas 1.0% or more for six months or more of year at 10 m. Classes of W_1 and W_2 are seen in winter, S in summer and T in transitional seasons (see text). Double horizontal lines show the upper limit of salinity range through the upper 10 m for every 1℃ temperature range. (Higher salinities than the limits have never been observed.

surface water scatter and their variations are great in spring, summer and autumn, frequently occurring classes of warm water during several months are fewer than those of cold water. The S group, extending from the warmest mode [20–21℃, 33.6–33.8] to colder, more saline classes, shows five month's duration (July-November) of the frequency of 1.0% or more excepting that the coldest class [17–18℃, 33.8–34.0] shows the frequency in June to August and in October to December. Figure 18 is an example of the *T-S* frequency distribution with the summer mode. Surface waters included in this group do not always occupy proper sea areas, that is, the water of the same range of *T-S* relation can be found in various places according to seasonal variation.

Area II November 0 m 1174 stations

	13	14	15	16	17	18	19	20	21	22	23	(°C)	Total
-32.0						0							0
32.0-32.2							0						0
32.2-32.4							1						1
32.4-32.6							3						3
32.6-32.8					2	1	2	0					5
32.8-33.0					8	3	12	11	0				35
33.0-33.2			2	10	12	20	13	15	8				80
33.2-33.4		2	8	34	7	10	34	25	13				134
33.4-33.6		8	7	35	28	33	47	37	19	1			215
33.6-33.8				1	5	38	32	40	33	8			158
33.8-34.0				3	15	35	44	36	55	22			210
34.0-34.2				3	2	1	12	22	34	10	1		86
34.2-34.4				0	2	4	13	13	17	11	1		61
34.4-34.6					1	0	6	2	3	0			12
34.6-34.8								1					1
Total		11	17	86	82	146	219	202	182	53	2		1000

Fig. 18. As in Fig. 3 but in November for Area II.

The last group T, centered at the class [14–15℃, 34.0–34.2], shows the frequency twice or three times in a year. The frequency of the centered class occurs in May, June and October to January, other three classes do not show the frequency in October or November.

6. Concluding remarks

On the basis of available hydrographic data taken in 1952-1988 (including partly in 1989-1990), I have divided the Japan Sea except the northwestern part into four areas according to pattern of seasonal variation of SST and SSS. Then I have obtained monthly relative frequency distributions of *T-S* relations in bivariate class of 1℃×0.2 in salinity at the sea surface and at 10 m depth for each of four areas and for the whole study area.

The water entering through Tsushima Strait clearly shows seasonal variations in water characteristics with standard deviations of mostly less than about 1℃ in temperature and 0.2 in salinity for the monthly means (e.g. OGAWA, 1983). The water is transported northeastward along the western margin of Japan showing propagation of high salinity during winter to summer and low salinity during spring to autumn (e.g. TANIOKA, 1962; KOLPACK, 1982). For example, the maximum of SSS occurring in the Tsushima Strait region in March appears in the central area in June about three months behind and in the northeastern part in September about six months behind.

One of the most striking features is that two or three modes are seen in *T-S* frequency distributions nearly through a year in the whole study area. This is due to the existence of the frontal zone between about 39° and 42°N in the central area. The frontal zone separating the surface water into the warm, high salinity water of the south and the cold, low salinity water of the north is well depicted in the SST distributions in winter to spring (e.g. ISODA *et al*, 1991, Fig. 4; Maizuru Marine Observatory, 1990, Fig. 1). Two modes of *T-S* frequencies suggest that this separation occurs even in summer, though scattered distributions and decreased meridional temperature gradients obscure separation of two modes (e.g. Figs. 10 and 12). According to ISODA *et al* (1991), the eastern part of the polar front is more stable than the western one throughout a year and its eastern end exists around the Tsugaru Strait. However, another weak mode often appears at a class a few degrees warmer than the class of the cold mode (e.g. Figs. 3a, 7a and 14). This corresponds to the warmer one of the two modes, about two degrees apart, found in Area IV, west of northern Japan. We have little knowledge of the surface water characteristics or current structure in the northeastern part of the Japan Sea north of 41°N except near the coast because of few observations. Nevertheless, front-like isotherms of SST occasionally extend northeastward along the coast of northern Japan (e.g. ISODA *et al*, 1991, Fig. 4). Besides, the subsurface high salinity core along the coast of Japan reaches as far north as northern Hokkaido, though its salinity is rapidly reduced west of Hokkaido (KOLPACK, 1982). Therefore, a weak mode seen for Area Ⅲ or the whole area in autumn to spring and a warm mode seen for Area Ⅳ, both mode classes being a few degrees warmer than the cold mode classes, must represent the surface water on the southeast side of the front-like zone or in the west of northern Japan. This mode occasionally merges into the cold mode during spring to summer. This frontal structure may be indiscernible at least in the topmost surface water in summer.

The yearly mean *T-S* frequency distribution for the whole study area suggests about four groups of significant surface water characteristics (Figs. 16 and 17). The first is the winter mode water of 5–13℃, 34.0–34.2, partly 33.8–34.0 or 34.2–34.4, seen in the south of the frontal zone at least during January to May; this possibly includes the surface water of west of northern Japan. The coldest water centered at the class [2–3℃, 33.8–34.0] exists in the north of the frontal zone during December to April. The third is the summer mode water of 17–21℃, 33.8–34.2 appearing mostly during July to December, this water cannot occupy proper sea areas during the months unlike the first two waters. The last group is the transitional water centered at the class [14–15℃, 34.0–34.2] occurring twice or three times in a year according to seasonal variations of surface water characteristics.

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日本海の海面と10m深とにおける水温—塩分度数分布

須藤英雄

要旨：北西部を除いた日本海は，海面水温—塩分の年変化の型により，4つの海域に分けられる。そのそれぞれおよび全海域について，海面と10m深とにおける水温—塩分特性を水温1℃×塩分0.2（‰またはpsu）でクラス分けしたときの相対度数分布を月ごとに求めた。日本海中央部には，北からの低温低塩分水と南からの高温高塩分水とが接触するフロント構造が存在するため，ほぼ年間を通して，この度数分布には2つのモードがみられる。このフロント帯の東端部分は，しばしば北日本ぞいに北上するらしく，その南東側すなわち北日本西方に存在するやや暖かい表層水を示す第3のモードが現れる。10m深において年間を通してもっとも多く現れるのは，5-13℃，塩分34.0-34.2，部分的には33.8以上あるいは34.4以下の特性をもった水で，1月～5月にフロント帯の南側にみられる。他には，2-3℃，33.8-34.0のクラスを中心とし，12～4月にフロント帯の北側に現れる冷たい水があり，これらは存在海域もほぼ一定しているとみられる。夏季には17-21℃，33.8-34.0の特性をもった水が，7～12月に広い範囲にわたりみられるが，同一海域に長く存続することはない。

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Societe franco-japonaise d'oceanographie, Tokyo

Underwater brightness in nighttime and behaviors of Japanese spiny lobsters*

Takashi KOIKE**, Yoshitaka MORIKAWA*** and Miyuki MAEGAWA**

Abstract: Diurnal variation of moving activity of Japanese spiny lobsters was investigated in small indoor tanks of the Fisheries Research Laboratory of the Mie University. We modeled the diurnal variation of light intensity with step-like brightness variation having 12 hour light period (daytime) and 12 hour dark period (nighttime). The lobster movement was detected by measuring tension of wire which hangs lobster cage.

Nocturnal habit of lobsters was reproduced; lobsters stay almost in rest in daytime if brightness is higher than 3.5×10^{-2} *lx*. The moving activity of the lobster in nighttime is strongly controlled by brightness. If nighttime brightness is lower than 2.3×10^{-5} *lx*, lobsters move very actively as just as in 0 *lx* brightness. The nighttime activity is suppressed when brightness is higher than 5.2×10^{-3} *lx*. Above this value, the activity tends to decrease slightly with brightness increase. The difference in activity level of lobsters is very conspicuous between in brightnesses higher than 2.3×10^{-5} *lx* and lower than 5.2×10^{-3} *lx*.

1. Introduction

Japanese spiny lobsets, *Panulirus japonicus*, have nocturnal habit, and are usually rest in cracks of rock in daytime. It has been reported by various investigators (e.g. YOZA, 1977) that the catch of spiny lobsters is low in the period of full moon. Decay rate of light with depth is generally high especially in coastal waters, and the underwater brightness at night would be very limited. It appears that Japanese spiny lobsters are aware of a little change of the brightness of moonlight level. The relationship between underwater brightness and fish activities (or fish catch) has been studied by many investigators; for examples, by KUBO and ISHIWATA (1964) for spiny lobster, and by MASHIKO (1979) and TABATA *et al.* (1991) for catfish.

Japanese spiny lobster is one of the most important species in Japanese fisheries. In this paper, we shall model the diurnal variation of the light intensity with step-like brightness variation having 12 hour light period and 12 hour dark period. Lobster cages are hanged by three wires, and movements of a lobster were detected by measuring the variation of tension of one of these wires. The tension was recorded continuously for several days, and diurnal variations of lobster activities were observed under various combinations of brightnesses in light and dark periods. In order to check the reliability of the experiment, movements of a lobster were also observed in an outdoor pool of much larger dimension which was covered with a blackout sheet, and the brightness in which was artificially controlled.

2. Experimental apparatus and procedure

2–1. Japanese spiny lobsters used

Japanese spiny lobsters used in our experiments had been caught near the Shima Peninsula of the Mie Prefecture. We selected lobsters having weight between 250g and 350g. We used three cages in parallel for each experiment, and put one lobster in each cage. Though three experiments were carried out in parralel, no data was obtained for many runs as some of lobsters were not active enough, some died or casted out their skin on halfway of experiments. In average, only one record of the lobster activity was

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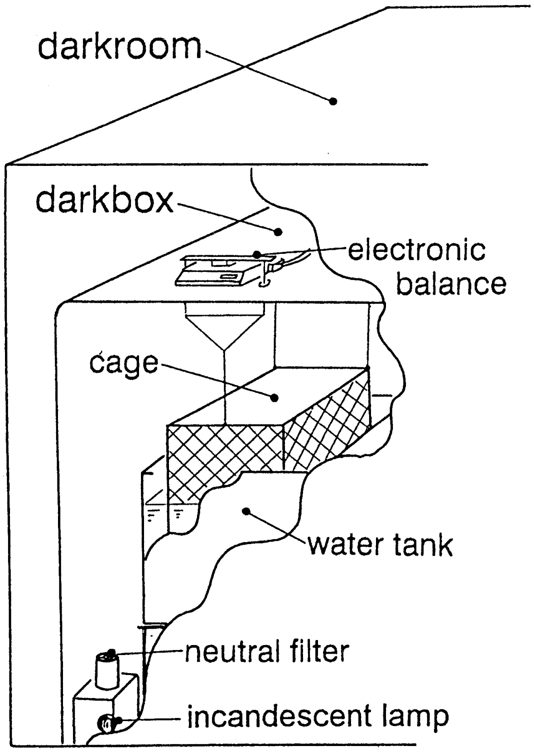

Fig. 1. Schematic sketch of the indoor experimental apparatus.

obtained for each experimental run. We usually replaced with a new lobster at beginning of each experimental run, except one case when the lobster was full of vigor for several consecutive experimental runs.

2-2. Dark box, water tanks and lobster cages.

The experimental apparatus used is shown schematically in Fig. 1. The apparatus is set in a dark box in a dark room in the Fisheries Research Laboratory of the Mie University in Zaga Island in Ago Bay near the tip of the Shima Peninsula. The dark box is of 2.0m length, 1.0m width and 1.5m height, and its sides and ceiling are covered with blackout sheets. In order to diffuse and homogenize the downward reflected light, a black fine net is placed just below the ceiling in wavy form. Three water tanks of 0.62m length, 0.42m width, and 0.35m depth are set in the dark box. The inside walls of the box are painted black and its surface is frosted. In each tank, one lobster cage of 0.40m length, 0.30m width, and 0.30m depth is set. One lobster was kept in each cage. Each cage is hanged by three wires from the ceiling of the dark box, and the variation of strain of one of the wires was measured to detect the movement of the lobster. The water inside tank is continuously replaced by supplying sea water at the rate of 3 liter per min. The water is supplied from a subtank where the water is kept overflowing to keep the supplying rate constant. The water is drained through two pipes, one of which is placed near the water surface and the other is placed near the tank bottom. The level of the lower drain is well below the bottom of the lobster cage.

2-3. Control of brightness

Eight incandescent lamps are installed on the floor of the dark box so as that each water tank has two lamps on its both sides, respectively. The light is shed upward, is reflected on the ceiling, and then penetrates into the experimental tanks. The downward illuminance at the level of the water surface at the center of each tank was measured by a high sensibility illuminance meter (International Light INC SELL 100/Y/L30) or a digital illuminance meter (Minolta T 1M). Obtained illuminance is used in this paper as a measure of brightness.

The light is turned on and off with 12 hours interval by using timekeepers (TWM-901 and TW1-101 made by Toshiba are used in parallel). Usually, we put the light on at 6:00 and off at 18:00 everyday. Hereafter, we shall call the light period as daytime and the dark period as nighttime for convenience' sake.

The light intensity is changed by putting various semitransparent filters (HOYA OPTICAL GLASS with transmission rates of 13.0%, 1.0% and 0.3%) on front of the lamps. Six combinations of the daytime and nighttime brightnesses were adopted in this experiment, and are shown in Table 1, together with several experimental parameters such as water temperature and density, dates of experiments and so on.

When all of the lamps are off, no signal comes out from our illuminance meters. We denote such brightness as 0 *lx* here.

Table 1. Experimental conditions for each experimatal run. Run 1 through run 6 were conducted in the indoor tanks and run 7 was in the outdoor tank.

	Brightness(lx)		Water temp. (℃)	Water density (σt)	Dates		Period (days)
	daytime	nighttime					
①	3.5×10^{-2}	0	23.1-26.0	24.8-25.3	Jun. 21-Jun. 30	1990	9
②	3.3×10^{2}	0	17.8-19.2	22.9-25.2	Nov. 18-Nov. 27	1992	10
③	3.3×10^{2}	2.3×10^{-5}	16.6-17.7	24.0-25.6	Apr. 14-Apr. 21	1992	7
④	3.3×10^{2}	5.2×10^{-3}	17.8-18.2	23.1-25.6	Apr. 24-May. 10	1992	15
⑤	3.3×10^{2}	3.5×10^{-2}	18.2-21.3	22.1-24.8	May. 11-May. 28	1992	16
⑥	3.3×10^{2}	2.0	22.6-25.0	21.5-23.8	Jun. 25-Jul. 12	1992	14
⑦	4.6×10^{2}	0	***	***	Jun.	1991	1

***no data

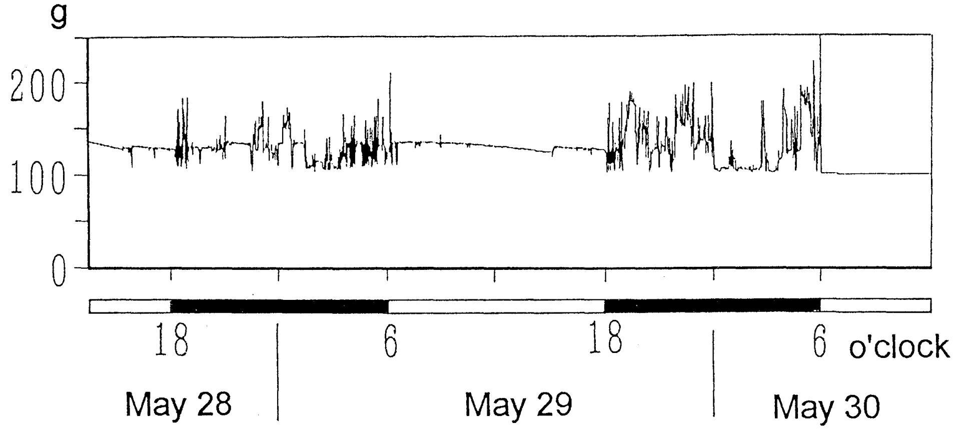

Fig. 2. An example of the recorded variation of the strain of a wire which hangs the lobster cage (the last two days of run 5). A clear diurnal variation of the lobster activity can be seen in the figure: the lobster is almost at reast in daytime and moves actively in nighttime. An extremely high strain value at 1.5 min. past 6 o'clock on May 29 indicates that the lobster jumped out from the tank. The constant strain value after this event shows the strain resulted from weight of the cage itself.

2-4. Detection of lobster movements

The lobster cages are hanged with three wires as shown in Fig. 1. One of the wires is connected to an electronic balance (AND EWA/B), and the output of the electronic balance is sent very three seconds to a personal computer (NEC 9801LV21) through RS232C cable.

Prior to the experiments, we observed movements of lobsters by eyes for several hours, and found that lobsters move usually by creeping on bottom of the cages, though they move occasionally by jumping. Interval of lobsters' stay and move, and changing frequency of the moving speed and direction, and moving trajectory were analyzed. We concluded that 15 sec would be the best for time interval to measure the moving activity of lobsters.

The strain is changed by about 13.7 gw when a lead weight of 150 gw (137 gw in water) is moved over 4cm distance in the longitudinal direction, and no strain change occurs when the weight is moved in the traverse direction. 2 gw strain change would correspond to 2.3cm move of 350g lobster (about 35 gw in water) or to 3.2cm move of 250 g lobster (about 25 gw in water) in the logitudinal direction. The sudden movement of lobsters, however, appears to cause a large strain change, probably when a lobster kicks the bottom hard and when a swing of cage occurs.

In Fig. 2, an example of the records of strain change is shown for the last two days of run 5 (Table 1). A diurnal variation of the lobster activity can be clearly seen in the figure: the lobster is almost at rest in daytime and moves actively in nighttime. At 1.5 min. past 6 o'clock on May 29 (just after the lamps were on), the strain value becomes extremely high (scaled out) and indicates that the lobster jumped out from the tank. The dead lobster was found on the floor of the dark box in the late morning (thereafter, we covered the surface of cage with net). The constant strain value after this event shows the strain resulted from weight of the cage itself. Small wiggles found in daytime may be caused from occasional chages of supply rate of sea water. This effect is, however, very small and is estimated to be of order of 0.1 gw in strain change. It should be noted that the strain changes occur both in the directions of strain increase and decrease by showing that the lobster goes and back in the cage. However, spike-like strain changes usually occur in the direction of strain increase. These would be caused mainly by jumps of the lobster. So, the strain change occurs not only due to the lobster movement in the longitudinal direction but also due to sudden movement of the lobster in any directions.

The strain data are basically obtained for every 3 sec, but the first and the last data in each segment of 15 sec length are missed as the digits of these parts are used to control the recording system. In order to make quantitative discussion, we defined a measure of lobster activities as follow. The averaged strain value was obtained for each experimental run, and then the deviations of the strain values from the averaged value were calculated. The deviations averaged for 9 sec (three successive data) for each 15 sec segment were obtained, and those larger than 2 gw is assumed to represent lobster movements. The occurrence frequency of these relatively large deviations for every 1 hour was calculated, and is used for a measure to represent lobster activity in this paper.

The threshold value, 2 gw, is selected empirically: if we count deviations larger than 1 gw, the occurrence frequency is enormously increased, presumably due to some occasional noise such as swings of cage. If we count deviations larger than 4 gw, the frequency is considerably decreased as we miss to detect small movements of the lobster.

2-5. *Experimental procedure*

In order to be habituated to the new circumstance in the tank, the lobster was kept under a control condition with daytime brightness of 3.3×10^2 *lx* and nighttime brightness of 0 *lx* for the first 2-4 days, except for run 1. This condition is the same as that in the experimental run 2 (see Table 1). We observed the variation of the lobster activity under various conditions for the periods ranging from 6 to 16 days (see Table 1). For one experimental run (run 5) in which the same lobster was used in the previous run (run 4), we added another two days experiment under the control condition, in order to check that the lobster activity was almost the same at beginning and end of the experiment.

We fed several living mussels, *Mytilus edulis*, to each lobster for each day. The weight of each mussel is about 5 gw. Feeding was made in daytime, but the feeding times were randomly selected by using a table of random numbers. However, the feeding time appears not to affect our experimental results as lobsters eat mussels usually in nighttime.

2-6. *Supplemental experiment in an outdoor pool*

The measure of the lobster activity defined above is arbitrary and somewhat ambiguous, as it may miss to count the movement of lobster in the traverse direction and may pick up erroneous signals caused by occasional swings of cage.

We conducted another supplementary experiment (run 7: see Table 1 for its experimental parameters) in an outdoor pool of 5.0m length, 2.0m width and 1.5m depth in the Fisheries Research Laboratory of the Mie University. The pool was covered with a blackout sheet, the brightness in which was artificially controlled just as similar to the indoor tank experiments. The light and dark periods were set from 6:00 to 18:00 and from 18:00 to 6:00, respectively. The daytime brightness is 4.6×10^2 *lx*, and a little higher than the control run above mensioned (see Table 1). The nighttime brightness can be regarded as 0 *lx* within our experimental accuracy.

A small red luminous diode was attached on the back of a lobster. The horizontal and vertical sizes of this cylindrical marker including a

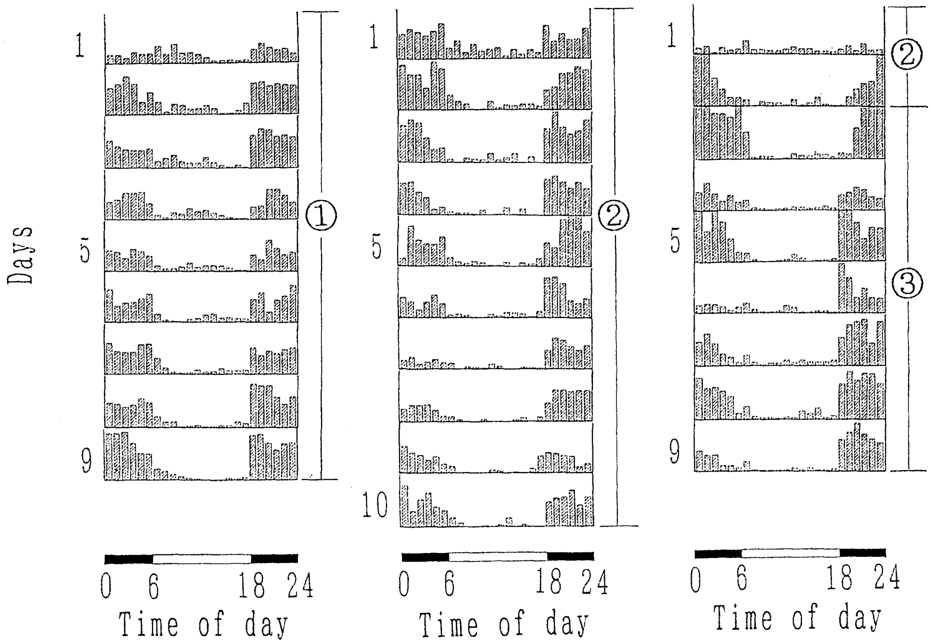

Fig. 3. Daily variation of the diurnal activity change of lobsters: the left column for run 1, the central column for run 2, and the right column for run 3. Run numbers are indicated by numbers in circles and are shown left side of each figure. The number 2 in the right figure indicates the habituation period under the control condition (as the same as run 2). The frequency of mean lobster activity (see text for its definition) per hour is shown. The day number from the beginning of each run is shown left side of each figure. The black and white horizontal bars beneath each figure indicates the dark period (nighttime) and the light period (daytime), respectively. The numbers attached below the bars indicate the time.

lithium battery are 35mm in length and 4mm in diameter, respectively, and its weight in water is 0.5 gw. The surface of the diode is painted by water-insoluble black ink, and its light intensity is decreased as just the position of the lobster can be traced by eyes.

One spiny lobster with the marker was released in the pool. The observation was conducted for one day after several hous habituation period, and the position of the lobster was determined every 15 sec. From this data, we calculated the moving distances for every 1 hour intervals.

Both the indoor and outdoor experiments were conducted in spring and autumn seasons as shown in Table 1. The water temperature and water density lie in the ranges from 16 to 23℃ and from 21.5 to 25.6 sigma-t, respectively (Table 1). The activity of the lobster would be influenced by changes of water temperature and density (salinity). However, the changes within these ranges appear not so significant in our experiments with limited accuracy.

3. Results

3-1. Diurnal variation pattern of lobster activity and its dependence on daytime brightness

The nighttime brightness is 0 *lx* both in runs 1 and 2, but the daytime brightness is 3.5×10^{-2} *lx* in run 1 and 3.3×10^{2} *lx* in run 2, respectively (see Talbe 1). The daily diurnal variations of the lobster activity for run 1 and for run 2 are shown in the left column and in the center column of Fig. 3, respectively.

As seen in these figures, the pattern of the diurnal activity variation of the lobster is considerably disturbed for the first few days just after the lobster was put in the new circumstance. (Note that no habituation period is set for run 1.) Some systematic changes in daily variation pattern can be recognized for further periods, but it is not so significant. The diurnal varia-

Table 2. The mean lobster activities for daytime and nighttime and their standard deviation. The occurrence freqency of the lobster move per hour is shown for run 1 through run 6, and the moving distance per hour for run 7. The brightness conditions in Table 1 for each experimental run is reproduced for convenience' sake.

	Brightness(*lx*)		Activity(freqency/h)	
	daytime	nighttime	daytime	nighttime
①	3.5×10^{-2}	0	13.8±4.5	72.2±21.7
②	3.3×10^{2}	0	9.9±6.5	74.4±21.1
③	3.3×10^{2}	2.3×10^{-5}	9.3±2.8	76.1±26.5
④	3.3×10^{2}	5.2×10^{-3}	2.1±1.1	19.0± 6.3
⑤	3.3×10^{2}	3.5×10^{-2}	2.6±1.6	17.3± 6.2
⑥	3.3×10^{2}	2.0	2.1±1.0	7.5± 2.6
			Activity(meter/h)	
⑦	4.6×10^{2}	0	12.3±36.7	200.5±75.6

tion pattern in run 1 is very similar to that in run 2. There is clear tendency that the moving activity of the lobster responds to the diurnal brightness variation: very low activity in daytime and high activity in nighttime. The activity suddenly increases just after the nighttime starts, but some activity remains for the first few hours of the daytime.

The experimental condition of run 2 would be the most similar to the natural condition (the control run). The lobster behavior is almost the same when the daytime brightness is decreased to 3.5×10^{-2} *lx* (run 1). The variation pattern for runs 1 and 2 may be considered as a basic activity variation pattern of Japanese spiny lobsters.

The diurnal activity variations averaged for whole experimental periods were calculated for run 1 and run 2, and are shown in Table 2 and Fig. 4 (the top and middle figures), respectively, together with their standard deviations. The daytime brightness in run 1 is considerably weaker than that in run 2 (daytime brightness in run 1 is the same as nighttime brightness in run 5). Though the activity of spiny lobster in daytime in run 1 is slightly higher than that in run 2, such a difference might be caused by a difference in character among individual lobsters. We cannot find no significant change in nighttime activity between runs 1 and 2. Lobsters appear not to be influenced significantly by the daytime brightness, at least if it is higher than 3.5×10^{-2} *lx*.

By keeping the daytime brightness as in run 2 (the control run), the brightness in nighttime is increased a little and is set as 2.3×10^{-5} *lx* in run 3. The daily diurnal activity variations are shown in the right column in Fig. 3, and the mean daytime and nighttime activities and their standard deviations are given in Table 2. The diurnal activity variation in run 3 is almost identical to those in run 2. Lobsters appear to recognize the brightness 2.3×10^{-5} *lx* as like as 0 *lx*.

The diurnal variation of the moving distance of the lobster for every 1 hour observed in the outdoor pool (the supplementary experiment) is shown in the bottom figure of Fig. 4. The mean moving distances per hour in daytime and in nighttime and their standard variations are shown in Table 2. The lobster traveled over 2,406m during the nighttime of 12 hours or moved in speed of about 2km/day. TAKAGI (1972) observed movements of tagged Japanese spiny lobsters in the sea south of the Boso Peninsula and reported that moving speed of lobsters reaches about 1.8km/day (29km for 16 days). HERRNKIND (1980) observed movements of New Zealand spiny lobster, *Jasus edwardsii*, in the sea 25–45m deep, and estimated their moving speed is from 5 to 7km/day. Our result coincides with these results in order of magnitude.

This moving distance would be another measure of the lobster activity. As seen in Fig. 4, the diurnal variation pattern of the moving distance is very similar to those of the lobster activity in run 1 and run 2. This indicates that the measure adopted in this paper is meaningful enough to represent lobster activity.

3–2. *Effects of nighttime brightness on lobster activity.*

As discussed in the previous sub-section, the nighttime activity is much higher than the daytime activity. In this subsection, we shall check how the change of nighttime brightness affects on lobster activity, by keeping the daytime brightness as just the same as that of the control run (3.3×10^{2} *lx*). We increased the nighttime brightness from 2.3×10^{-5} *lx* in run 3 through 2.0 *lx* in run 6 (see Table 1 or 2).

As discussed already, lobsters appear to rec-

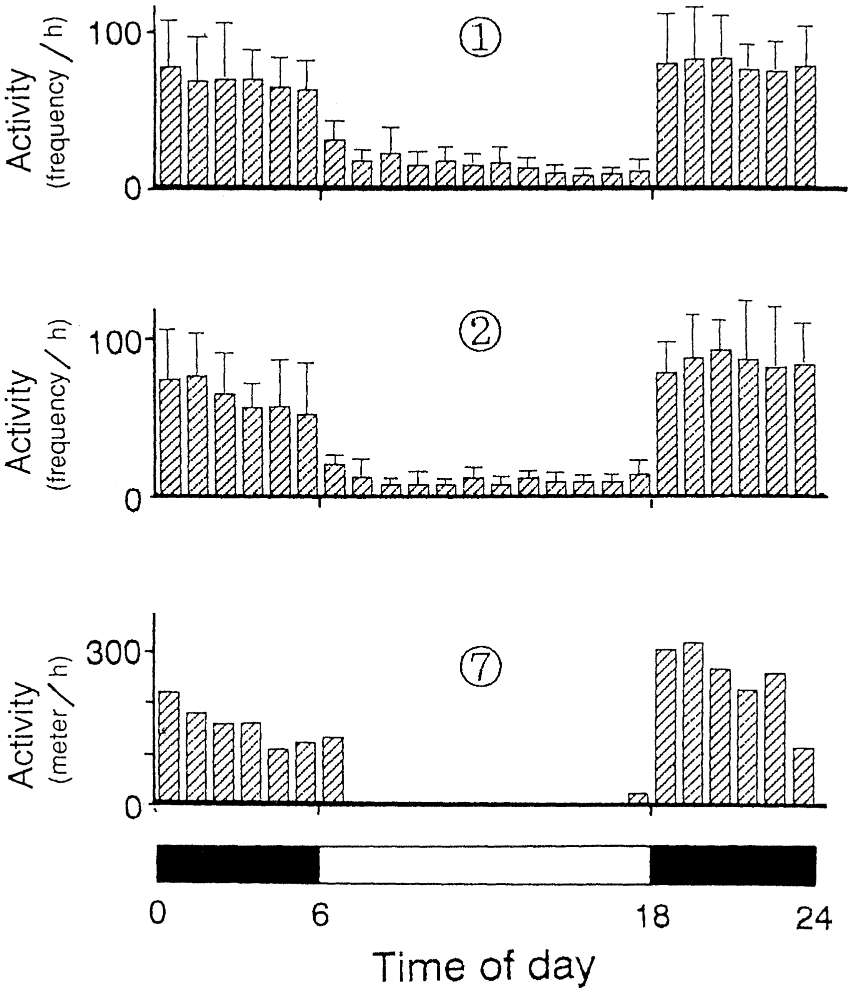

Fig. 4. Averaged diurnal variations of the lobster activity for run 1 (the top figure) and for run 2 (the middle figure). The activities per hour are shown by vertical columns, and their standard deviation by vertical bars. The result of the supplementary experiment (run 7) in a pool is shown in the bottom figure. The vertical column in this figure indicates the moving distance per 1 hour in m.

ognize that the brightness 2.3×10^{-5} *lx* is as just dark as 0 *lx*. However, when the nighttime brightness is increased to 5.2×10^{-3} *lx* (run 4), the nighttime activity is considerably suppressed as seen in the left column of Fig. 5. The daily diurnal variations for run 5 (the nighttime brightness is 3.5×10^{-2} *lx*) are shown in the center column in Fig. 5. The difference between run 4 and run 5 is not significant. Run 4 and run 5 are conducted successively by using the same lobster, and the lobster is kept in the condition of the control run for two days at beginning and end of the experiment, respectively. The activity of the lobster appears to be almost the same before and after this experiment.

The activity is generally higher in the first half than in the second half of nighttime both for run 4 and run 5. ARECHIGA and ATKINSON (1975) and PHILLIPS *et al.* (1980) reported that activity peak occurs just after sunset for other lobsters (*Nepherops norvegicus*, *Panulirus argus* and *Jasus lalandii*). This may correspond to our results. However, KUBO and ISHIWATA (1964) reported that catch of Japanese spiny lobster

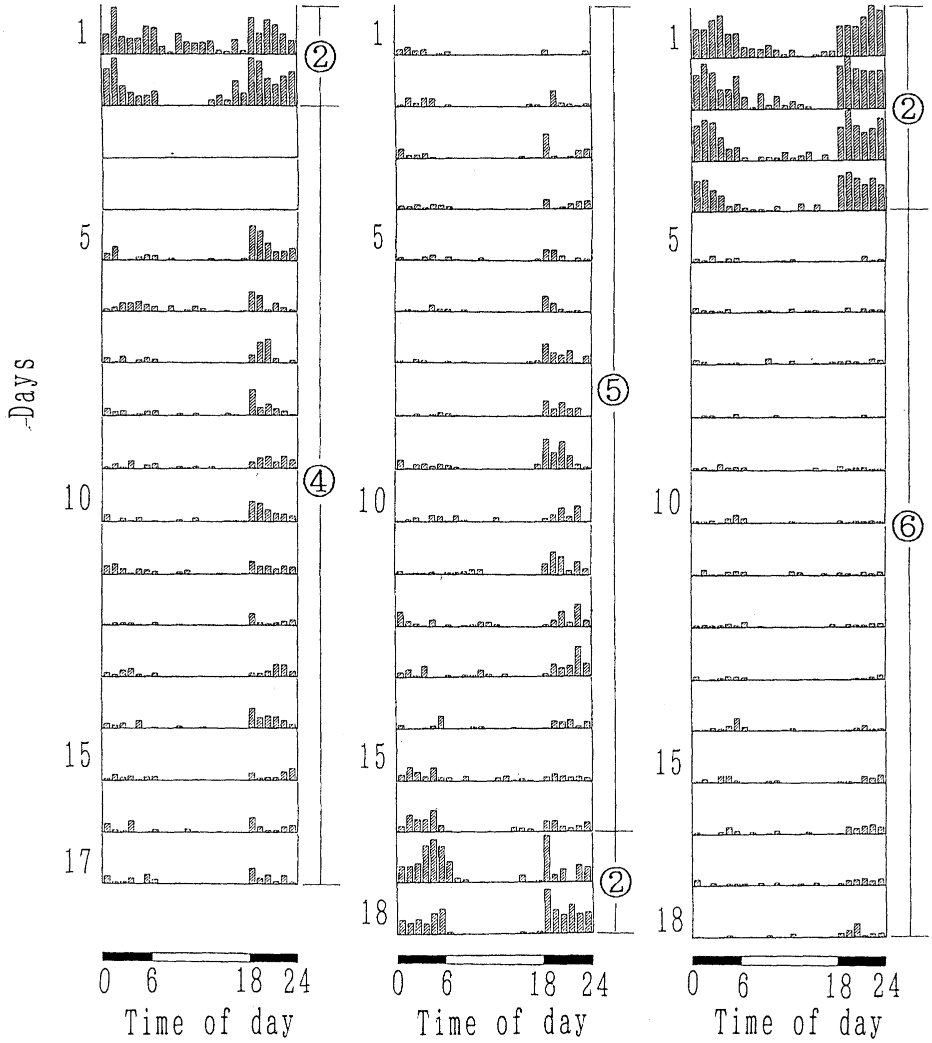

Fig. 5. The same as in Fig. 3 except for run 4 (the left column), for run 5 (the central column) and for run 6 (the right column), respectively. The habituation periods are shown with number 2 in circle. The same lobster was used for run 4 and run 5, and the habituation periods were set prior to run 4 and after run 5.

occurs not only just after sunset but also just before sunrise. For a prawn, *Penuaeus japonicus*, high activity is observed just after sunset and at midnight (NAKAMURA, 1987). The further elaborated investigation would be needed for such detailed activity variation of lobsters in nighttime.

When nighttime brightness is increased up to 2.0 *lx* (run 6), nighttime activity is much decreased as shown in the right column of Fig. 5. The mean daytime and nighttime activities and their standard variations are summarized in Talbe 2 and in Fig. 6. The difference between run 4 (or 5) and run 6 is much smaller than that between run 3 and run 4. This suggests that a threshould brightness value of lobster activity exists between 2.3×10^{-5} *lx* and 5.2×10^{-3} *lx*. Such a threshold brightness is often discussed for many kinds of fishes: for example, MASHIKO (1979) and TABATA *et al.* (1991) reported a threshold brightness for activities of catfish, *Pseudobagrus aurantiacus*, and showed that its

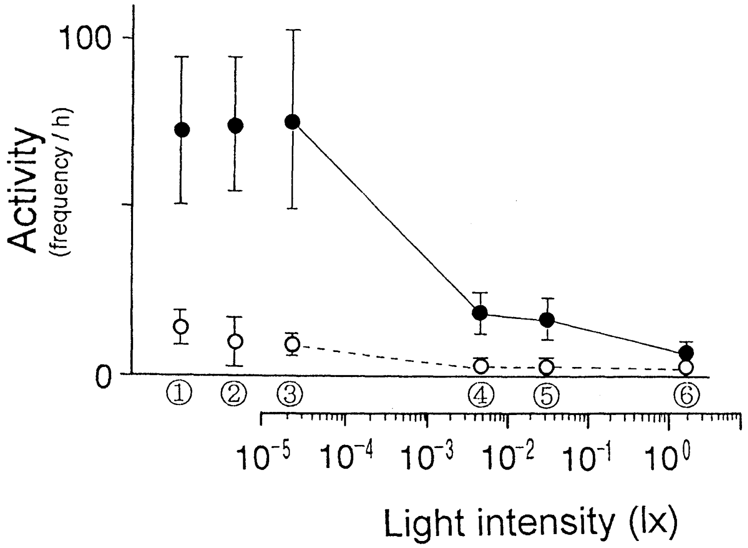

Fig. 6. Dependence of the lobster activity on change of the nighttime brightness. The daytime brightness is the same as in the control run (run 2). The nighttime brightness is taken in the abscissa, and the mean lobster activities for daytime and nighttime are shown with dark circles and white circles, respectively. The results for run 1 and run 2 (nighttime brightnesses are 0 *lx*) are also shown in the left-hand side of the figure. Run numbers are indicated with numbers in circles. The result might be influenced by individual lobster character, but the figure suggests that a threshold brightness value for the lobster activity exists between 2.3×10^{-5} and 5.2×10^{-3} *lx*.

value lies in the range from 10^{-2} to 10^{-3} *lx*.

The lobster catch by bottom-set gillnets, which are installed in depths ranging from 5 to 10 min the sea near the Boso Peninsula is influences by moonlight intensity (YOZA *et al.* 1977). The water off the Shima Peninsula, where is one of the good fisheries ground of Japanese spiny lobster and where the lobsters used in our experiment were caught, is considerably clean and corresponds to the coastal type of grade 1 according to JERLOV (1976) (MAEGAWA, personal communication). Acording to FUSHIMI (1978), the spiny lobsters are caught in the seas shallower than 50m. Lobster gillnets are usually set at the bottom shallower than about 15m depth off the Shima Peninsula. If we assume the brightness of full moon at sea surface is 0.24 *lx*, the brightness at 16.5m becomes to be 5.2×10^{-3} *lx*. It would be reasonable from our results that lobster catch is influenced by moonlight brightness.

4. Concluding remarks.

Diurnal variation of the activity of Japanese spiny lobsters was investigated in the small indoor thanks and in the outdoor pool of the Fisheries Research Laboratory of the Mie University. The nocturnal habit of the lobstaer is reproduced in our experiments, and lobsters stay almost in rest in daytime if the brightness is higher than 3.5×10^{-2} *lx*. the moving activity of the lobster in nighttime is shown to be strongly controlled by underwater brightness. If the nighttime brightness is lower than 2.3×10^{-5} *lx*, the lobster moves very actively as just as in 0 *lx* brightness. The nighttime activity is considerably suppressed when the brightness is higher than 5.2×10^{-3} *lx*. Above this value the activity tends to decrease with brightness increase. The difference in activity level is very conspicuous between in brightnesses higher than 2.3×10^{-5} *lx* and lower than 5.2×10^{-3} *lx*. There would be a threshold value of brightness which separates high and low activity regime.

Recently, we found that some of lobsters can be kept in the tank for long time, say more than one year. If we use such lobsters, we may get much more quantitative results and may determine the accurate value of the threshold and other quantities which characterize the lobster behavior.

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夜間の水中照度とイセエビの活動度

小池　隆・森川由隆・前川行幸

要旨：イセエビの日周行動を，屋内水槽で調べた．実験は三重大学附属水産実験所で行った．明るさの日変化は，12時間の明期（昼間）と12時間の暗期（夜間）がステップ状（短形）に変動するように設定した．イセエビの行動は飼育カゴを吊したひもの張力を測定することによって検出した．また，目印をつけたイセエビの行動を屋外の大型水槽で目視観察して補助実験とした．

イセエビは夜行性を示し，昼間明るさが$3.5\times10^{-2}\,lx$以上あるとほとんど休止状態であった．夜間の明るさが$2.3\times10^{-5}\,lx$以下の場合，イセエビは$0\,lx$（真暗）の場合と同様活発に行動した．イセエビの行動は，夜間の明るさがある限度を越すと非常に抑制された．夜間の明るさが，$2.3\times10^{-5}\,lx$より低い場合と$5.2\times10^{-3}\,lx$より高い場合とでは活動度に顕著な差が認められ，活動度でみた明るさの閾値がこの間に存在することが推定される．夜間の明るさが$5.2\times10^{-3}\,lx$以上では，明るさの増加とともに活動度が若干低下する傾向が見られた．

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鮮魚のロール式大小仕分け機構*

東　川　直　史**・矢　田　貞　美**

Study on mechanism of an automatic fishes selector of role type for catched fresh fish**

Naobumi HIGASIKAWA** and Sadami YADA**

Abstract: We made researches in the mechanism to select accurately the size of fishes by the Automatic Fishes Selector of role type for catched fresh fish. Following results were obtained.

1) It was difficult to select accuratly the size of fishes if this system have the present efficiency, because there were difference in individuality of fish breadth. Making decrease inclination angle of the selecting role, and fix the shoot in the horizontal position, it might possible theoretically to select accuratly the size of fishes.

2) In this system, if fishes were fresh, and selecting role had highly a peripheral velocity, and water was sprinkled on roles and fishes, fish might selected size not only the differnce in it's breadth, but also it's weight.

3) If the adjacent selecting roles were revolting on the same directions, more outside selecting role must keep coefficient of large friction for good selection.

Consequently, it was sure that this system might selected size of fishes by fish breadth and weight.

1．はじめに

一般に，鮮魚の大小仕分け作業には，傾斜ロール式が使用されている（小原，1981）．本方式では，本機の傾斜ロール（以降，ロールと称する）上端中央に投入された魚体は，間隔が上端から下端へと漸次拡大する一対のロール間を滑降し，魚体幅より広いロール間隔になると落下するが，ロール間隔は魚体の大小により調整可能となっている（Fig. 1参照）．11本ロールの場合，左端のロール5本は左回転，右端のロール6本は右回転し，各々定速回転する．その際，ロール上端の間隔の狭幅部で小さい魚体を，下端の広幅部で大きい魚体を篩い分けるので，魚体の小さいものから大きいものが無段階にロール下へ落下する縦目篩に分類される大小仕分け方法であり，農産物の大小仕分けにも利用されている（宝谷，1987）．

このように本システムは，見掛け上では数段階に仕分け可能と推定される．しかし，現地調査によると，魚体はシステム当たりロール上，ロール下の2段階の大きさに仕分けられており，ロール下へ落下した魚体を2段階以上の大きさに仕分けることは困難であった．

そこで，本報では，本システムの仕分け精度の向上を目的として，大小仕分け機構について検討した．

2．実験方法

1）魚体のロール間の移動軌跡の測定

ロール式大小仕分け機の外観をFig. 1に示す．同機の稼働中のビデオ画像を解析し，ロール間の魚体の移動状態を解析した．まず，画像処理装置（FOR㈱：VPA-1000，およびピアス(株)：PIAS Ⅲ）により撮影画像のロール1に定間隔の測定範囲を適宜設け，魚体の滑降所要時間を計測した．次に，ロール下端より落下する魚体の運動を画像解析し，ロール下端における魚体の移動速度を算出した．また，大小仕分け機の上段に設置されたベルトコンベヤの魚体運動，並びに同コンベヤより供給される魚体の移動軌跡を解析して，魚体の供給速度および供給位置を計測し，ロールと魚体間の見掛けの摩擦係数を算出した．

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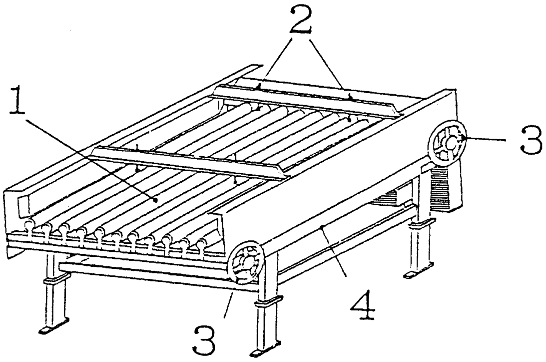

Fig. 1. Automatic Fishes Selector
Note; 1: Role (the first role is left, the eleventh role is right), 2: Sprinkler, 3: Adjustment handle of crevice between roles, 4: Shoot

さらに，一定時間内にベルトコンベヤ上を滑降する魚体を計数し，大小仕分け機の単位時間当たりの仕分け能率を試算した.

2）仕分けロール上における魚体の運動解析

後述の理論式における，魚体とロール面との見掛けの動摩擦係数μ'等の係数は，理論的に決定することは困難である（東川ら，1993；桜井・広中，1981). そこで，次の試作機に測定器具を付設して，これらの係数を計測した. 試作機は市販機の約2分の1の全長1mの回転ロールを2本装着し，ロール傾斜角を調節した. なお，市販機のロール材質はステンレス製であるが，試作機では鉄鋼（SS41）である. この試作機により，理論式の所要な各係数を把握し，また各種ロール条件で魚体を供給して，魚体の移動状態を解析した. なお，ロール面に1尾当たり約50cc散水しながら，頭部または尾部方向より滑降させた.

次に，Fig. 2(a) に示すように，回転数の変動可能なロールを水平に設置して，ロール間に置いた魚体を頭部または尾部方向より一定速度で牽引し，その測定張力から摩擦係数を試算した. また，同図（b）に示すように，ロール間に置いた魚体に取付けた糸の張力を，魚体が落下する際の力とみなした.

3. 結果と考察

1）ロール下端からの魚体の落下運動

ロール下端からの魚体の落下状況を画像解析した結果，魚体は垂直距離 0.5m，水平距離 0.45m を 0.32 秒で落下する放物線運動を行っていた. したがって，質点の放物線運動に関する力学公式より，魚体のロール下端における速度は1.4m/s と試算される. また，魚体がロール上において等速運動するものと仮定すると，魚体のロール全長の滑降所要時間は1.71秒と短いので，魚体はロール上で等加速度運動しているものと推定される. ロール上における魚体は，初速度約 0.93m/s，加速度 0.27m/s^2 と推算される.

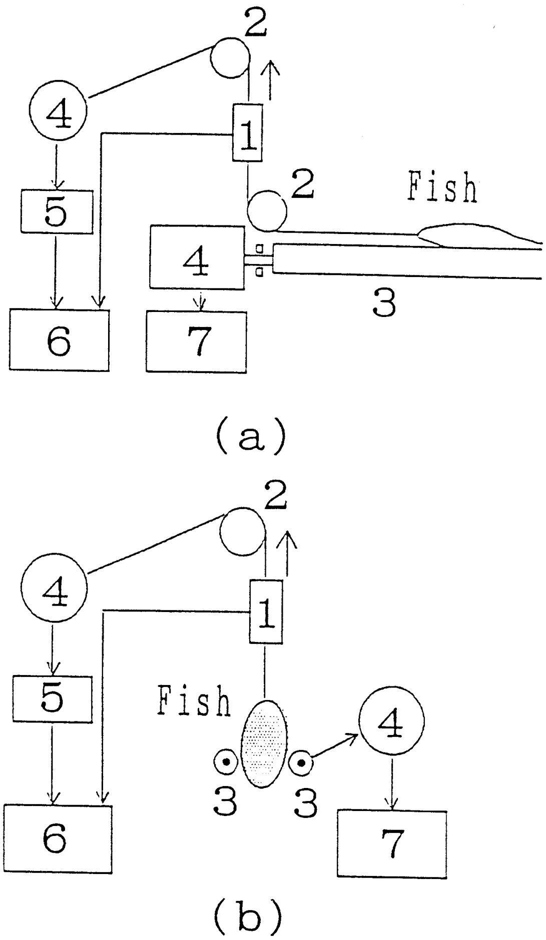

Fig. 2. The system for measuring the friction force.
1: Role, 2: Pulley, 3: Tennsion meter, 4: Motor and tachometer, 5: Pulse convertor, 6: Recorder, 7: Inverter

ところで，傾斜角6度のロール上における魚体の初速度を 0.93m/s，下端速度を 1.4m/s，加速度を 0.27m/s^2 とすると，魚体とロール間の見掛けの動摩擦係数は0.08程度と試算され，魚体と金属間の摩擦係数（三輪・池本,

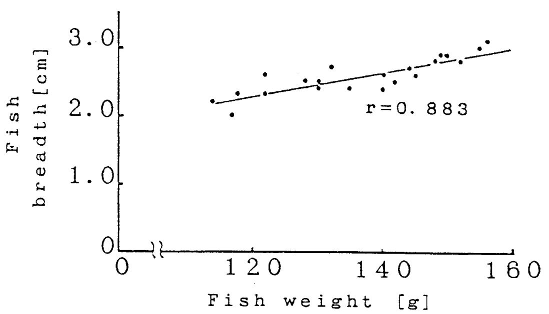

Fig. 3. The relationship between fish breadth and fish weight.

1975）としては小さいことが判明した．これは後述するように，散水による魚体とロールとの付着防止効果により，動摩擦係数が大幅に減少したものと推察される．

なお，Fig. 3に示すように，体長約30cm，体重114 gから170 gの市販の刺身用の生鮮サンマの体重と体幅の関係には，若干の個体差が認められた．供試魚は出荷前に傾斜ロール式で仕分けされたものであり，鮮魚は体重および体幅による高精度な大小仕分けが困難なことを示している．

2）ロール式大小仕分け機構の解析

Fig. 4にロール下端の間隔が漸増する1対のロールより構成される仕分け機のモデルを示す．ここで，ロールの軸心を座標軸，魚体を質量m(kg)の質点とみなし，重力加速度をg(m/s^2)とすると，ロール間から落下した瞬間の魚体に作用するx軸方向の力Fx，y軸方向に作用する力Fyは，次式(1)で示される．

$$\left.\begin{aligned} Fx &= m\ddot{x} = mg\sin\theta \\ Fy &= m\ddot{y} = mg\cos\theta \end{aligned}\right\} \qquad (1)$$

(1)式で示される魚体の放物運動の経過時間をt_1(s)，ロール間より落下した瞬間のt_1を零，その際のx方向の初速度をv_0(m/s)とし，t_1が零の際の魚体位置を座標の原点とすると，魚体のx方向およびy方向に作用する力は(1)式を2回積分することにより次式(2)で示される．

$$\left.\begin{aligned} x &= \frac{1}{2}g\sin\theta\, t_1{}^2 + v_0 t_1 \\ y &= \frac{1}{2}g\cos\theta\, t_1{}^2 \end{aligned}\right\} \qquad (2)$$

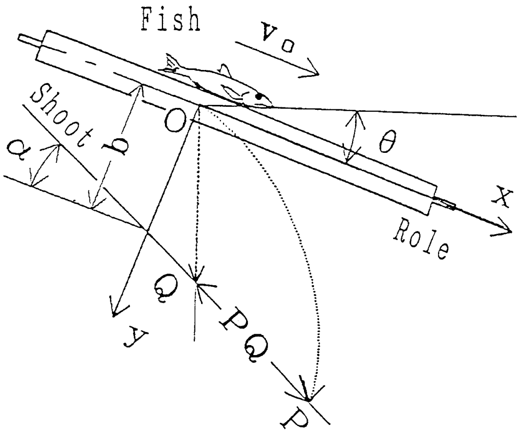

Fig. 4. Schematic diagrams of an Automatic Fishes Selector.
Note: V_0: initial velocity of fish on role (m/s)
θ: angle to horizon of role (deg)
α: angle to horizon of shoot (deg)
b: distance between O and shoot on y axis (m)
P: position of fish with V_0 of maximum
Q: position of fish which V_0 was 0
PQ: distance which fish fall on shoot (m)

t_1が零のときのx方向の初速度v_0は，ロール上における魚体の等加速度運動により決定される．そこで，供給されるロール上の魚体のx方向の初速度をV(m/s)，魚体とロール表面との見掛けの動摩擦係数をμ'，ロール上の滑降所要時間をt_2(s)とすると，v_0は次式(3)で示される．

$$v_0 = V + mg(\sin\theta - \mu'\cos\theta)t_2 \qquad (3)$$

ただし，魚体はロール上で相互に衝突・干渉するので，t_1が零のときのx方向の初速度v_0は，零から(3)式の範囲にあるものと考えられる．

ところで，ロール下段の平板シュートは，原点より下段の間隔b(m)に水平面との角度α(deg)で設置するが，同シュートの位置は次式(4)の直線で示される．

$$y = b + (\tan\alpha)x \qquad (4)$$

したがって，落下した魚体がシュート上に着底するまでの所要時間t(s)は，(2)式および(4)式より次式(5)で示される．

$$t = \sqrt{\frac{2\{b+(\tan\alpha)x\}}{g\cos\theta}} \qquad (5)$$

v_0の値は，零から(3)式の範囲となり，v_0が零の場合，魚体は原点Oの垂直下方Qに落下する．また，(2)式のt_2にtを代入してyを消去すると，初速度v_0が(3)式で示される場合の，平板シュート上における魚体の落下点Pのx座標が得られる．したがって，平板シュート上にお

ける魚体の落下点の座標$P(x,\ y)$は次式(6)で示される.

$$\left.\begin{aligned}&P(x,y)=(x,b+(\tan\alpha)x)\\&\text{ただし,}\\&\quad x=\frac{D_2+\sqrt{D_2^2-D_1^2D_3}}{D_1^2}\\&\quad D_1=(1-\tan\theta\ \tan\alpha)\\&\quad D_2=b\tan\theta\ D_1+\frac{v_0^2\tan\alpha}{g\tan\theta}\\&\quad D_3=(b\tan\theta)^2-\frac{v_0^2\ 2b}{g\cos\theta}\end{aligned}\right\}\qquad(6)$$

また，初速度v_0が零の場合における魚体の落下点Qの座標は次式(7)で示される.

$$\left.\begin{aligned}&Q(x,y)=(x,b+(\tan\alpha)x)\\&\text{ただし,}\quad x=\frac{b}{\cot\theta-\tan\alpha}\end{aligned}\right\}\qquad(7)$$

(6)式および(7)式より，平板シュート上の魚体の落下範囲PQは，落下時における魚体のx方向の初速度v_0，ロール傾斜角θ，平板シュート設置角α，原点Oと平板シュートとの間隔bなどにより決定可能と考えられる．そこで，初速度v_0で落下する同体幅魚の平板シュートの上落下範囲PQが狭いほど，平板シュート上における異体幅魚の混在が少なくなるので，仕分け精度は向上するものと推察される.

なお，魚体の落下範囲PQを求めることにより，仕分け精度が良好な平板シュートの設置位置，同角度，ロール傾斜角などが推定される.

次に，Fig. 5に落下時におけるロールと魚体の関係を示す．ロール間から落下する魚体には，重力，ロールより加わる抗力R(N)，および鉛直方向の摩擦力が作用する．ロールと魚体との見掛けの摩擦係数をμとすると，魚体を落下させるように作用する力F(N)は次式(8)で示される.

$$F=mg+q\cdot 2\mu R \qquad (8)$$

ただし，状態変数qは，魚体とロール接触面の回転方向が魚体の落下方向と同じ場合には1，逆方向の場合には-1で示す.

ロール回転により加わる抗力Rは，魚体の体幅および弾性抵抗に起因し，体幅が増大すると大きくなる．すなわち，(8)式において，魚体は$F>0$ではロール間を落下し，$F=0$ではロール間に挟持され落下しないが，$F<0$ではロール間を滑降する．したがって，体幅がロール間隔以下では，Rは零となり，魚体は重力の作用により落下する．体幅がロール間隔より広いと，魚体の弾性抵抗は大きくなり，また魚体はロール間に挟持されるので，見掛けの摩擦係数が大きくなるから，魚体はロール間から落下しないでロール間を滑降することになる.

以上より，任意のロール間隔における仕分け可能な魚体の体幅および体重が推定可能と考えられる.

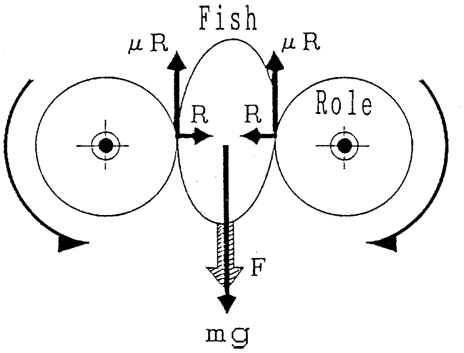

Fig. 5. Schematic diagrams of the fish and roles
Note: F: force which the fish has fallen dawn (N)
m: mass of fish (kg)
g: acceleration of gravity (m/s^2)
R: normal force (N)
μ: coefficient of friction between fish and role surface

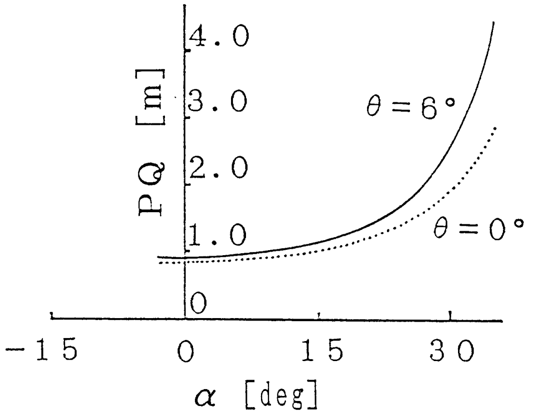

Fig. 6. The simulated curve of suitable angle to horizon of role and shoot
Note: PQ: distance which fish fall on shoot (m)
θ: angle to horizon of role (deg)
α: angle to horizon of shoot (deg)

3）ロールおよび平板シュートの好適傾斜角

初速度0.93m/sの場合において，(6)式および(7)式より幾何学的に求めたロール傾斜角θが0度および6度にお

ける，平板シュート上における魚体の落下範囲PQと，平板シュートの設置角αとの関係をFig. 6に示す．任意のαにおける落下範囲PQは，θが小さいと小さく，θが零の場合に最小となり，実測値と同程度の約50cmとなった．

また，PQは平板シュートとロールとの間隔bによっても変動するが，シミュレーションによると平板シュートの設置角αは，魚体が平板シュートに対して垂直に落下するように設置すると，魚体の落下範囲PQは最小になるものと推察される．ただし，実際には，魚体は相互に衝突・干渉しながら滑降するため，(3)式による魚体の滑降速度ほどには高速にならない．そのため，平板シュート付近まで落下魚体はほぼ鉛直下向きに運動していると考えられる．したがって，平板シュートの設置角αは，市販機ではロールと平行の約6度に設定されているが，水平に設置するべきと考える．

なお，魚体の落下範囲PQとロール傾斜角θの関係は，ロールを傾斜させると，魚体は下方に投射運動し，また落下時のx方向の初速度v_0も増大するので，ロール上の任意の位置で落下を開始してもほとんど同じ落下範囲PQに着底したため，図示は省略した．

これより，ロール傾斜角θが小さいと，また平板シュートの設置角αは床面に並行に設置すると，平板シュート上における異体幅魚の重複確率が低下するので，仕分け精度は向上するものと推察される．同図より平板シュートの設置角αが-5度から10度程度において，PQはロール長の2分の1の1m以下になるので，理論的には現状のシステムでも複数段階の仕分けが可能と考えられる．ただし，ロール傾斜角θが小さいと魚体の滑降速度は遅くなるため，単位時間当たりの仕分け量は減少する．したがって，現状と同程度の単位時間当たりの仕分け量を維持するためには，魚体の滑降速度を速くする必要があり，そのためにロール上へ供給される魚体の初速度Vの増大，あるいはロール傾斜角θの増大，またはロール数の増加が必要となる．しかし，ロール数を増加させると，システム本体の平面的占有率が増大し，また新たにロール上端に魚体を斉一に供給するための装置が必要となる．

ロール上端へ供給されるる魚体の初速度Vを速くすると，(6)式および(7)式より魚体の落下範囲PQが大幅に増大し，加えて魚体の運動エネルギも増加するため，本来なら仕分けされない体幅の大きい魚体がロール間から落下するなど，仕分け精度の低下が懸念される．したがって，ロール傾斜角θを増大させて魚体の滑降速度を速くする方法が有効と考えられる．そこで，ロール上における実測値1.7秒以下で魚体を滑降させるには，ロール傾斜角θは5.7度以上必要と試算される．これは，市販機のロール傾斜角6度とほぼ近似している．

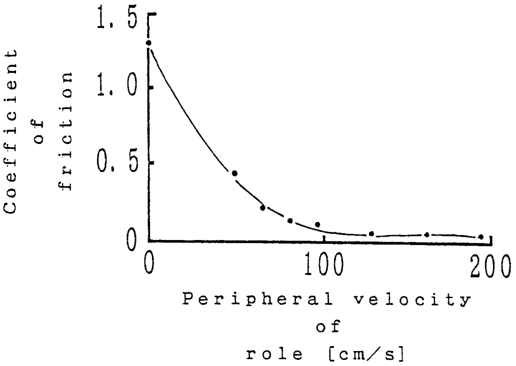

Fig. 7. Relationship between the peripheral velocity of the role and coefficient of friction between fish and role surface

以上より，ロール式で大小に鮮魚を仕分ける場合，現状と同程度の単位時間当たりの仕分け量を維持する場合には，高精度な仕分け精度は困難なもとの推察される．ただし，1台当たりの仕分け量を現状の約60%程度まで減少させると，2段階以上の大小仕分けが可能と推察される．

4）ロール回転数が魚体とロール間の見掛けの動摩擦係数に及ぼす影響

Fig. 7に，魚体とロール間の見掛けの動摩擦係数と，ロール回転数との関係を示す．図示は省略したが，見掛けの動摩擦係数は散水すると，ロール周速度が1 m/s以上ではほぼ零となり，散水量を増すと，さらに見掛けの動摩擦係数は減少した．これは，散水用海水は粘度が低いので，魚体がロール間を滑降する際に接触面に薄い水膜が生じるため摩擦が小さくなるハイドロプレーニング現象が生じているものと推察される（三輪・池本，1975；桜井・広中，1981；高島，1987）．なお，散水量が少ないと，体重および体幅の大小に関わらず魚体がロール面に付着し，回転ロール間から強制的に落下させられるので仕分け精度は低下した．

魚体に取付けた糸の張力から，ロール間より魚体が落下する力を測定したところ，ロールの回転数が高いと，魚体に作用する垂直方向の力は，ロールの回転方向に無関係なことが判明した．これは，前述したように魚体と回転ロールとの接触面の間に薄い水膜が生じ，摩擦係数

が著しく減少したためと考えられる．なお，(7)式の状態変数 q は，これらの実測値から－0.8程度と試算された．

ところで，供試サンマは100 g の体重差でも，体幅差はほぼ0.8cm以下であった．現地調査では5段に設置した仕分け機で6段階に仕分けていたが，魚体の体幅差のみにより仕分けられると考えると，約0.1cmの体幅差により仕分けられることになる．しかし，0.1cm程度の体幅差であれば，魚体は弾性に富むため落下や滑降の勢いでロール間の通過が可能であり，体幅差のみで大小に仕分けられる可能性は低いものと推察される．

5）ロールによる魚体の仕分け機構

Fig. 1のロール1から同5までは左回転であり，同6から同11までは右回転している．ロール上端の中央に投入された魚体は，ロール5と同6により左右斜め下方向に移送されながら落下する．本システムでは，逆回転する隣接ロール5と同6間は，魚群を左右に分散させると共に，次項のような仕分け機構を有し，同方向に回転する隣接ロール間（左回転：ロール1から同5，右回転：同6から同11）では，仕分け機作が異なり，次項のように考察することができる．

（1） 逆回転する隣接ロール間の機作

左回転のロール5と，右回転の同6のように隣接ロールが各左右に逆回転する場合について考える．ロールが高速回転する場合，魚体とロール間の摩擦にはロールの回転方向は影響しないので，実測値より(7)式の状態変数 q は－0.8とする．出荷対象となる魚体の体幅の個体差はほとんど認められないので，Fig. 5および(7)式において，ロールより加わる抗力 R の大きさも魚体の大小に無関係に一定とすると，上方に魚体を持ち上げるように回転するロールの作用に逆らってロール間から落下するための魚体重の条件は次式(9)で示される．

$$mg \geqq 1.6\mu R \tag{9}$$

本式から，ロール間隔および魚体の体幅が一定でも，体重に差があると，仕分けが可能なことを示している．ただし，魚体は本式で示される原理のみにより仕分けられるのではなく，体幅差との両作用により仕分けられるものと推察される．

なお，魚体を上方に持ち上げるように逆回転する複数の隣接ロールを，並列に連続配置することによっても，大小の仕分けロール機構を構成することも可能と考えられる．その場合には，魚体を強制的に繰り下げるような作用を防止するため，ロール径の上方2分の1以上が覆われるように右回転と左回転の2本の隣接ロールに蓋をする必要がある．しかし，この場合には仕分け能力の大幅な低下が懸念される．

（2） 同方向に回転する隣接ロール間の機作

左回転するロール1から同5までと，右回転する同6から同11までの両隣接ロール間の機作は同様と推察される．このような場合における，2本の隣接ロールが同方向に回転する場合について考える．ロールは高速回転するから魚体に働く上下方向への力 μR は相殺されるので，(8)式の第2項は零になる．それ故，第一項の重力のみで仕分けらることになるので，仕分け精度は低下する．そのため，例えば逆回転するロール5と同6間を通過する体重 mg の魚体と，ロール4と同5間を通過する体重 $(mg-2\mu R)$ の魚体とがシュート上の同じ落下範囲 PQ に着底することになるので，仕分け精度が低下することになる．

仕分け精度のバラツキが大きい一因は，このように同方向に回転する隣接ロール間における仕分け精度の低下に起因するものと考えられる．同方向に回転するロール間の仕分け精度の低下防止には，(9)式の値に近似させるように (8)式の第2項を零以上にする必要がある．具体的には，同方向に回転する隣接ロールは，中央部の逆回転するロール5及び同6から各外側のロールほど徐々に摩擦係数を大きくする．その方法としては，ロール5及び同6より各外側のロール径を徐々に大きくする，各外側のローラの回転数を徐々に低下する，各外側のロールには摩擦の高い材質を使用する，などにより下向きの μR より上向きの μR の値を大きくすると，効果的と考えられる．

例えば，(10)式において，ロール番号を n で表すとロール4と同5の各摩擦係数は各々 μ_4 と μ_5 で示され，ロール1から同5までは $(\mu_{n-1}-\mu_n)>0$ の場合に，またロール6から同11までは，$(\mu_{n-1}-\mu_n)<0$ の場合に高精度な仕分けが可能となる．ロール4と同5間を落下した魚体に働く力は，(8)式から次式(10)で示される．

$$F=mg-q(\mu_{n-1}-\mu_n)\cdot R \tag{10}$$

(10)式より，体幅が広くなると弾性抵抗により摩擦係数の増大する分，ボール間を滑降してシュート上への落下範囲 PQ は広くなるので仕分け段数を多くすることが可能となるから，必然的に仕分け精度を向上させることが可能になるものと推察される．

なお，大小仕分け機の1台（ロール数：11本）当たりの仕分け量は，一定時間内にベルトコンベヤ上を滑降す

る魚数から判断すると，重量で約15.5t/hr，尾数で約11万1千尾/hrと推定された.

以上より，魚体は体幅差および体重差により仕分けられるものと推定される.

4. 要　約

魚体大小のロール式仕分け機構について解析し，仕分け精度の向上を試みた. 結果は次のとおりである.

1）魚体の大小は体幅差により仕分けられるが，現状の単位時間当たりの仕分け能力を維持すると，高精度な仕分けは期待できないことが判明した. しかし，ロールの傾斜角を小さくし，またシュートを水平に設置すると，単位時間当たりの仕分け量は減少するが，高精度な仕分けが可能と推察される.

2）鮮魚では，魚体とロールに散水し，さらにロールを高速回転させると，同程度の体幅でも，体重差により仕分けられることが理論的に推定された.

3）仕分け精度の向上には，同方向に回転する隣接ロールの各外側の摩擦係数を大きくする必要がある.

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Société franco-japonaise d'océanographie, Tokyo

学会記事

1．1994年11月22日（水）東京水産大学において平成6年度第2回幹事会が開かれた．主要な議事は下記のとおり．

報告事項

1）学術定期刊行物補助金の申請を行うこととした．

2）日仏関連学会連絡協議会が12月5日に開催される．

3）水産学研究連絡会議より国際学術集会への派遣候補者推薦の依頼があった．

4）10月31日現在での会計報告が行われた．

5）11月22日現在での編集報告が行われた．32巻3号まで発行済みであり，4号はJECSS-VII Proceedingsとして印刷中．

6）岩波出版「海に何が起こっているか」の訂正箇所正誤表を作成した．出版社へ重版時の改訂を依頼中であるが，出版社としては新刊印刷の意向が強いことが報告された．

協議事項

1）日仏関連学会連絡協議会への出席を高木副会長，佐伯渉外幹事に依頼した．

2）国際学術集会への派遣候補者推薦について，水産学研連として推薦する方式となり，本年度は推薦を見合わせることとした．

3）学会誌無料掲載頁数の改正について，編集委員会よりの報告をもとに審議し，6頁か8頁かを評議員会で決定するよう検討を続けることとした．

4）第4回日仏海洋シンポジウムについて審議し，95年10月下旬の3〜4日間の会期で，全体テーマとして“Integrated Coastal Management”を考え，増養殖，沿岸域管理，水産経営経済の3項目を中心に今後詳細を検討する．準備日程として，1月下旬以後に実行委員会を発足するものとし，開催地・予算案の検討や開催期間・学協会への依頼を進める事とした．

5）日仏学者交換事業によりフランスへ派遣されていた八木宏樹会員の帰国報告会を年明けに計画することとした．

2．会員所属・住所変更（正会員）

岡嵜守良　〒103　中央区日本橋堀留町 1－13－17
三洋テクノマリン　環境技術部
井上敏彦　〒338　浦和市木崎 2－13－20
島津仁一　〒338　浦和市西堀 7－6－33

3．訃　報

阿部友三郎・和達清夫（名誉会員）

4．退会（正会員）

岩下光男，石渡直典，浅田　敏，南雲昭三郎，児玉理彦，須賀次郎

5．受贈図書（受領順）

Chinese Science Bulletin 39（11〜21）
Annales Linstitute OCeanographique 70
Israel Oceanographic & Limnological Research 16（1，2）
ОКЕАНОЛОТИЯ 34 (5)

日仏海洋学会役員・評議員
（1994-1995年度）

顧　　問：ユーベル・ブロシェ　ジャン・デルサルト　ジャック・ロベール　アレクシス・ドランデール　ベルナール・フランク　ミシェル・ルサージュ　ローベル・ゲルムール　ジャック・マゴー　レオン・ヴァンデルメルシュ　オーギュスタン・ベルク　ユーベル・セカルディ
名誉会長：オリビエ・アンサール
会　　長：有賀　祐勝
副 会 長：高木　和徳　岡市　友利
幹　　事：（庶務）　須藤　英雄　有元　貴文
（会計）　森永　　勤　岸野　元彰
（編集）　佐藤　博雄　落合　正宏
（研究）　関　　文威　小池　勳夫
（渉外）　佐伯　和昭　隆島　史夫
監　　事：久保田　穰　辻田　時美
編集委員長：山口　征矢
評 議 員：
有元　貴文　有賀　祐勝　石丸　　隆
今脇　資郎　宇野　　寛　大塚　一志
岡市　友利　奥田　邦明　落合　正宏
梶浦欣二郎　金成　誠一　鎌谷　明善
岸野　元彰　国司　秀明　久保田　穰
黒田　一紀　小池　勳夫　佐伯　和昭
坂本　　亘　佐藤　博雄　杉森　康宏
須藤　英雄　関　　文威　関根　義彦
平　　啓介　高木　和徳　隆島　史夫
高野　健三　高橋　正征　谷口　　旭
辻田　時美　寺崎　　誠　寺本　俊彦
鳥羽　良明　中田　英昭　永田　　豊
中村　重久　奈須　敬二　西沢　　敏
畑　　幸彦　半沢　正男　堀越　増興
前田　明夫　松生　　洽　松村　皐月
松山　優治　丸茂　隆三　村野　正昭
森田　良美　森永　　勤　柳　　哲雄
山口　征矢　和田　　明　渡邊　精一

PAMS (Pacific–Asian Marginal Seas)–
JECSS (Japan & East China Seas Study)
VIII Workshop
At Ehime University, Matsuyama, Japan
26–28 September, 1995

First Circular: A Call for Paper

Scope and Objective: PAMS & JECSS Workshop has been held biannualy in Japan, Korea or China in order to exchange the present knowledge on the physical, chemical, biological and geological aspects of the Pacific–Asian Marginal Seas, especially on the currents and circulations there. The 8th PAMS–JECSS Workshop will be held at Ehime University, Matsuyama, Japan during **26 to 28 September 1995**.
Official Language: English
Registration: Any participants have to send the registration form, which is attached to this circular, to the Secretariat by **30 April 1995**.
Registration fee: It is free.
Submission of Abstracts: Any scientists wishing to present a paper should send a 1 page abstract to the Secretariat by **30 April 1995**. The format of abstract is attached to this circular. The notice of acceptance will be sent by **30 June 1995** and a extended abstract is due to **31 July 1995**.
Accommodations: Hotel rooms will be reserved for foreign participants by the Secretariat. The room charge including breakfast for participant is free for foreign participants but the charge for the accompanying person has to be paid by him–or–herself.

Secretariat
Prof.Tetsuo YANAGI
Department of Civil & Ocean Engineering
Ehime University
Matsuyama 790, Japan
Tel. 81-899-24-7111 ext.3751
Fax 81-899-27-5852

Registration Form of PAMS & JECSS VIII Workshop

Name Prof. Dr. Mr. Ms. ____________________
First Middle Family

Accompanying person
Yes, No If Yes, Name Mr. Ms. ____________________

Affiliation ____________________
____

Mailing address ____________________
____

Tel. ____________ Fax ____________

日本学術会議だより　№33

第15期最後の総会開催される

平成6年6月　日本学術会議広報委員会

今回の日本学術会議だよりでは，5月25日から27日まで開催された第118回総会の概要と同総会で採択された「新しい方式の国際研究所の設立について(勧告)」，「公的機関の保有する情報の学術的利用について(要望)」，「女性科学研究者の環境改善の緊急性についての提言(声明)」についてお知らせします。

日本学術会議第118回総会報告

日本学術会議第118回総会（第15期・第6回）が，5月25日～27日の3日間にわたって開催されました。

総会の初日（25日）の午前は，会長からの前回総会以降の経過報告に続いて，各部，各委員会等の報告が行われました。次いで，今回総会に提案されている13案件について，それぞれ提案説明と質疑応答が行われました。午後からは，各部会が開催され，総会提案案件の審議及び各部会個別案件について審議が行われました。

総会2日目（26日）の午前は，前日提案された13案件のうち，9案件の審議・採択が順次行われました。

まず，「日本学術会議会則の一部を改正する規則」，「日本学術会議の運営の細則に関する内規の一部改正」，「日本学術会議の行う国際学術交流事業の実施に関する内規の一部改正」，「副会長世話担当研究連絡委員会の運営について（申合せ）の一部改正」及び「第16期における研究連絡委員会委員の在任期間等に関する規定の適用について（申合せ）」について一括して討論が行われ，採決の結果，いずれも可決されました。これらの会則，内規等の改正は，

1．運営審議会の構成員等の見直し

常置委員会と運営審議会の連絡を緊密にし，運営審議会の議論をより充実させるため，常置委員会委員長が常時運営審議会に出席することとし，併せて，運営審議会の構成員の見直しを行うこと。

2．第7常置委員会の設置及び第16期に向けての研連の見直し

国際対応委員会の改組について（申合せ）（平成5年4月22日第116回総会決定）に沿って第7常置委員会を設置し，併せて，各部等での検討結果を踏まえ，第16期へ向けての研連の見直しを行うこと。

3．研連委員の在任期間等関係

研連委員の在任期間に関する運営内規の解釈をより一層明確化するとともに，将来に向けての研連活動の継続的発展・活性化を図るため，研連委員の在任期間等についての関係規定を整備すること。

を趣旨とするものです。

次に，「運営審議会附置会員推薦手続検討委員会の設置」についての討論・採決が行われ，可決されました。これは，会員推薦制度導入以来，今回で4度目となり，会員推薦手続の過程において，幾つかの問題点がみられたことから，これらの諸問題について審議するため，新たな委員会を運営審議会に附置するものです。

続いて，「新しい方式の国際研究所の設立について（勧告）」，「公的機関の保有する情報の学術的利用について（要望）」，「女性科学研究者の環境改善の緊急性についての提言（声明）」についての討論・採決が行われ，可決されました。午後は，「第6常置委員会報告～国際学術交流・協力の飛躍的発展のために～」，「人口・食糧・土地利用特別委員会報告～21世紀の人口・食糧問題に対する全人類的取組に向けて～」，「学術国際貢献特別委員会報告～学術国際貢献のための新たなシステムについて～」及び「死と医療特別委員会報告～尊厳死について～」の4件の対外報告について討論が行われ，それぞれ承認されました。

総会3日目（27日）は，午前は各常置委員会及び国際対応委員会が，午後は各特別委員会がそれぞれ開催されました。

新しい方式の国際研究所の設立について（勧告）（抄）

近年，学術の国際交流がますます盛んになるとともに，新しい方式の研究所が世界の国々に設立されている。それらの新しさは，固有の研究員をほとんどもたず，国内外から招請した客員研究員による共同研究を企画し実行する点にある。この方式にふさわしい分野としては，自然科学のみならず，人文科学，社会科学を含め様々な領域が考えられるが，理論構築を主眼とする研究領域においては，研究テーマを学際的、機動的に選択する上で特に有効である。これは，また国を異にする若手研究者が相集い，生活と研究ないし研修を共にする場としても大きな効果を生むであろう。実際，世界的には，この意味で成果をあげている新研究所も少なくない。

さらに，いま国際貢献が基礎科学においても強く求められているが，それは，学術研究の推進と相互に強め合うべきものであって，このためにも新しい方式は最適である。

こうした観点から，新しい方式の国際研究所の設立が必要であり有用であるとの結論に達したので，ここにその設立を勧告する。

公的機関の保有する情報の学術的利用について（要望）（抄）

研究者が学術研究のために必要とする情報には、極めて広範囲なものが含まれており，その内容は，学問分野によっても多種多様である。学問分野によっては，公的機関の保有する情報が学術研究にとって極めて重要ないしは不可欠な意味をもつことになる場合も少なくないが，多くの場合に，かかる公的機関の保有する情報を学術情報として利用することには困難が伴っている。それは，公的機関の保有する情報の少なくない部分が公開されておらず，学術情報としての利用についてもその開示を求めることができないからである。

このような公的機関の保有する情報の学術的な利用のためにも，まず基本となるのは，国民の基本的な権利に基づく公的機関の保有する情報の公開制度である。この制度の確立によって，公的機関の保有する情報の学術情報としての利用も同時に保障されることになるからである。公的機関としては，国家機関及び地方公共団体機関を挙げることができるが，国家機関の保有する情報についての公開制度が設けられていないことは，学術研究にとっても特に重大な障害となっている。国民の「知る権利」を中心とする基本的権利を保障するための国家機関の保有する情報の公開制度は、学術研究にとっても極めて重要な意味をもっているということができる。国民の基本的な権利を保障するために，また学術研究の推進のためにも，原則公開を基本とし的確な内容を持つ国の情報公開制度の確立が不可欠であると考えられるので，ここに情報公開法の制定を要望する。

なお，公的機関の保有する情報の学術的利用については，情報の保存及び研究者による非公開情報の利用についての検討が必要である。

女性科学研究者の環境改善の緊急性についての提言（声明）（抄）

女性の社会的地位の向上を目指す取組が，国際的にも国内的にも種々行われているが，日本学術会議においても第10期及び第12期に女性科学研究者の地位の向上に関する「要望」を決議した。今期，すなわち第15期の発足に当たり，日本学術会議は「女性研究者の地位の向上」に留意することを再確認し，今期の活動計画の一つにこの課題を取り上げ審議してきた。その結果，女性科学研究者の地位の向上の必要性は理念的には一般化したものの，科学者全体の対応の遅れもあって，その地位は実質的に余り改善されていないことが明らかになった。

このため，特に基礎科学分野における科学研究者不足の事態が目前に迫っている現在，我が国における科学の調和のある発展のために，第10期，第12期での男女平等の視点を前提としつつ，日本学術会議は，改めて女性科学研究者の環境改善の緊急性を指摘するとともに，関係方面に環境改善の促進を強く訴えるものである。

「日本学術会議だより」について御意見，お問い合わせ等がありましたら，下記までお寄せください。

〒106 東京都港区六本木7-22-34
日本学術会議広報委員会　電話03(3403)6291

日本学術会議だより　№.34

第16期最初の総会開催される

平成6年8月　日本学術会議広報委員会

日本学術会議の第16期が平成6年7月22日(金)からスタートし，7月25日から7月27日までの3日間，第119回総会が開催されました。今回の日本学術会議だよりでは，総会の概要等についてお知らせします。

日本学術会議第119回総会報告

平成6年7月22日から，第16期が開始されましたが，この第16期会員による最初の総会である，日本学術会議第119回総会が，7月25日から27日までの3日間にわたって開催されました。

初日（25日）の午前は，辞令交付式が，総理大臣官邸ホールで行われ，210名の会員のうち海外出張中等の22名を除く188名の会員が出席しました。式は，村山内閣総理大臣，五十嵐内閣官房長官，石原官房副長官，文田総理府次長等の出席を得て行われ，第1部から第7部までの全会員の名前が読み上げられた後，会員を代表して最年長である中田易直第1部会員が，村山内閣総理大臣から辞令を受け取りました。この後，村山内閣総理大臣が「会員の皆様には独創性豊かな学術研究の発展等のため，総合的観点に立って学術研究に係わる諸問題の解決に御尽力いただきたい」とあいさつし、これに応えて，中田易直第1部会員が「微力ながら全力を尽くし，重要な職責を全うし，国民の期待に応えたい」とあいさつしました。午後は，日本学術会議講堂において，総会が開催され，会長，副会長（2名）の互選が行われました。その結果，会長には，伊藤正男第7部会員が，人文科学部門の副会長には，利谷信義第2部会員が，自然科学部門の副会長には，西島安則第4部会員が，それぞれ選出され，伊藤会長及び利谷副会長（西島副会長は海外出張中）からそれぞれ就任のあいさつを行いました。続いて，各部会が開かれ，各部の部長，副部長及び幹事の選出等が行われました。（第16期の役員については，別掲を参照）

2日目（26日）は，午前10時から総会が開催され，近藤前会長が海外出張中のため代理として川田前副会長が第15期の総括的な活動報告を行い，続いて，会員推薦管理会報告として，久保亮五委員長の代理として高岡事務総長が，第16期会員の推薦を決定するまでの経過報告を行いました。引き続き，事務総長から第16期会員対して実施した「第16期の日本学術会議が取り組むべき課題について」のアンケートの結果について説明がありました。総会終了後は，各運営審議会附置委員会，各部会，各常置委員会等が開催されました。また，夕方には，総理大臣官邸ホールにおいて，村山内閣総理大臣主催の日本学術会議第16期会員との懇談会が初めて開催されました。懇談会は，村山内閣総理大臣のあいさつで開会し，五十嵐内閣官房長官の発声による乾杯，伊藤会長の答礼のあいさつの後，懇談に入りました。来賓として，与謝野文部大臣，田中科学技術庁長官，吉田農林水産政務次官，藤田日本学士院院長ほか大勢の方が出席され，あふれんばかりの人々で歓談が続き盛会となりました。

3日目（27日）は，午前10時から総会が開会され，会長から「第16期活動計画の作成について」の申合せ案について提案があり，原案どおり可決されました。続いて，第16期の活動計画についての自由討議が行われ，各部長から各部会での意見が披露されるなど活発な発言がありました。総会終了後は，地区会議合同会議，各運営審議会附置委員会，各常置委員会等が行われました。その後，運営審議会が開催され，第16期の活動計画の素案作成のために，運営審議会構成員の中から起草委員を選出し，審議に入りました。

第16期日本学術会議役員

会　長	伊藤　正男（第7部・生理科学） 理化学研究所国際 フロンティア研究システム長
副会長	利谷　信義（第2部・基礎法学） お茶の水女子大学（生活科学）教授
副会長	西島　安則（第4部・化学） 日本ユネスコ国内委員会会長

〔各部役員〕

第1部	部　長	中田　易直	（歴史学）
	副部長	戸川　芳郎	（哲学）
	幹　事	堀尾　輝久	（教育学）
	幹　事	森岡　清美	（社会学）
第2部	部　長	中山　和久	（社会法学）
	副部長	山口　　定	（政治学）
	幹　事	兼子　　仁	（公法学）
	幹　事	山中永之佑	（基礎法学）
第3部	部　長	柏崎利之輔	（経済政策）
	副部長	岡本　康雄	（経営学）
	幹　事	河野　博忠	（経済政策）
	幹　事	二神　恭一	（経営学）
第4部	部　長	伊達　宗行	（物理科学）
	副部長	竹内　郁夫	（生物科学）
	幹　事	井口　洋夫	（化学）
	幹　事	新藤　静夫	（地質科学）
第5部	部　長	内田　盛也	（応用化学）
	副部長	大橋　秀雄	（機械工学）
	幹　事	増子　　昇	（金属工学）
	幹　事	松尾　　稔	（土木工学）
第6部	部　長	志村　博康	（農業工学）
	副部長	北村貞太郎	（農業工学）
	幹　事	島田　淳子	（家政学）
	幹　事	平田　　熙	（農芸化学）
第7部	部　長	渥美　和彦	（内科系科学）
	副部長	金岡　祐一	（薬科学）
	幹　事	入江　　實	（内科系科学）
	幹　事	細田　泰弘	（病理科学）

〔常置委員会〕

第1常置	委員長	利谷　信義	（第2部）
第2常置	委員長	中塚　　明	（第1部）
第3常置	委員長	村上　英治	（第1部）
第4常置	委員長	増本　　健	（第5部）
第5常置	委員長	山中永之佑	（第2部）
第6常置	委員長	鹿取　廣人	（第1部）
第7常置	委員長	井口　洋夫	（第4部）

（注）カッコ内は，所属部・専門

第16期日本学術会議会員の概要について

この度任命された210人の第16期日本学術会議会員の概要を以下に紹介します。（カッコ内は第15期）

1　性別　男性209人　女性1人

2　年齢別

45～49歳	1人	50～54歳	3人
55～59歳	26人	60～64歳	93人
65～69歳	72人	70～74歳	12人
75～79歳	1人		

最年長　75　歳（74　歳）
最年少　47　歳（54　歳）
平均年齢　63.6歳（63.3歳）

3　勤務機関及び職名別

(1)　大学関係	国立大学	59人
	公立大学	2人
	私立大学	111人
	公私立短期大学	2人
	計	174人
(2)　国立私立試験研究機関・病院等		9人
(3)　その他	法人・団体関係	5人
	民間会社	6人
	無職	14人
	その他	2人
	計	27人

4　その他の分類

(1)　前・元・新別	前会員	82人
	元会員	3人
	新会員	125人

(2)　地域別（居住地）

北海道	3人（5人）
東　北	9人（8人）
関　東	136人（133人）
中　部	14人（19人）
近　畿	41人（34人）
中国・四国	3人（5人）
九州・沖縄	4人（6人）

（注）詳細については，日本学術会議月報7月号を参照

「日本学術会議だより」について御意見，お問い合わせ等がありましたら，下記までお寄せください。

〒106　東京都港区六本木7-22-34
日本学術会議広報委員会　電話03(3403)6291

日仏海洋学会会則

昭和35年4月7日 制定
昭和60年4月27日 改正
平成4年6月1日 改正

第1条　本会は日仏海洋学会と称する。

第2条　本会の目的は日仏海洋および水産学者の連絡を密にし，両国のこの分野の科学の協力を促進するものとする。

第3条　上記の目的を実現するため本会は次の事業を行なう。

(1)　講演会の開催
(2)　両国の海洋学および水産学に関する著書，論文等の相互の翻訳，出版および普及
(3)　両国の海洋，水産機器の技術の導入および普及
(4)　日仏海洋，水産学者共同の研究およびその成果の論文，映画などによる発表
(5)　両国間の学者の交流促進
(6)　日仏海洋，水産学者の相互の親睦のために集会を開くこと
(7)　会報の発行および出版
(8)　その他本会の目的を達するために必要な事業

第4条　本会には，海洋，水産学の分野に応じて分科会を設けることができる。

分科会は評議員会の決議によって作るものとする。

第5条　本会の事務所は日仏会館（〒101 東京都千代田区神田駿河台2丁目3番地）に置く。

第6条　本会に地方支部を置くことができる。

第7条　本会会員は本会の目的に賛成し，所定の会費を納めるものとする。

会員は正会員，学生会員および賛助会員とする。

第8条　正会員会費は年額6,000円，学生会員会費は年額4,000円，賛助会員会費は一口年額10,000円とする。

第9条　本会は評議員会によって運営される。

評議員の定数は50名とし，正会員の投票によって選出される。選挙事務は別に定める選出規定による。

会長は評議員会の同意を得て5名までの評議員を追加することができる。

評議員の任期は2年とする。ただし，重任を妨げない。

第10条　評議員はその内より次の役員を選ぶ。ただし，幹事は評議員以外からも選ぶことができる。

会長　1名，副会長　2名，幹事　10名，
監事　2名

役員の任期は2年とする。ただし，重任を妨げない。

役員の選出方法は別に定める選出規定による。

第11条　本会に名誉会長，顧問および名誉会員を置くことができる。名誉会長，顧問および名誉会員は評議員会の決議により会長これを委嘱または推薦する。

日仏会館フランス人学長を本会の名誉会長に推薦する。

第12条　会長は本会を代表し，総会および評議員会の議長となる。会長事故あるときは副会長がこれに代わる。

会長，副会長および幹事は幹事会を構成し，本会の庶務，会計，編集，研究発表，渉外などの会務を行なう。

監事は本会の会計を監督する。

第13条　年に1回総会を開く。総会では評議員会の報告を聞き，会の重要問題を審議する。会員は委任状または通信によって決議に参加することができる。

会長は必要に応じて評議員会の決議を経て臨時総会を招集することができる。

第14条　本会則の変更は総会の決議による。

日仏海洋学会評議員・役員選出規定

1. 本規定は日仏海洋学会会則第9条および第10条に基づき本会の評議員および役員の選出方法について規定するものである。
2. 評議員は正会員の50名連記無記名投票により選出する。
   評議員の選挙事務は庶務幹事が行なう。ただし，開票にあたっては本会役員以外の会員2名に立会人を委嘱するものとする。
3. 会長は評議員の単記無記名投票により選出する。
   会長選挙の事務は庶務幹事が行なう。ただし，開票にあたっては本会役員以外の会員2名に立会人を委嘱するものとする。
4. 副会長，幹事，および監事は，会長の推薦に基づき評議員会で決定する。
5. 本規定の改正は評議員会の議を経て行なう。

日仏海洋学会賞規定

1. 日仏海洋学会賞（以下「学会賞」という）を本学会に設ける。学会賞は本学会員で，原則として本学会誌に発表した論文の中で，海洋学および水産学において顕著な学術業績を挙げた者の中から，以下に述べる選考を経て選ばれた者に授ける。
2. 学会賞受賞候補者を選考するため学会賞受賞候補者推薦委員会（以下「委員会」という）を設ける。
3. 委員会の委員は13名とする。
   委員は毎年春の評議員会で選出し，委員長は委員の互選により定める。
   会長は委員会が必要と認めた場合，評議員会の同意を得て2名まで委員を追加委嘱することができる。
4. 委員会は受賞候補1件を選び，12月末までに選定理由をつけて会長に報告する。
5. 会長は委員会が推薦した候補者につき無記名投票の形式により評議員会にはかる。投票数は評議員総数の3分の2以上を必要とし，有効投票のうち4分の3以上の賛成がある場合，これを受賞者として決定する。
6. 授賞式は翌年春の学会総会において行ない，賞状，メダルおよび賞金を贈呈する。賞金は5万円とする。
7. 本規定の改正は評議員会の議を経て行なう。

覚書

1. 委員は各専門分野から選出されるよう十分配慮すること。
2. 受賞者は原則として順次各専門分野にわたるよう十分配慮すること。

賛助会員

阿部嘉方	東京都練馬区春日町 2-15-6
株式会社 内田老鶴圃 内田悟	東京都文京区大塚 3-34-3
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㈶ 海洋生物環境研究所	東京都千代田区内神田 1-18-12 北原ビル内
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新日本気象海洋株式会社	東京都世田谷区玉川 3-14-5
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日本アクアラング株式会社	神奈川県厚木市温水 2229-4
㈱ 三菱総合研究所 (社会情報システム部)	東京都千代田区大手町 2-3-6
㈱ 本地郷	東京都千代田区神田須田町 2-2-4 須田町藤和ビル7F
株式会社 読売広告社	東京都中央区銀座 1-8-14
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株式会社 渡部計器製作所	東京都文京区向丘 1-7-17

日仏海洋学会入会申込書

（正会員・学生会員）

	年度より入会	年　　月　　日申込
氏　名 ローマ字		年　　月　　日　生
勤務先	住　所　〒 機関名 電　話	
自　宅	住　所　〒 電　話	
紹介会員氏名		
送付金額　　　円	送金方法	
会誌の送り先（希望する方に○をつける）	勤務先　　自　宅	

（以下は学会事務局用）

受付	名簿 原簿	会費 原簿	あて名 カード	学会 記事

入会申込書送付先：〒101　東京都千代田区神田駿河台 2-3

(財)日仏会館内

日仏海洋学会

郵便振替番号：00150-7-96503

投稿の手引

1. 「うみ」(日仏海洋学会機関誌；欧文誌名 La mer) は，日仏海洋学会正会員およびそれに準ずる非会員からの投稿 (依頼稿を含む) を，委員会の審査により掲載する。
2. 原稿は海洋学および水産学両分野の原著論文，原著短報，総説，書評，資料などとする。すべての投稿は，本文，原図とも正副2通とする。副本は複写でよい。本文原稿用紙はすべてA4判とし，400字詰原稿用紙 (和文) に，または厚手白紙にダブル・スペース (和文ワープロでは相当間隔) で記入する。表原稿および図説明原稿は，それぞれ本文原稿とは別紙とする。
3. 用語は日，仏，英3カ国語の何れかとする。ただし，表および図説明の用語は仏文または英文に限る。原著論文 (前項) には約200語の英文または仏文の要旨を，別紙として必ず添える。なお，欧文論文には，上記要旨の外に，約500字の和文要旨をも添える。ただし，日本語圏外からの投稿の和文要旨については編集委員会の責任とする。
4. 投稿原稿の体裁形式は最近号掲載記事のそれに従う。著者名は略記しない。記号略号の表記は委員会の基準に従う。引用文献の提示形式は，雑誌論文，単行本分載論文(単行本の一部引用を含む)，単行本などの別による基準に従う。
5. 原図は版下用として鮮明で，縮尺 (版幅または1/2版幅) に耐えられるものとする。
6. 初校に限り著者の校正を受ける。
7. 正会員に対しては7印刷ページまでの掲載を無料とする。ただし，この範囲内であっても色彩印刷を含む場合などには，別に所定の費用を著者負担とすることがある。正会員の投稿で上記限度を超える分および非会員投稿の印刷実費はすべて著者負担 (10,000円/頁) とする。
8. すべての投稿記事について，1篇あたり別刷50部を無料で請求できる。50部を超える分は請求により，50部単位で作製される。別刷請求用紙は初校と同時に配布される。
9. 原稿の送り先は下記の通り。

〒108 東京都港区港南4-5-7 東京水産大学　山口征矢 気付
日仏海洋学会編集委員会

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