La mer

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The western boundary current east of the Ryukyu Islands

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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 x 10^6 m^3/s and the VT of the southwestward current is 6.0 x 10^6 m^3/s, so that the net northward VT is 24.8 x 10^6 m^3/s. Through a transect northwest of Okinawa the total VT of the Kuroshio and Taiwan Warm Current is 32.1 x 10^6 m^3/s and the VT of a southwestward countercurrent is 3.7 x 10^6 m^3/s, so that the net northward VT is 28.4 x 10^6 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 northward from the east of the Ryukyu Islands into the East China Sea through a gap of the Ryukyu Ridge. Its VT west of Okinawa is about 2.4 x 10^6 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 northeastward current. However, so far there have been few studies on it.

Yuan et al. (1991a, 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., 1991a, b) and the modified inverse method (Yuan et al., 1992).

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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., 1993b). 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.
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 $\sigma$-iso-

![Diagram](image)

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: Amami-shima 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.

Isopycnal values of 25, 27, 30 and 33. At Sections PCM1-2-W and WE-1 in Sept. 1992, depths of \( \sigma_e = 25, 27, 30 \) 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 \(-1.05 \times 10^7\) J/(m² day) and 1.26 \( \times 10^7\) J/(m² 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 \( 10^{-2}\)m²/s for momentum and \( 10^{-2}\)m²/s for heat and salinity. The horizontal eddy diffusion is neglected because it is very small with the diffusion coefficient of the order of \( 10^0\)m²/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 1800m 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 VERNONIS (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.

<table>
<thead>
<tr>
<th>Mooring station</th>
<th>Location</th>
<th>Water depth(m)</th>
<th>Meter depth(m)</th>
<th>$v^*$ (cm/s)</th>
<th>$\theta^{**}$ (°)</th>
<th>$v'^{***}$ (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OB</td>
<td>25°48'N, 128°03'E</td>
<td>2020</td>
<td>1890</td>
<td>3.6</td>
<td>263</td>
<td>-2.8</td>
</tr>
<tr>
<td>OC</td>
<td>25°34'N, 128°20'E</td>
<td>4630</td>
<td>2000</td>
<td>3.1</td>
<td>193</td>
<td>-2.7</td>
</tr>
<tr>
<td>OC</td>
<td></td>
<td>4500</td>
<td>2.0</td>
<td>200</td>
<td></td>
<td>-1.9</td>
</tr>
</tbody>
</table>

* 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
The western boundary current east of the Ryukyu Islands

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 southwest 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 %)
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 hydrographic 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_a

Section P_a 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_a. 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_a 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: northeaestward) and salinity (b, %) at P_a.

Fig. 7. Total volume transports. units: 10^6 m/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_b is similar to that at PCM 1-2-E and PCM 1-2-W. However, the salinity minimum water area at P_b 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_b 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 $32.1 \times 10^4$ m$^3$/s. The VT of the southwestward countercurrents below, and east of, the Kuroshio is $3.7 \times 10^4$ m$^3$/s, so that the net northeastward VT across PCM 1-2-W is $28.4 \times 10^4$ m$^3$/s. The northeastward VT of the Ryukyu Current, $30.8 \times 10^4$ m$^3$/s, and the southwestward VT, $6.0 \times 10^4$ m$^3$/s, through PCM 1-2-E make a net northeastward VT of $24.8 \times 10^4$ 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 $22.8 \times 10^4$ m$^3$/s to the west of Okinawa and about $30 \times 10^4$ 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, $1^\circ \times 1^\circ$, is not fine, the coefficient of eddy viscosity is large ($10^6$ m$^2$/s), which broadens the western boundary current
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 $2.9 \times 10^6$ m$^3$/s, of which the first layer about 100 m thick transports $0.5 \times 10^6$ m$^3$/s and the deeper layer $2.4 \times 10^6$ 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 $0.8 \times 10^6$ m$^3$/s.

The total 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, resulting in a net westward VT of $3.7 \times 10^6$ m$^3$/s.

The total northeastward and southwestward
VT through $P_n$ are $52.8 \times 10^4$ m$^3$/s and $3.8 \times 10^4$ m$^3$/s, resulting in a net northeastward VT of $49.0 \times 10^4$ 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 4.5 cm/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, (25° 24' N, 128° 18' E, water depth: 4570m) located 18.8 km apart from OC was 4.3 cm/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 20 cm/s or greater. The other is located above 200m depth further to the east. (ii) There is a southward flow at 200 m 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 620 m depth above the maximum slope of the bottom. The maximum velocity is at the surface layer, and an isotherm of 20 cm/s reaches from the surface to 600 m depth, while in fall the maximum velocity is at the mid-layer. The other core is located in the layer from 550 m to 1300 m further 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 200 m depth around OC. The velocities at two Cp nearest to OC (c and d in Fig. 9c) is 9.2 cm/s and 3.0 cm/s, giving an average of about 6 cm/s, which agrees with the monthly average, 5.5 cm/s, of the observed velocities at 2000 m depth of OC in April 1992.

5. Summary


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 $30.8 \times 10^4$ m$^3$/s and $6.0 \times 10^4$ m$^3$/s, resulting in a net northeastward VT of $24.8 \times 10^4$ m$^3$/s.

The total VT of the Kuroshio and Taiwan
Warm Current through PCM 1-2-W is 32.1 × 10^3 m/s, and the VT of the southwestward undercurrent is 3.7 × 10^4 m/s, so that the net northeastward VT is 28.4 × 10^3 m/s.

The northeastward VT through P1 is 52.8 × 10^4 m/s, and the southwesterly VT is 3.8 × 10^4 m/s, so that the net northeastward VT is 49.0 × 10^3 m/s.

(5) The salinity minimum water in the midlayer flows northward through a gap of the Ryukyu ridge from the east of the Ryukyu Islands to the East China Sea. Its northeastward VT at WE-2 is 2.4 × 10^4 m/s. The westward and eastward VT through WE-1 are 8.0 × 10^3 m/s and 4.3 × 10^3 m/s, making a net westward VT of 3.7 × 10^3 m/s.

References
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 $1^\circ C \times 0.2$ (‰ 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 3-13°C, 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°C, 33.8-34.0 occurring during December to April and the warm water of 17-21°C, 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°C) 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 (hence 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 ($\theta$)-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
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 Island, 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°C×0.2 (°C 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°C and 0.2 (°C or psu) are adequate because standard deviations of temperatures and salinities of the water entering the Tsushima Strait are mostly about 1°C 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°C, an increase in σθ with a temperature decrease of 1°C 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).
Temperature-salinity frequency distribution of the upper 10 m water of the Japan Sea

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 north-western 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.
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°C 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°C 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°C or more is the largest of the four areas.
Temperature-salinity frequency distribution of the upper 10 m water of the Japan Sea

Fig. 2b.

Fig. 2c.

Fig. 2d.
Table 1. Figure numbers of temperature-salinity frequency distributions shown in the present paper.

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January  
February  
March  
April  
May  
June  
July  
August  
September  
October  
November  
December  

(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  

(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  

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°C × 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, [9-1°C, 34.0-34.2], 7.0% and [9-10°C, 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°C, extending roughly zonally from the Korean coast to the Japan coast between 36° and 39°N, make a little broad zones between neighboring 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°C is the largest area. In Area II, the southwestern part, the distribution has the mode [11-12°C, 34.2-34.4] (10.1%). The mean SSS in February decreases northeastward from the Tsushima Strait and an isoline 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°C, 34.6-34.8] (14.4%) in February as expected from Fig. 2a. A weak mode [4-5°C, 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 Current 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.
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. Temperature-salinity frequency distribution of the upper 10 m water of the Japan Sea

(a) Whole Area March 0 m 4903 stations

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Fig. 6. As in Fig. 3 but in March (a) for the whole area and (b) for Area I.
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°C warmer class, [1–2°C, 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°C, 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°C, 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°C completely disappears.

The cold mode is weaken shifting to a lower salinity class [2–3°C, 33.8–34.0] and its frequency (3.8%) is less than that of the middle mode [5–6°C, 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°C, 33.8–34.0] (9.1%) and the warm mode to 0.2 higher class.

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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.
[9-10°C, 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°C, 34.0-34.2], 4.3%, [12-13°C, 34.2-34.4], 3.8% and [15-16°C, 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°C, 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°C, 34.0-34.2], 4.6% and [7-8°C,
Temperature-salinity frequency distribution of the upper 10 m water of the Japan Sea

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</tbody>
</table>

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

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<th>7605 stations</th>
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<td>34.4-34.6</td>
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</table>

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°C, 33.8-34.0], 5.6%) in May and the two warmer ones into the warmer one ([12-13°C, 34.2-34.4], 6.0%). At 10 m there is a weak middle mode in April (Fig. 7c, [5-6°C, 34.0-34.2], 3.9%) and in May three modes still exist two degrees apart for each neighboring two (Fig. 8c, [8-9°C, 33.8-34.0], 6.3%, [10-11°C, 33.8-34.0], 5.2% and [12-13°C, 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.

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<td>32.4-32.6</td>
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<tr>
<td>Total</td>
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<td>10</td>
<td>26</td>
<td>98</td>
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</table>

Whole Area | July | 0 m | 558 stations | Total |
---|---|---|---|---|
| 29.0 | 0 | 0 | 0 | 0 |
| 29.0-30.0 | 0 | 0 | 0 | 0 |
| 30.0-30.2 | 0 | 0 | 0 | 0 |
| 30.2-30.4 | 0 | 0 | 0 | 0 |
| 30.4-30.6 | 0 | 0 | 0 | 0 |
| 30.6-30.8 | 0 | 0 | 0 | 0 |
| 30.8-31.0 | 0 | 0 | 0 | 0 |
| 31.0-31.2 | 0 | 0 | 0 | 0 |
| 31.2-31.4 | 0 | 0 | 0 | 0 |
| 31.4-31.6 | 0 | 0 | 0 | 0 |
| 31.6-31.8 | 0 | 0 | 0 | 0 |
| 31.8-32.0 | 0 | 0 | 0 | 0 |
| 32.0-32.2 | 0 | 0 | 0 | 0 |
| 32.2-32.4 | 0 | 0 | 0 | 0 |
| 32.4-32.6 | 0 | 0 | 0 | 0 |
| 32.6-32.8 | 0 | 0 | 0 | 0 |
| 32.8-33.0 | 0 | 0 | 0 | 0 |
| 33.0-33.2 | 0 | 0 | 0 | 0 |
| 33.2-33.4 | 0 | 0 | 0 | 0 |
| 33.4-33.6 | 0 | 0 | 0 | 0 |
| 33.6-33.8 | 0 | 0 | 0 | 0 |
| 33.8-34.0 | 0 | 0 | 0 | 0 |
| 34.0-34.2 | 0 | 0 | 0 | 0 |
| 34.2-34.4 | 0 | 0 | 0 | 0 |
| 34.4-34.6 | 0 | 0 | 0 | 0 |
| 34.6-34.8 | 0 | 0 | 0 | 0 |
| 34.8-35.0 | 0 | 0 | 0 | 0 |
| Total | 1 | 6 | 23 | 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°C 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. 8h, it is discernible at 9-10°C (9.9%) in Fig. 8a and clearly seen at 8-9°C 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% in Area II (Fig. 5b); but 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°C, 33.8–34.0]), 4.4% at 0 m (Fig. 9a); 4.7% at 10 m (Fig. 9a); 4.9% at 10 m) and warm modes shift to 0.2 lower salinity class ([17-18°C, 34.2-34.4]), 4.3% at 0 m (Fig. 9a); [16-17°C, 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°C, 33.8–34.0] 7.1% and [13–14°C, 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 38.8–34.0 (17–18°C, 2.9% at 0 m (Fig. 10) and 16–17°C, 3.3% at 10 m in the whole area; 18–19°C, 2.7% at 0 m and 17–18°C, 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-

### Table: Temperature-salinity distribution of the upper 10 m water of the Japan Sea

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Whole Area</th>
<th>August</th>
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<th>7483 stations</th>
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**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.
increases 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°C) completely disappears and warm water of 27-29°C 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. 

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

<table>
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<tr>
<td>32.4-32.6</td>
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<td>1</td>
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Whole Area 

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<td>30.0-30.2</td>
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</tr>
<tr>
<td>30.2-30.4</td>
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<tr>
<td>Total</td>
<td>0</td>
</tr>
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Fig. 12. As in Fig. 3 but in September for the whole area.

There is no mode other than [21–22°C, 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°C, 33.4–33.6] (1.8%) is formed at the sea surface besides the first mode [23–24°C, 33.8–34.0] (4.6%).

Double modes are clear at the sea surface in Area IV (Fig. 11d, [21–22°C, 33.6–33.8], 7.4% 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°C, 33.4 at the sea surface and at a little colder side at 10 m, though the distribution evens out.
### Table 3

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<th>Whole Area</th>
<th>October 0 m</th>
<th>8155 stations</th>
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<td>34.8-35.0</td>
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</tr>
</tbody>
</table>

Total: 2331525315071711991161331287646153001000

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

### Table 4

<table>
<thead>
<tr>
<th>Whole Area</th>
<th>November 0 m</th>
<th>3958 stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>-32.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>32.0-32.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>32.2-32.4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>32.4-32.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>32.6-33.0</td>
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</tr>
<tr>
<td>33.0-33.2</td>
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<td>33.2-33.4</td>
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<tr>
<td>33.4-33.6</td>
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<tr>
<td>33.6-33.8</td>
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<td>33.8-34.0</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>34.8-35.0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Total: 111232516174166594776839311712310467182001000

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

and [19–20°C, 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. 24). 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°C, 33.6–33.8], 3.2%), deviating towards a colder, lower salinity side as in August. The weak second mode of high temperature is seen at [24–25°C, 33.2–33.4] (2.0%). Two modes are discernible at both depths in Area III ([19–20°C, 33.6–33.8] 3.7% at 0 m and 3.3% at 10 m; [23–24°C, 33.4–33.6] 3.1% at 0 m and [24–25°C, 33.6–33.8] 3.1% at 10 m) as well,
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°C, 33.2–34.2 at the sea surface. The mode [17–18°C, 33.8–34.0] (3.4%) deviates towards a colder, more saline class from the center; the second mode seems to be around 21°C, 33.5. On the contrary, the first mode is warmer one at 10 m ([17–18°C, 33.8–34.0], 2.9% and [20–21°C, 33.2–34.0]).
33.4], 3.4%). In addition, a cold mode [15–16°C, 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°C, 34.0–34.2] 9.4% at 0 m and [16–17°C, 34.0–34.2] 7.3% at 10 m; [18–19°C, 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 [17–8°C, 33.8–34.0] 3.1%, [12–13°C, 33.8–34.0] 3.7% and [18–19°C, 33.4–33.6] 3.2% in November; [2–3°C, 33.8–34.0] 5.9%, [6–7°C, 34.0–34.2] 4.4% and [12–13°C, 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°C at the sea surface fall on the lower salinity sides of the line connecting (17°C, 34.7), (13°C, 34.7) and (5°C, 34.1) and of the salinity 34.1 line for less than 5°C in winter to spring; the upper limit of salinity for more than 17°C 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°C or a little warmer temperatures. The limit does not depend on temperature for the cold water of less than 8-9°C.

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°C, 34.0–34.2] (W) 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) 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°C, 34.0–34.2] covers eight months. The W 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, the only class [2–3°C, 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
Temperature-salinity frequency distribution of the upper 10 m water of the Japan Sea

![Temperature-salinity distribution](image)

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 $1^\circ C \times 0.2$ (°C 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 W1 and W2 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 $1^\circ C$ 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°C, 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°C, 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.
La mer 33, 1995

The last group T, centered at the class [14-15°C, 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°C × 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°C 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. Tanaka, 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°C, 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°C, 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°C, 33.8-34.2 appearing mostly during July to October, 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°C, 34.0-34.2] occurring twice or three times in a year according to seasonal variations of surface water characteristics.

Acknowledgements

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References


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 $3.5 \times 10^{-4}$ lx. The moving activity of the lobster in nighttime is strongly controlled by brightness. If nighttime brightness is lower than $2.3 \times 10^{-1}$ lx, lobsters move very actively as just as in 0 lx brightness. The nighttime activity is suppressed when brightness is higher than $5.2 \times 10^{-1}$ 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 $2.3 \times 10^{-1}$ lx and lower than $5.2 \times 10^{-1}$ lx.

1. Introduction

Japanese spiny lobsters, 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 parallel, 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
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 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 T1M). 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 TWI-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 lights are off, no signal comes out from our illuminance meters. We denote such brightness as 0 lux here.
Behaviors of Japanese spiny lobsters

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

<table>
<thead>
<tr>
<th>Run</th>
<th>Brightness (lx)</th>
<th>Water temp. (°C)</th>
<th>Water density (at)</th>
<th>Dates</th>
<th>Period (days)</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>$3.5 \times 10^{-1}$</td>
<td>23.1-26.0</td>
<td>24.8-25.3</td>
<td>Jun. 21-Jun. 30</td>
<td>1990</td>
</tr>
<tr>
<td>2</td>
<td>$3.3 \times 10^1$</td>
<td>17.8-19.2</td>
<td>22.9-25.2</td>
<td>Nov. 18-Nov. 27</td>
<td>1992</td>
</tr>
<tr>
<td>3</td>
<td>$3.3 \times 10^1$</td>
<td>16.6-17.7</td>
<td>24.0-25.6</td>
<td>Apr. 14-Apr. 21</td>
<td>1992</td>
</tr>
<tr>
<td>4</td>
<td>$3.3 \times 10^2$</td>
<td>5.2 $\times 10^{-1}$</td>
<td>23.1-25.6</td>
<td>Apr. 24-May. 10</td>
<td>1992</td>
</tr>
<tr>
<td>5</td>
<td>$3.3 \times 10^2$</td>
<td>18.2-21.3</td>
<td>22.1-24.8</td>
<td>May. 11-May. 28</td>
<td>1992</td>
</tr>
<tr>
<td>6</td>
<td>$3.3 \times 10^2$</td>
<td>2.0</td>
<td>21.5-23.8</td>
<td>Jun. 25-Jul. 12</td>
<td>1992</td>
</tr>
<tr>
<td>7</td>
<td>$4.6 \times 10^2$</td>
<td>***</td>
<td>***</td>
<td>Jun. 1991</td>
<td></td>
</tr>
</tbody>
</table>

***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 rest 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 980ILV21) 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 250g 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 lob-
ster 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 changes 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 $3.3 \times 10^4$ 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 $4.6 \times 10^3$ lx, and a little higher than the control run above mentioned (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
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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 hours 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°C 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 $3.5 \times 10^{-7}$ lx in run 1 and $3.3 \times 10^{6}$ lx in run 2, respectively (see Table 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 frequency 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.

<table>
<thead>
<tr>
<th>Brightness (lx)</th>
<th>Activity (frequency/h)</th>
<th>Activity (meter/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>daytime</td>
<td>nighttime</td>
<td>daytime</td>
</tr>
<tr>
<td>1</td>
<td>$3.5 \times 10^{-1}$</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>$3.3 \times 10^{0}$</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>$3.3 \times 10^{0}$</td>
<td>$2.3 \times 10^{-1}$</td>
</tr>
<tr>
<td>4</td>
<td>$3.3 \times 10^{0}$</td>
<td>$5.2 \times 10^{-1}$</td>
</tr>
<tr>
<td>5</td>
<td>$3.3 \times 10^{0}$</td>
<td>$3.5 \times 10^{-1}$</td>
</tr>
<tr>
<td>6</td>
<td>$3.3 \times 10^{0}$</td>
<td>2.0</td>
</tr>
<tr>
<td>7</td>
<td>$4.6 \times 10^{0}$</td>
<td>0</td>
</tr>
</tbody>
</table>

The diurnal variation pattern in run 1 is very similar to that in run 2. There is a 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 $3.5 \times 10^{-2}$ 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 a 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 $3.5 \times 10^{-2}$ 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 $2.3 \times 10^{-1}$ 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 $2.3 \times 10^{-1}$ 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 subsection, 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 ($3.3 \times 10^{0}$ lx). We increased the nighttime brightness from $2.3 \times 10^{-1}$ 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 $2.3 \times 10^{-3}$ lx is as just dark as 0 lx. However, when the nighttime brightness is increased to $5.2 \times 10^{-3}$ 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 $3.5 \times 10^{-3}$ 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. Areciga and Atkinson (1975) and Phillips et al. (1980) reported that activity peak occurs just after sunset for other lobsters (Nephrops norvegicus, Panulirus argus and Jasus lalandii). This may correspond to our results. However, Kubo and Ishwata (1964) reported that catch of Japanese spiny lobster
occurs not only just after sunset but also just before sunrise. For a prawn, *Peneaus 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 Table 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 threshold brightness value of lobster activity exists between $2.3 \times 10^{-3}$ lx and $5.2 \times 10^{-1}$ 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 changes 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 activity frequencies 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 characters, but the figure suggests that a threshold brightness value for the lobster activity exists between $2.3 \times 10^{-1}$ and $5.2 \times 10^{-3}$ 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 use the sea near the Boso Peninsula is influenced by moonlight intensity (Yoza et al. 1977). The water off the Shima Peninsula, where one of the good fisheries grounds 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). According 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 $5.2 \times 10^{-4}$ lx. It would be reasonable from our results that lobster catch is influenced by moonlight brightness.


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 lobster is reproduced in our experiments, and lobsters stay almost in rest in daytime if the brightness is higher than $3.5 \times 10^{-2}$ 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 $2.3 \times 10^{-3}$ 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 $5.2 \times 10^{-3}$ 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 $2.3 \times 10^{-3}$ lx and lower than $5.2 \times 10^{-3}$ 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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References


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 caught 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 caught fresh fish. Following results were obtained.
1) It was difficult to select accurately 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 accurately 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 difference in it's breadth, but also it's weight.
3) If the adjacent selecting roles were revolving 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（以下、ロールと称する）上端に設けられた魚体は、間隔が上端から下端へと次第に拡大する2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、下端の幅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観点から、魚体の大きさに仕分け方法は、農産物の大小仕分けにも利用されている（宮谷，1987）。

このような本システムは、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100、ロール下の段階の大きさに仕分けられており、ロール下で落下した魚体を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。同機の作動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剖した。まず、魚体処理装置（FOR映：VPA-1000、およびビアス（株）PIASⅢ）により撮影画像のロール1に定間隔の測定範囲を設けて矢田、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、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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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力を試算した。

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（種倉ら, 1993; 桟井・広中, 1981)。そこで、次に示すように、試作機に測定器具を付着して、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本装置し、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、理論式の所要各係数を把握し、また各種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のうね水しながら、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引出し、その測定張力から摩擦係数を試算した。また、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て結果、魚体は垂直距離0.5m、水平距離0.45mを0.32秒で落下する。そして得られた結果から魚体の滑降速度を求めた。

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

Fig. 2. The system for measuring the friction force.
1: Role, 2: Pulley, 3: Tension meter, 4: Motor and tachometer, 5: Pulse convertor, 6: Recorder, 7: Inverter
魚のロール式大小仕分け機構

1975年」としては小さいことが判明した。これは後述するように、放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ことと推察される。

なお、Fig.3に示すように、体長30cm、体重114gから170gの市販の両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増減する1対のロールによりも菌される仕分け機構のモデルを示す。ここで、ロールの軸心を座標原点、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、ロール間から下落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、次式で示される。

\[ Fx = m\ddot{x} = mg \sin \theta \]
\[ Fy = m\ddot{y} = mg \cos \theta \]

（1）式で示される魚体の放物運動の経過時間を、t_{0}(s)、ロール間より下落した瞬間のt_{0}を零、その時のx軸方向の初速度をv_{x} (m/s)とし、t_{0}が零の時魚体位置を座標の原点とする、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。

\[ x = \frac{1}{2} g \sin \theta t^2 + v_{x} t \]
\[ y = \frac{1}{2} g \cos \theta t^2 \]

t_{0}が零のときのx方向の初速度v_{x}は、ロール上における魚体の等加速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_{s}(s)とすると、v_{x}は次式（3）で示される。

\[ v_{x} = V + mg(\sin \theta - \mu \cos \theta) t_{s} \]  （3）

ただし、魚体はロール上で相互に衝突・干渉するので、t_{s}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、ロール下端の平板シュートは、原点より下段の間隔b(m)に水平面と角度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。

\[ y = b + (\tan \alpha) x \]  （4）

したがって、下落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。

\[ t = \sqrt{\frac{2(b + (\tan \alpha) x)}{g \cos \theta}} \]  （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_{s}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2座標が得られる。したがって、平板シュート上にお
魚体の落下点の座標 \( P(x, y) \) は次式で示される。

\[
P(x,y) = (x, b + (\tan \alpha)x)
\]

ただし、

\[
x = \frac{D_1 + \sqrt{D_1^2 - D_2^2}}{D_1}
\]

\[
D_1 = (1 - \tan \theta \tan \alpha)
\]

\[
D_2 = b \tan \theta \left( 1 + \frac{v_i^2 \tan \alpha}{g \tan \theta} \right)
\]

\[
D_3 = (b \tan \theta)^2 - \frac{v_i^2}{g \cos \theta}
\]

また、初速 \( v_i \) が零の場合における魚体の落下点 \( Q \) の座標は次式で示される。

\[
Q(x,y) = (x, b + (\tan \alpha)x)
\]

ただし、

\[
x = \frac{b}{\cot \theta - \tan \alpha}
\]

（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、落下時の魚体の \( x \) 方向の初速度 \( v_i \)、魚体の傾斜角 \( \alpha \)、平板シュート設置角 \( \theta \)、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 \( v_i \) で落下する同型魚の平板シュートの上落下範囲 \( PQ \) や斜度など、平板シュート上における異体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、魚体傾斜角などは推定される。

次に、Fig. 5 に落下時におけるロールと魚体の関係を示す。ロール角から落下する魚体には、重力、ロールにより加える抗力 \( R(N) \)、および斜面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 \( \mu \) とすると、魚体を落下させるように作用する力 \( F(N) \) は次式で示される。

\[
F = mg + q \cdot 2 \mu R
\]

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一の場合には 1、逆方向の場合には -1 で示す。

ロール回転により加えられる抗力 \( R \) は、魚体の体幅および弹性抵抗に起因し、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、\( F = 0 \) ではロール間に挟まれさらに落下しないが、\( F < 0 \) 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、\( R \) が零となり、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、魚体の後退性抵抗は大きくなり、また魚体はロール間に挟まれるので、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の体幅および体長が推定可能と考えられる。

3）ロールおよび平板シュートの付加傾斜角

初速 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魚体傾斜角 \( \theta \) が 0 度および 6 度にお
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。図は省略したが、見掛けの動摩擦係数は放水すると、ロール周速度が1 m/s以上ではほぼ零となり、放水量を増やすと、さらに見掛けの動摩擦係数は減少した。これに対し、放水用海水の粘度が低いので、魚体がロール間を滑らかに接触面に薄い水膜が生じるため摩擦が小さくなることが推察される（三輪・池本, 1975; 椎井・広中, 1981; 高島, 1987）。なお、放水量が少なく、体重および体幅の大きさに関わらず魚体がロール面に付着し、回転ロール角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ほど、魚体の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。これより、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

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

進行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が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度とはほぼ近似している。

以上より、ロール式で大小を鮮魚を仕切る場合、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のと推察される。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。
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、供試サンプルは100g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2段階に仕分けけていたが、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がなる。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落の勢いで魚体の姿勢が問題であり、体幅差の幅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、魚体5と同6により左右斜め下方に移植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、魚群を左右に分配させると共に、次項の仕分け機構を有し、同1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、仕分け機構が異なり、次項のよう

（1）逆回転する隣接ロール間の機構

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左右に逆回転する場合について考えると、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が影響しないので、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ので、Fig.5および(7)式において、体幅がゆるやかに圧力の大きさは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動作に逆ってロール間から落下するための魚体価の条件は次式(9)で示される。

\[
ms \geq 1.6 \mu R
\]  \( (9) \)

本式から、ロール間隔および魚体の体幅が一定でも、体幅に差があると、仕分けが可能であることを示している。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、魚体を指示申し上げるように逆回転する複数の隣接ロールを、並列に連結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。その際には、魚体を強制的に繋ぎ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左回転と左回転の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構

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器は同様に推察される。このような場合においては、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と、ロールは高速回転するから魚体に働く上下方向への力 \( \mu R \) は相殺されるので、(8)式の第2項を零にすることは、故に、第1項の重力のみで仕分けられることになるので、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間を通過する仕分け精度の魚体と、ロール4と同5間を通過する仕分け精度の魚体（\( ms - 2 \mu R \)）の魚体がショート上の同じ落差範囲 \( PQ \) 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。

仕分け精度のパラメタが大きい一因は、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。同方向に回転する隣接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では魚体の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より外側のロール径を徐々に大きくする、各外側のロール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 \( \mu R \) より上向きの \( \mu R \) 的値を大きくすると、効果的と考えられる。

例えば、6cmにおける、ロール間隔を1cmで表すとロール5と同4の各摩擦係数は各々 \( \mu_2 \) と \( \mu_3 \) で示され、ロール1から同5までは \( (\mu_1 - \mu_2) = 0 \) の場合に、またロール6から同11までは \( (\mu_1 - \mu_3) < 0 \) 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。

\[
F = ms - q(\mu_2 \mu_3 - \mu_1 \mu_3) R
\]  \( (10) \)

順回転し、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、魚体は挙げてシ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台）当たりの仕分け量は、一定時間内でペルトンベガ上を滑降す
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。

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）魚体の大小は水深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、魚体とロールに載水し、さらにロールを高速回転させると、同程度の体積でも、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。

以上より、魚体は体積差および体重差により仕分けられるものと推定される。

文 献
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宝谷幸男（1987）：水産加工機械。恒星社厚生閣、東京。pp. 21-24。
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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）学術定期刊行物助成金の申請を行うこととした。
2）日研関連学会連絡協議会が12月2日開催される。
3）水産学研究連絡協議会より水産学者推進への派遣の提案が提案された。

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ECSS-VII Proceedingsとして印刷中。

6）岩波出版「海に何が起こっているか」の訂正箇所を訂正表を作成した。出版後は印刷に誤りがなかったが、出版者としては新刊印刷の意向が強いことか報告された。

協議事項
1）日研関連学会連絡協議会への出席を高木ふじ会長、佐伯渕幹事に依頼した。
2）国際学術会合への派遣候補者推薦について、水産学研究連絡推進推進委員会で提案された。本年度は推薦を決定することとした。
3）学会誌の数値表紙の改正について、編集委員会よりの報告をもとに審議し、6頁から8頁までを編集委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月4日間の会期で、全体テーマとして"Integrated Coastal Management"を提案、増殖、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月下旬に実行委員会を設立するとのことで、関係者・予算の検討や関係者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水産宏樹教授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）

間崎守直 〒103 中央区日本橋箱崎町1-13-17
三洋テクノマリン 環境技術部

井上敏彦 〒338 浦和市西浦町1-13-20
島津仁一 〒338 浦和市西浦町7-6-33

3. 郵便

阿部友三郎・渡辺清治（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

5. 受贈図書（受領願）

Chinese Science Bulletin 39 (11-21)
Annales llnstitute Oceangraphique 70
Israel Oceanographic & Limnological Research 16 (1, 2)

OKEANOLITIA 34 (5)

日仏海洋学会役員・評議員（1994-1995年度）

顧問：スペース・プロジェクト ジャン・デルサルト
ジャック・ロジェール アレクシス・ドラン
デール ベルナール・フランク ミシェル・ルサーリュ ローベル・グルメール
ジャック・マギー レオン・ヴァルデメルジュ オギュスタン・ベルク ユーベル・セカディ

名誉会長：オビエ・アンサール
会長：有賀 祐樹
副会長：高木 和徳 岡田 友利
幹事：（会務） 須藤 英雄 有元 賢文
（編集） 森永 勤 岸野 元彰
（研究） 関 文義 小池 慎夫
（編著） 佐藤 昭宏 陸島 史夫

監事：久保田 雄 池田 時美

編集委員長：山口 征矢

評議員：有元 賢文 有賀 祐樹 石丸 隆
今協 資郎 宇野 寛 大塚 一志
岡田 友利 奥田 邦明 落合 正宏

編集委員会：金成 華一 鎌谷 明善

※ 本号の発行について

平成7年2月発行

本号の発行について

平成7年2月発行

本号の発行について

平成7年2月発行
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 biannually 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 an 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

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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、会長から数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。
総会第2日目（26日）の午前、前日採択された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、「日本学術会議制度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」、「日本学術会議の運営に関する内規の一部改正」、「副会長選任担当研究連絡委員会の運営について（集中）」を含む4件について一括して採択され、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. 運営委員会の構成員等の見直し

運営委員会と運営審議会の連絡を緊密にし、運営審議会の講演をより充実させることを、運営委員会委員長が運営審議会に出席することを、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（集中）

5月4日-22日第117回総会決議に沿って第7常置委員会を設置し、併せて、各部会等での検討結果を踏っ

3. 総務委員の在任期間等

総務委員の在任期間に関する運営内規の解釈をよ

4. 女性科学研究者の環境改善の緊急性についての提言

5. 提言についての提言（声明）の採択

これらの会則、内規等の改正は、

次に、「運営審議会附属委員会の研究を検討委員会の設置」についての討論・採択が行われ、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、会員推薦制度の過程において、幾つかの問題点が見られたことから、これらの問題点について審議するため、新たな委員会を運営審議会に設置することです。統一、「新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を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・採択が行われ、可決されました。後の、「第7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件の研究報告についての審議が行われ、それぞれ承認されました。総会第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、学術的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、国内外から招聘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、社会科学を含む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、生活と研究なしに修道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い求めるものであって、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多く含まれており、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がある場合も少なくないが、多くの場合には、かかる公的機関の保有する情報は学術情報として利用することは困難が伴っている。それ故、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利用のためには、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もある。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では、学術研究にとっても特に重要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、確実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、情報の保有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。

女性科学者研究者の環境改善の緊急性についての提言（声明）（抄）

女性の社会的統制の向上を目指す取組が、国際的にも国内外にも広く行われているが、日本学術会議においても第10期及び第12期に女性科学者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、女性科学者研究者の地位の向上の必要性は理念的にも一般化したもので、科学者全体の対象の関係もあって、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者不足の事態が目前に迫っている現在、我々国内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、日本学術会議は、改めて女性科学者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。

日本学術会議の事務局は、この提言について御意見、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 東京都港区北青山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。この第16期会員による総会である。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、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、文部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、会員を代表して最長年である中島義雄第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「会員の皆様には絶対的な尊重で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尽力いただきたい」とあいさつし、これに応えて、中田直勝第1部会員が「従来ながら全力を尽くし、重要な職務を全うし、国民の期待に応えたい」とあいさつしました。午後は、日本学術会議講演において、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、人文社会科学部門の副会長には、利根信義第2部会員が、自然科学部門の副会長には、西島安治第4部会員が、それぞれ選出され、伊藤会長及び利根副会長（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し等に行われました。（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期の総合的な活動報告を行い、続いて、会員推薦管理会報告として、久保田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期会員実施で実施した「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、各運営審議会附属委員会、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期会員との懇親会が初めて開催されました。懇親会は、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言による乾杯、伊藤会長の答辞のあいさつの後、懇親に入りました。米倉として、お与野文部大臣、田中科学技術学術庁長官、吉田農林水産副大臣、藤田日本学士院院長ほかが出席され、あふれんばかりの人々で歓談が続きました。懇親会終了後、第16期の活動計画の作成についての運営審議会附属委員会、各常置委員会等が開かれ、会長から第16期活動計画の作成についての案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論が行われ、各部会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、各運営審議会附属委員会、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期の活動計画の案作成のために、運営審議会構成委員の中から起草委員を選出し、審議に入りました。
<table>
<thead>
<tr>
<th>会長</th>
<th>伊藤 正男（第7部・生理科学）</th>
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<tr>
<td>副会長</td>
<td>村上 美治（第1部）</td>
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<td>副会長</td>
<td>根本 健（第5部）</td>
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<td>副会長</td>
<td>井口 幸夫（第6部）</td>
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</tbody>
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【常任委員会】

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<td>1. 第1部</td>
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<td>2. 第2部</td>
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<td>3. 第3部</td>
<td>村上 美治</td>
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<td>4. 第4部</td>
<td>増本 健</td>
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<td>5. 第5部</td>
<td>山中道之介</td>
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<td>6. 第6部</td>
<td>鹿取 健人</td>
</tr>
<tr>
<td>7. 第7部</td>
<td>井口 幸夫</td>
</tr>
</tbody>
</table>

（注）カッコ内は、所属部・専門

第16期日本学術会議員の概要について

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歳以下: 1人
   - 46~54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

3. 年長: 75歳（74歳）
   - 年少: 47歳（54歳）

平均年齢: 63.6歳（63.3歳）

3. 勤務機関及び職名等

(1) 大学関係
   - 国立大学: 59人
   - 公立大学: 2人
   - 私立大学: 111人
   - 公立短期大学: 2人

(2) 国立研究開発法人: 9人

(3) 法人、団体関係
   - 民間会社: 6人
   - 無職: 14人

その他
   - 2人

計: 174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）
   - 東京: 136人（133人）
   - 近畿: 41人（34人）
   - 中国: 3人（5人）
   - 九州: 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

〒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
学会記事

日仏海洋学会則

第1条 本会は日仏海洋学と称する。
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) 両国間の海洋学および水産学に関する著作、
論文等の相互の翻訳、出版および普及
(3) 両国間の海洋、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密のために
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 本会は地方支部を立つことができる。
第7条 本会会員は本会の目的に従事し、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挙規定
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、重選を妨
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、重選を妨げ
ない。
役員の選出方法は別に定める選挙規定による。
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。会長事務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を構成し、本
会の庶務、会計、編集、研究発表、海外などの
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
を聴き、会の重要問題を審議する。会長は委任
状または通牒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う。ただし、開票にあたっては正会員経由の会員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う。ただし、開票にあたっては正会員経由の会員2名に立会人を委嘱するものとする。

4. 副会長、幹事、および委任は、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的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かける。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. 受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授与する。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顕着各専門分野にわたるべきよう十分配慮すること。
贊助会員

阿部嘉方 東京都練馬区垂井町 2-15-6
株式会社 内田老舗内田悟 東京都文京区大塚 3-34-3
有限会社 英和出版印刷社 東京都北区中里 2-7-7
株式会社 カイセウ 東京都西多摩郡羽村町栄町 3-1-5
創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
株式会社 川合海苔店 東京都大田区大森本町 2-31-8
株式会社 自然・情報環境研究所 横浜市栄区桂町 1-1, 3-401
新日本気象海洋株式会社 東京都世田谷区玉川 3-14-5
全日本昆虫類皮革産業連合会 東京都足立区梅田 4-3-18
株式会社 萩間屋 東京都台東区上野 6-7-22
株式会社 東京久栄技術センター 埼玉県川口市芝緑ヶ丘 6906-10
株式会社 西日本流体技研 長崎県佐世保市相府町 283
日本アクアラング株式会社 神奈川県厚木市温水 2229-4
三麦総合研究所（社会情報システム部） 東京都千代田区大手町 2-3-6
本郷 東京都千代田区内神田須田町 2-2-4 須田町築和ビル7F
株式会社 読売広告社 東京都中央区銀座 1-8-14
渡辺機関工業株式会社 愛知県豊田市田原町神戸大塚 230
株式会社 渡部計器製作所 東京都文京区向丘 1-7-17
私たちは、快適環境の創造を目指す環境科学分野の専門家集団として、多岐にわたる環境に関する技術の開発・研究に努め、経験豊かな各部門が蓄積されたノウハウを駆使して、地域社会に貢献しております。
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<td>送付金額 円</td>
<td>送金方法</td>
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| 会誌の送り先（希望する方に〇をつける） | 勤務先 | 自宅 |

（以下は学会事務局用）

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<tr>
<th>受付</th>
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