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Observation of near-inertial internal waves in the abyssal Japan Sea

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Abstract: Observation with a moored Acoustic Doppler Current Profiler (ADCP) set to a very short measurement interval revealed vertical propagation of near-inertial internal waves (NIW) in the abyssal Yamato Basin in the Japan Sea. Flow and temperature measurements showed a sinusoidal variation having near-inertial period associated with NIW. From the polarization of flow vectors, vertical and horizontal wave numbers of the NIW were estimated to be 1.741×10^{-3} m^{-1} and 2.563×10^{-4} m^{-1}, respectively. Phase propagation of the NIW was downward at speed of 5.34×10^{-2} ms^{-1}, indicating an upward group velocity. Back-tracing of the energy ray path of NIW passing through the observation point shows that the observed NIW were the bottom-reflected waves. The bottom reflected waves were the downward-propagating NIW generated in the upper layer. An event of clockwise rotation of wind vectors was suggested as a cause of the observed NIW.

Keywords : *Yamato Basin, ADCP, short measurement intervals, vertical propagation*

1. Introduction

Internal gravity waves with frequency close to the local inertial frequency (near-inertial internal waves, NIW) are ubiquitous in the world oceans (WEBSTER, 1968; FU, 1981). NIW have been considered to be an important agent for mixing in the ocean interior (HIBIYA *et al.*, 1996) which controls the intensity of the global-scale thermohaline circulation (TOOLE and McDOUGALL, 2001); however, NIW structure and propagation processes in the deep sea have not been clarified.

It is known that the Japan Sea, a semi-enclosed marginal sea in the northwestern North Pacific (Fig. 1), has its own thermohaline circulation system (GAMO and HORIBE, 1983; SENJYU *et al.*, 2002). NIW have been frequently reported in the Japan Sea not only in the upper layer (KANARI *et al.*, 1987; LIE, 1988; KIM *et al.*, 2001; KIM *et al.*, 2005; PARK and WATTS, 2005; OKEI *et al.*, 2009; IGETA *et al.*, 2009, 2011; BYUN *et al.*, 2010), but also in the deep layer (TAKEMATSU *et al.*, 1999; SENJYU *et al.*, 2005; MORI *et al.*, 2005). Considering that the frequency of internal gravity waves (ω) must be in the band between local inertial frequency (f) and buoyancy frequency (N) (GILL, 1982), we have some advantages to NIW observation in the Japan Sea. First, the frequency of NIW generated in there is limited to 0.837–1.149×10^{-4} s^{-1}, because of the Japan Sea's latitudinal extent (35°–52° N). Second, deep water in the sea, the Japan Sea Proper Water, has very narrow ranges of temperature and salinity (WORTHINGTON, 1981),

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which results in a buoyancy frequency on the same order of f (typically $1.0–5.0 \times 10^{-4}$ s^{-1} below 1000 m). These facts indicate that NIW in the abyssal Japan Sea have a narrow frequency range. In addition, tidal flows in the Japan Sea are generally weak (SENJYU *et al*., 2005). This fact indicates little contamination from tidal motions. The weakness of tidal flows also indicates that the most of sub-diurnal variations in the Japan Sea are the near-inertial motions, which suggests that the intensity of the basin-scale thermohaline circulation in the sea is mainly controlled by the near-inertial flows associated with NIW, analogous to the global-scale thermohaline circulation.

One reason that the behavior of NIW in deep water has not been clarified is that deep flow observations with high spatial and temporal resolution are not common. For example, in the Japan Sea, it has been common in long-term current monitoring for serial single-layer current meters to be spaced at tens to hundreds of meters in the vertical, with 30–60 minute sampling intervals (SENJYU *et al*., 2005). Therefore, we made special observations to capture NIW propagation in the abyssal Japan Sea, using a moored Acoustic Doppler Current Profiler (ADCP) set to a very short measurement interval. Although the period of observation was only about 2 days, we successfully observed vertical NIW propagation in the deep sea. This paper describes the results of the observation and discusses the NIW structure, propagation, and generation in the abyssal Japan Sea.

2. Observation

The ADCP (300 kHz Workhouse, Teledyne RDI) was deployed at Sta. SH in the Yamato Basin of the Japan Sea (38° 17.05' N, 135° 50.0 6' E) at 07:12 on 13 May and recovered at 05:39 on 15 May 2013 by TR/V Nagasaki Maru of Nagasaki University (Fig. 1). The ADCP was moored

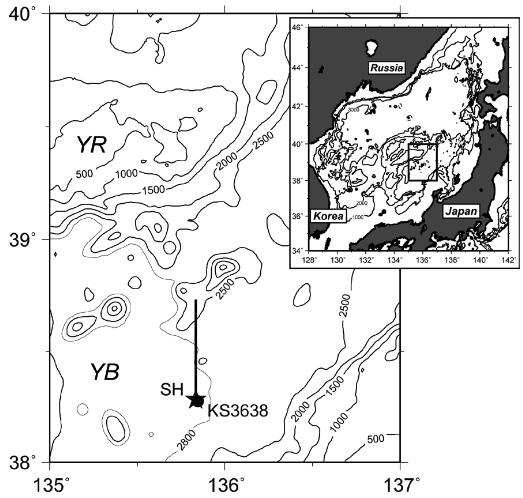

Fig. 1 Observation site. Contour lines indicate water depth in meters. Star and circle indicate Sta. SH of ADCP mooring and Sta. KS3638 of JMA, respectively. YB and YR denote the Yamato Basin and Yamato Rise, respectively. The ray-tracing was done in the section along the solid line. The area is enlarged map of the square in the inset showing the Japan Sea.

upward looking at 2650 m. To detect NIW propagation, we set bin size and measurement intervals at 4 m (with the first bin at 6.2 m) and 10 seconds, respectively. The nominal accuracy of the ADCP is ±0.5% of water velocity relative to the instrument ± 0.5 cms^{-1}. The accuracy and precision of flow direction are ±2.0° and ±0.5°, respectively.

The posture of ADCP during the observation was very stable. Pitch and roll angles monitored by a tilt sensor in the instrument were within ±1° throughout the mooring period. Nevertheless, no flow data were obtained by the equipment for layers farther than 50 m because of weak acoustic echo intensity, though the nominal observation distance was set to 100 m. In addition, data at the first layer (2644 m) were noisy. Therefore, we analyzed the velocity profile in the 40 m range from 2600 to 2640 m (lay ers 2–12 of the equipment, for a total of 11).

Six successive velocity profiles at 10-second intervals were averaged to yield 1-minute interval data. Furthermore, 5-minute running mean was applied to the 1-minute data to reduce short-term fluctuations. The size of the averaging time window (5-minute) was determined try and error to reserve the signal of vertical propagation of NIW. Owing to the averaging, standard deviation in a current measurement was reduced to 0.16 cms^{-1}. The available data length is 45 hours 54 minutes from 07:43 on 13 May to 05:37 on 15 May 2013.

In addition to the flow observation, temperature at 2650 m was measured with a sensor embedded in the ADCP transducer head at the same sampling intervals as flows. Though the nominal precision of the sensor is ±0.4°C and the accuracy and time constant of the sensor are unknown, the temperature measurements are useful for the present study because the relative values of temperature are available by the resolution of the sensor, 0.01°C. The same procedure of flows was applied to the temperature data.

3. Results

Time series of east-west (u) and north-south (ν) components of velocities at 2604, 2620, and 2636 m are shown in Fig. 2, along with temperature measurements (T) at 2650 m. Flows at each layer exhibited similar temporal variations to each other, showing a prevailing barotropic flow. Speed and direction of the vertically-averaged mean flow for the observation period were 2.73 cms^{-1} and 315.8°, respectively. This northwestward flow may be part of the cyclonic circulation in the Yamato Basin (Senjyu *et al.*, 2005), though the observed flows showed a linear temporal trend.

A sinusoidal flow variation with a period of about 20 hours, superimposed on the linear trend, was clear in each layer. The phase of sinusoidal variation in ν led by about 90° than that in u, showing a clockwise change of flow direction. Similar periodical variation to that of flows was found for temperature. In addition, vertically-coherent fluctuations with relatively large amplitude were occurred intermittently, for example a velocity shift in 16:30–17:00 on 13 May and a jump in ν in 09:00–10:00 on 14 May. However, most of short period fluctuations in flow and temperature measurements are probably due to noise, which amplitudes are near the measurement threshold and tend to be large as increase of distance from the equipment.

For a rough estimate of the dominant period of variation, we separated the periodical components in u, ν, and T (hereafter u', ν', and T') from background variations by subtracting the tempo-

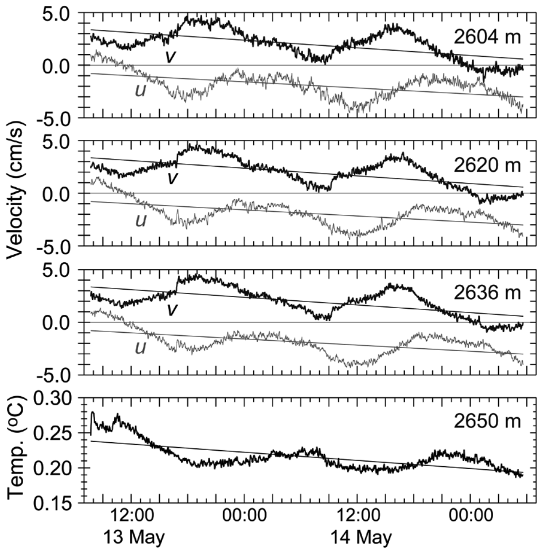

Fig. 2 Time series of velocity at 2604, 2620, and 2636 m and temperature at 2650 m. Gray thin and black bold lines in velocity show east-west (u) and north-south (ν) components, respectively. Thin strait lines in each panel denote the linear trend throughout the observation period.

Table 1 Mean relative angles of the velocity vector at each layer to the velocity at 2640 m

Depth (m)	2636	2632	2628	2624	2620	2616	2612	2608	2604	2600
Relative Angle (°)	0.86	1.83	0.88	2.06	2.47	1.54	2.29	3.06	3.93	3.17

ral linear trends from the measurements, then calculated auto-correlation functions for u', v', and T' The linear temporal trend for flows was calculated from the vertically-averaged flow by least square method. The estimated periods (frequencies) of u' and v' as the mean for the all observation depths were 1118.3 minutes ($\omega_u = 9.364 \times 10^{-5}$ s^{-1}) and 1192.6 minutes (ω_v=8.781 × 10^{-5} s^{-1}), respectively, and the estimated period (frequency) of T' at 2650 m was 1136 minutes ($\omega_T = 9.218 \times 10^{-5}$ s^{-1}). Since the local inertial period (frequency) at the observation site is 1158.9 minutes (f=9.036 × 10^{-5} s^{-1}), the observed periodical variations of flows and temperature are mostly attributable to NIW. It may seem strange that the frequency of v' is lower than the local inertial frequency. This is likely due to an insufficiently long observation period for precise estimation of near-inertial motions, though a region of negative relative vorticity can trap sub-inertial frequency motions (KUNZE, 1985).

Because of the noisy short period fluctuations, it is hard to confirm the polarization relation in a snapshot profile of u' and v'. Therefore, we calculated the angles between the velocity vector at each layer and that at 2640 m (relative angles referred to the deepest layer velocity vector), and averaged them for the observation period (Table 1 and Fig. 3). The mean relative angles exhibited positive values throughout the observation depths, indicating a clockwise rotation of velocity vectors in the shallower layers. Furthermore, the mean relative angles tend to decrease from 3–4° at 2600–2608 m to less than 1° at 2628 and 2636 m. This polarization suggests a downward phase propagation of NIW (GILL, 1982).

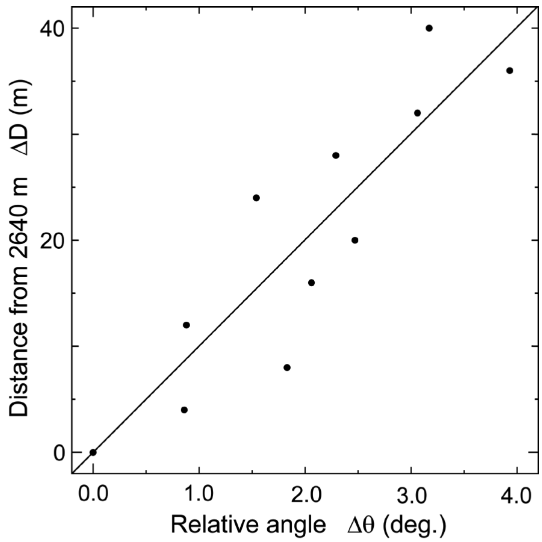

Fig. 3 Relationship between the mean relative angles of velocity vector to that at 2640 m ($\Delta\theta$) and the vertical distance from 2640 m (ΔD). The regression line is shown by the strait line.

As a typical example of vertical NIW propagation, time-depth diagrams of u' and v' are shown in Fig. 4 for 11:00–17:00 on 14 May. Vertical phase propagation from upper to lower layers is discernible in both components. Similar vertical phase propagations in u' and v' to that in Fig. 4 were detected several times during the observation period.

4. Discussions

4.1 Structure of the NIW

At first, vertical phase speed and wave number of the NIW were tried to estimate from vertical cross-correlation functions for u' and v'. However, broad peaks in the cross-correlation functions prevented us from a reliable estimation.

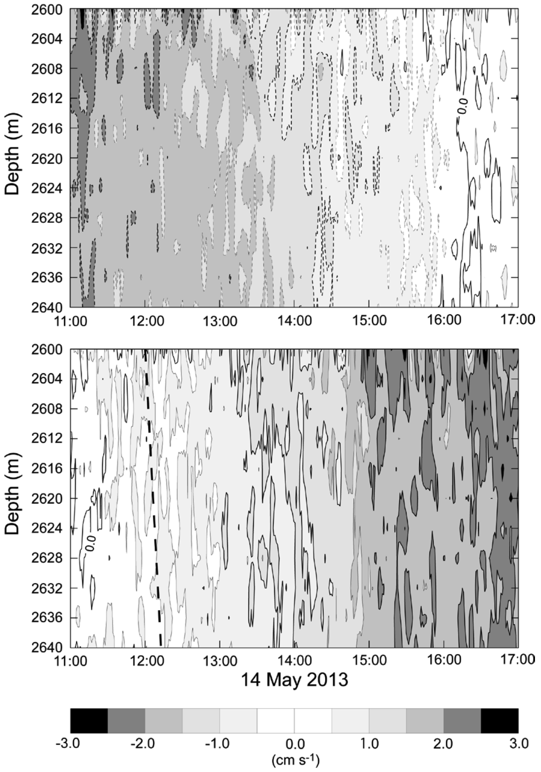

Fig. 4 Time-depth diagram for u' (upper) and v' (lower) during 11:00 to 17:00 on 14 May 2013. Negative values were denoted by dashed contours. Broken line in lower panel shows the estimated propagation speed 5.34×10^{-2} ms^{-1}.

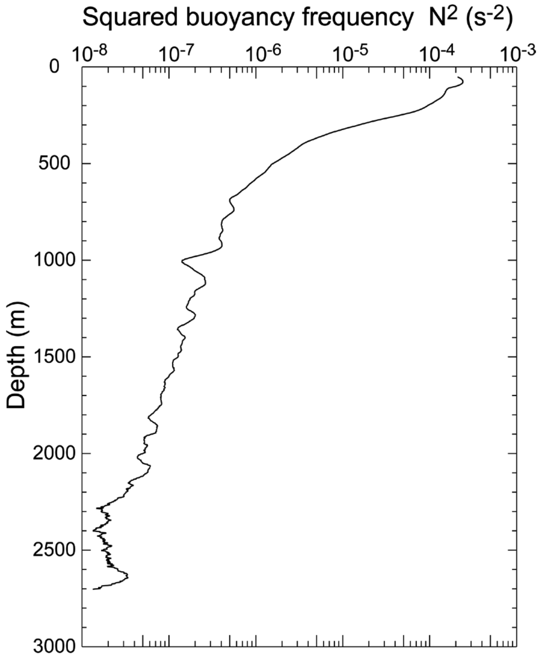

Fig. 5 Vertical profile of squared buoyancy frequency (N^2) at Sta. KS3638 of JMA.

Therefore, we estimated the vertical wave length of the NIW from the polarization relation; Fig. 3 shows a clear linear relationship between the relative angle ($\Delta\theta$) and distance from the reference depth 2640 m (ΔD), with the correlation coefficient of +0.89. The polarization relation determined by least square method is

$$\Delta D = 10.025 \times \Delta\theta \qquad (1),$$

which shows the vertical wave length λ_z of 3609 m (vertical wave number $=1.741 \times 10^{-3}$ m^{-1}) as ΔD at $\Delta\theta = 360°$. If we take $\omega = 9.291 \times 10^{-5}$ s^{-1} as the mean of ω_u and ω_T, reasonable frequencies higher than the local inertial frequency at the observation site, then vertical phase speed C_Z ($= \omega/m$) is estimated to be 5.34×10^{-2} ms^{-1} (broken line in the lower panel of Fig. 4). Such fast phase propagations cannot be captured by typical deep-sea mooring observations with few current meters of tens to hundreds of meters vertical spacing and 30–60 minutes sampling intervals.

Unfortunately, there were no stratification data near the observation site during the mooring period. Therefore, we inferred squared buoyancy frequency N^2 in the abyssal Yamato Basin from temperature and salinity data at Sta. KS3638 (38°16.52' N, 135° 50.69' E), obtained by the Japan Meteorological Agency (JMA) on 4 November 2012 (Fig. 1). N^2 from 2600 to 2640 m is 2.554–3.385×10^{-8} s^{-2} (Fig. 5), with mean 3.022×10^{-8} s^{-2} corresponding to the buoyancy frequency (period) of 1.739×10^{-4} s^{-1} (602.4 minutes).

Using the values of f, ω, and N^2 above, the phase propagation angle of the NIW from the horizontal (φ) was estimated at 81.6° from

$$\tan^2\varphi=\frac{N^2-\omega^2}{\omega^2-f^2}=46.13 \qquad (2).$$

Since the above relationship also represents the aspect ratio of NIW ($m^2/\kappa_H{}^2$, where κ_H is horizontal wave number), κ_H of the observed NIW was estimated to be 2.563×10^{-4} m^{-1} (horizontal wave length λ_H=24512 m).

4.2 Propagation of the NIW

Since phase propagation of the observed NIW was directed from upper to lower layers, the direction of the group velocity must be upward according to the linear wave theory (GILL, 1982). This suggests that the observed NIW were generated at the seabed or were bottom-reflected waves. To examine the bottom generation/reflection possibility, we back-traced the NIW energy ray from the observation site. The WKB approximation is not applicable because of the large vertical wave length of the NIW comparable to the length scale of density stratification N. However, variation of N is on the order of 10^{-4} s^{-1} below 1000 m (from 1.153×10^{-4} s^{-1} near the bottom to 5.140×10^{-4} s^{-1} at 1116 m, Fig. 5). Therefore, we considered that N is almost constant and assumed that the ray-tracing method is locally applicable below 1000 m.

Since NIW can only freely propagate equatorward from its generation area (GARRETT, 2001) and the critical latitude at which the local inertial frequency f is the same as the observed NIW frequency ω is 39°35.3' N, the generation or reflection region of the observed NIW is likely to be north of the observation site. Therefore, tentatively, the backward ray-tracing was done northward in the section along 135°50.0' E with origin 38°17.0' N (observation site) on the β-plane, assuming the profile of N^2 at Sta. KS3638 of JMA for the entire region (Fig. 1). Southward propagation of the observed NIW is qualitatively supported by the relationship between ν', and T' in Fig. 2; when ν' was negative (southward) T' tended to decrease because of upward advection of cold water in the lower layer, and vice versa (see Fig. 8.4 in GILL, 1982).

The ray-tracing shows that the NIW passing through a point 2620 m of the observation site with upward group velocity are bottom-reflected waves (Fig. 6), which were downward-propagating NIW incident on the bottom about 1.1 km north of the observation site. Further back-tracing suggests that the observed NIW were generated in the upper layer, rather than the seabed around the observation site.

4.3 Generation of the NIW

It has been reported that near-inertial motions observed in the upper layer of the Japan Sea were associated with atmospheric disturbances (KIM *et al*., 2005; OKEI *et al*., 2009; IGETA *et al*., 2009, 2011). Part of the near-inertial motions generated in the upper layer can propagate down into the deep layer (ALFORD *et al*., 2012), though most of wind energy injected into the ocean is confined in the surface mixed layer (FURUICHI *et al*., 2008). Therefore, we examined wind conditions before and during the observation period using the Grid Point Value/Meso Spectral Model (GPV/MSM) data provided from JMA. The GPV/MSM is hourly operational weather forecasting data with spatial resolutions of 0.05° and 0.0625° in latitude and longitude, respectively.

The time series of wind speed averaged over the area in Fig. 1 (38°–40° N, 135°–137° E) is shown in Fig. 7a for the period of 8–15 May 2013. Although the wind speed was less than 10 ms^{-1} throughout the analysis period, a marked event occurred in 10–11 May. Fig. 7b shows the time series of wind vectors for the 20-hour high-pass filtered component including the local inertial period variations. A clockwise change in wind direction is clear during the period from 13:00 on May 10 to 12:00 on May 11. This clockwise change in wind direction was dominant variation because the high-pass filtered component accounts for more than 40% of the total wind speed in this period (Fig. 7a). Since surface near-inertial currents are most efficiently enhanced when wind vector rotates inertially (LARGE and CRAWFORD, 1995), this atmospheric event may be a cause of the observed NIW.

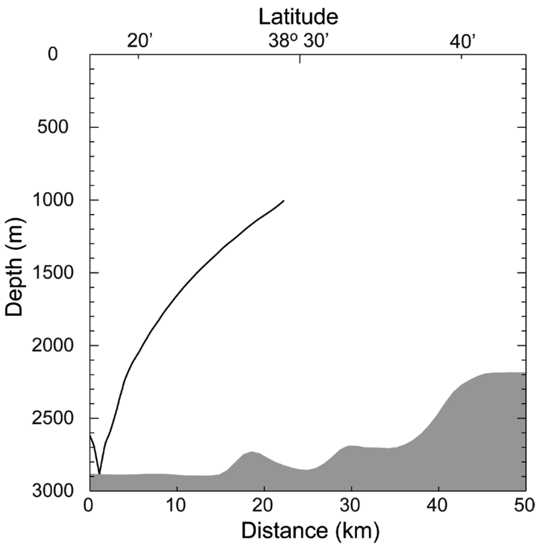

Fig. 6 Ray path of the southward propagating NIW passing through a point 2620 m of the observation site in the section along the solid line in Fig. 1.

Another possible process of the NIW generation is geostrophic adjustment accompanied with instabilities of the mean flow (TANG, 1979). North of the observation site, the subarctic front in the Japan Sea lies about 40° N with significant variability due to mesoscale eddies generated by instability (ISODA, 1994). Besides, internal lee waves may be excited by interactions between deep flows and the Yamato Rise (NIKURASHIN and FERRARI, 2010), because the subarctic front intersects the Yamato Rise throughout the year (PARK *et al.*, 2007) and the mesoscale fluctuations in the subarctic front influence the deep flow field (SENJYU *et al.*, 2013). The high level of internal wave energy in the Yamato Basin (MORI *et al.*, 2005; SHCHERBINA *et al.*, 2003) is partly attributable to the instability of flows along the subarctic front and the Yamato Rise. However, the observed NIW may be not the case because of its large

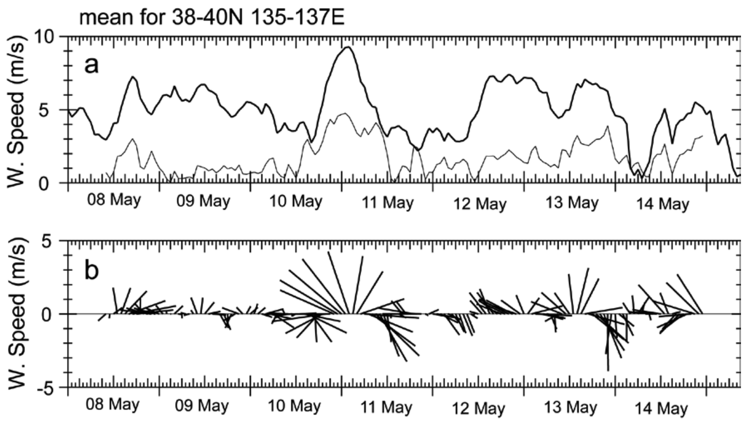

Fig. 7 Time series of the GPV/MSM wind averaged over the area 38°–40° N, 135°–137° E (Fig. 1) for the period of 8–15 May 2013. (a) Wind speed (bold line) and that for the 20-hour high-pass filtered component (thin line). (b) Wind vectors for the 20-hour high-pass filtered component.

vertical wave length; it has been reported that the vertical scale of internal lee waves excited by interactions between deep flows and topography are ~600 m (NIKURASHIN and FERRARI, 2010).

5. Remarks

Vertical propagation of NIW was observed in the abyssal Japan Sea, where a barotropic flow generally prevails. It is feasible to use the detailed flow structure revealed by moored-ADCP observation of high spatial and temporal resolution to elucidate mixing processes in the deep ocean interior. Although vertical shears during the observation period were relatively stable, typically on the order of 10^{-3} s^{-1}, seasonal and intermittent intensifications of near-inertial flows have been reported in the abyssal Japan Sea (MORI *et al.*, 2005). Strong vertical shear promoting oceanic mixing is possible during such periods.

The horizontal wave number and propagation angle of NIW were estimated from equation (2) which relates wave parameters m, κ_H, and φ with ω. In particular, the propagation angle φ depends sensitively on ω, because the denominator of equation (2) becomes very small for NIW. However, since our observation period was only about 46 hours, 2.4 times of the local inertial period, we could not estimate ω precisely, posing major limitation of this study. Precise estimation of ω based on longer-period observation remains as a problem to be solved in future.

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Temporal variation of microalgal chlorophyll *a* in surface ice and the underlying Water in lagoon Notoro-ko, Hokkaido, Japan.

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Abstract: Lagoon Notoro-ko is a large brackish lake on the Okhotsk Sea coast of Hokkaido. It is completely covered with sea ice during winter and hydrographic and biological conditions during this season are unknown. Previous investigations done in warm seasons indicate that the lagoon water is almost the same as the Okhotsk Sea water because there are few inflows from the land. We conducted a winter investigation into the temporal changes of microalgal chlorophyll *a* in the sea ice and water column beneath it during the period from February 6 to March 18, 2008. Of the surface PAR, 1% penetrated to 6–10 m depth in the water column beneath the ice, where 0.4–6.0 mg/m^3 chlorophyll *a* was detected. Integrated chlorophyll *a* in 18 m ranged 8.7–119.1 mg/m^2. In contrast, chlorophyll *a* levels in 20–31 cm thick ice ranged 2.5–11.6 mg/m^2, relatively less than in the water column. However, because chlorophyll *a* was largely concentrated in the bottom-most part of the ice, it might be available to grazers in the underlying water. During ice melting, a large proportion of the populations released from the ice likely sunk to the sea bottom rather than remaining in the water column.

Keywords : *ice algae, phytoplankton, chlorophyll a, Lagoon Notoro-ko*

1. Introduction

The Okhotsk Sea is a marginal subarctic sea in the western North Pacific. It is bordered by Siberia Russia in the north and west and by Hokkaido, Japan, in the south. It is the southern-most ice-covered sea in the northern hemisphere during winter (WATANABE, 1963; PARKINSON and GRATZ, 1983). Many of the lagoons and brackish lakes on the Okhotsk Sea coast of Hokkaido also freeze every winter. However, few studies on the relationship between sea ice and biological production have been conducted in the sea. One of the reasons for this is that the majority of the sea ice in the Okhotsk Sea is floe or drifting ice, which makes it very difficult to follow its effect on biological production over time. To avoid this difficulty, we focused on fast sea ice.

There are several lagoons and brackish lakes in the coastal region of eastern Hokkaido, Japan that are permanently connected to the Okhotsk Sea and freeze on the surface in winter. These lagoons and lakes are productive fishing grounds, particularly for marine demersal resources. Among them, Lagoon Notoro-ko is the second

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largest and its water is exchanged with the Okhotsk Sea water by tidal force. On the other hand, there is little inflow from land drainage. As a result, the physical and chemical properties of the lagoon water are quite similar to those of the Okhotsk Sea (IMADA *et al.*, 1995; NISHINO *et al.*, 2007). Because of this, the ice cover in Lagoon Notoro-ko can be considered as a fast ice of the Okhotsk Sea and a suitable stage to investigate the Okhotsk Sea ice (KURATA and NISHIHAMA, 1987; WATANABE *et al.*, 1991; ASAMI and IMADA, 2001).

The ice in Lagoon Notoro-ko starts to form in late December, becomes fast enough for human activities between late January and late March and melts away by mid-April. We conducted a series of investigations on the distribution of microalgal chlorophyll *a* in both the ice (ice algae) and the underlying water (phytoplankton) in February and March 2008. This paper reports temporal changes in the distributions of the ice algae and the phytoplankton and discusses the ecological role of the sea ice in the Okhotsk Sea.

2. Methods

Field surveys were conducted approximately once a week or five times in total during the period from February 6 to March 18, 2008, when on-ice activity was feasible, at a fixed station in the deepest part of the Lagoon Notoro-ko. Its geographical position is 44°03′03″N, 144°09′45″E, and the depth to the bottom is approximately 20 m (Fig. 1). Ice cores were taken with an ice auger of 7 cm in diameter and water samples were taken at 1 m, 5 m, 10 m, 15 m and 18 m with a Van Dorn bottle. Vertical temperature, salinity and density (sigma-t) profiles were recorded with a CTD (JFE Advantech, Model ASTD102). Penetration of photosynthetically active radiation (PAR) into the water column beneath the ice was measured with a quantum meter (JFE Advantech, AL30-CMP) by susupending the sensor into the underlying water column through the hole left after ice core sampling (diameter: ca. 10 cm). PAR at different depths is expressed in relative values (%) to that above the ice (in air).

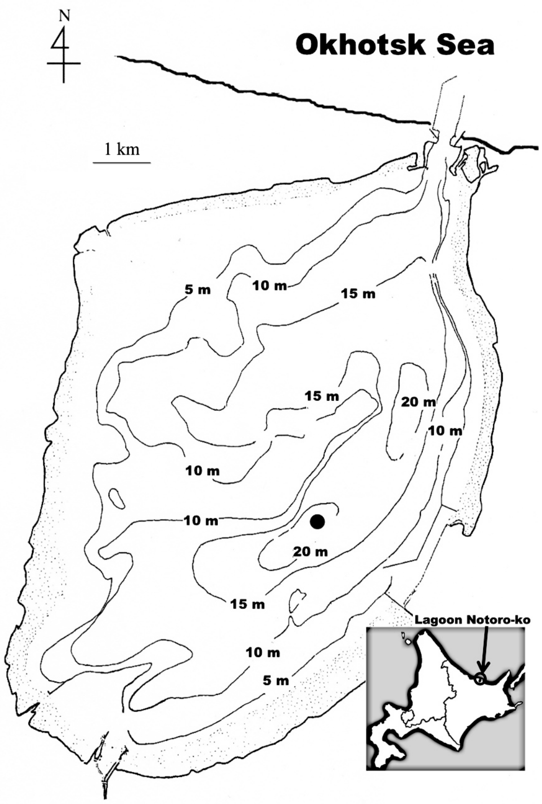

Fig. 1 Station (solid circle) for serial observations on microalgal chlorophyll *a* contents in ice cover and the underlying water column at the center of the deepest basin in Lagoon Notoro-ko onthe Okhotsk Sea coast of Hokkaido, Japan, from February 6 to March 18, 2008. Depth contours are given at 5 m intervals.

The ice cores were divided into five parts, i.e. upper, upper-middle, middle, middle-lower and lower. The upper, middle and lower parts were exactly 5 cm in length, while length of the upper-middle and middle-lower parts differed depending on the thickness of the ice on the day of survey. Each of the ice cores was thawed and chlorophyll *a* measured. Size-fractionated (> 10

Table 1. Underwater PAR (photosynthetically active radiation) at five sampling depths in values relative to those on the ice cover (%) during the ice-covered period from February 6 to March 18, 2008 in Lagoon Notoro-ko. Sea ice thickness (cm) is also given for each sampling day.

Sampling date (Ice thickness)		Feb. 6 (20)	Feb. 18 (29)	Feb. 29 (30)	Mar. 10 (31)	Mar. 18 (21)
	Depth (m)	2.60	1.50	1.70	3.10	6.00
	5	0.75	0.42	0.53	0.98	1.15
	10	0.30	0.17	0.23	0.40	0.37
	18	0.17	0.10	0.11	0.25	0.25
	~20	0.11	0.07	0.03	0.24	0.11

μm, 2–10 μm, < 2 μm) chlorophyll *a* concentrations were measured in the seawater samples and thawed ice by a serial filtration through polycarbonate filters of 10 μm and 2 μm in pore size (Whatman) and a glass fiber filter (GF/F, Whatman). Chlorophyll *a* on the filters was extracted in dimethylformamide and measured with a fluorometer (Turner-Design, 10-AU) according to the WELSCHMEYER (1994).

3. Results and Discussion

3.1 Hydrographic conditions beneath ice cover (Fig. 2, Table 1)

Temperatures in the water column beneath the ice ranged from −2.3℃ to −1.0℃ and generally increased with depth. On February 18, supercool water below −1.8℃ had formed in the upper 5 m and, as a result, an inverse thermocline formed around 5 m. Thereafter, temperature gradually increased at every depth, particularly below 10 m, and a thermocline formed around 15 m.

Salinity was < 32.7 throughout the water column during the survey period, except for February 18, when very saline water appeared in the surface and bottom layers (maximum: 33.3). On February 29, it was indicated that the saline surface water has sunk and been diluted. Salinity dropped to < 32.4 through the water column in March. Very low salinity water was detected at the surface (minimum: 29.3) on March 18.

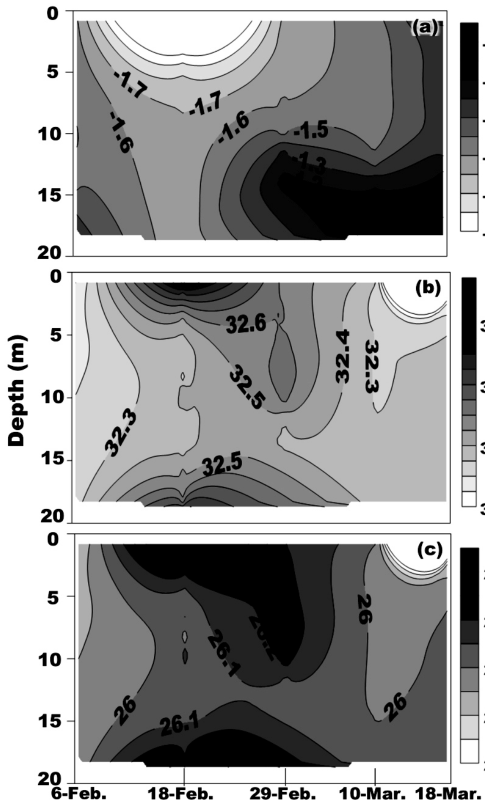

Fig. 2 Time courses in vertical section of temperature (a: ℃), salinity (b) and density (c: sigma-T) in the water column observed during the ice-covered period from February 6 to March 18, 2008, at the fixed station in Lagoon Notoro-ko on the Okhotsk Sea coast of Hokkaido, Japan. The bottom depth was about 20 m.

Sigma-t was over 26 in most cases, which was higher than that in warm seasons, i.e. 21.5–26.1 (NISHINO unpublished data). The temporal and vertical changes of sigma-t generally followed those of salinity. High sigma-t values, > 26.9, were observed in both the surface and bottom layers on February 18. The lowest density (23.5) was observed on March 18 in the diluted surface water.

A coastal divergence from the East Sakhalin Current reaches the coast of eastern Hokkaido in autumn and winter (OHSHIMA *et al.*, 2002; SHIMIZU and OHSHIMA, 2006), which is characterized by salinities below 32 (FUJII and SATOH, 1979; TAKIZAWA, 1982). Salinity at or below 32.4 in the coastal water in winter indicates the presence of the East Sakhalin Current (AOTA, 1979). The present results revealed the intrusion of this water mass (< 32.4) into Lagoon Notoro-ko in winter. Within this water mass, high salinity water appeared separately in the surface and the bottom layers in late February, forming an inverse pycnocline in the surface and a normal pycnocline in the bottom layer. Such unusual stratification indicates that some unfrozen brine water had sunk rapidly to the bottom before February 18 and the exclusion of the brine continued until February 29. We conclude that ice is most actively formed in February in Lagoon Notoro-ko. In March, the low salinity water affected by the East Sakhalin Current again filled the entire water column, except for the surface water which was diluted by melting ice. It is possible that the high salinity bottom water observed in February may have been the result of a temporary intrusion of Okhotsk Sea Intermediate Cold Water, which is highly saline being 32.8–33.3 (TAKIZAWA, 1982). If it had been the case, it occurred within a very short period and was limited to a thin bottom layer (Fig. 2). Therefore, it is a reasonable conclusion that the water mass occupying Lagoon Notoro-ko during winter is basically the coastal water affected by the East Sakhalin Current and temporarily modified by the formation and melting of the ice. Further investigations on nutrient compositions and plankton assemblages are necessary.

Table 1 shows underwater PAR intensities in relative values (%) to that above the ice. Relative PAR at 5 m depth was 2.6% on February 6; it decreased afterwards in February (1.5–1.7%) and increased again to 6.0% in March. PARs at other depths varied in parallel with this. The 1% PAR depth, which is generally assumed to be the compensation depth of phytoplankton photosynthetic production, was 6.5–10.7 m during the entire period, indicating that positive production was continually performed at significant depths through the ice covered period. This is not surprising because the lagoon is located in the southern half of the northern hemisphere (44° 03' N). Recorded values of the ten-day average of daily solar irradiance during the same period were 5.3–7.1 MJ/m^2 in January, 8.8–10.5 MJ/m^2 in February and 11.9–12.5 MJ/m^2 in March, which were about 23–54% of the annual maximum recorded in middle of May (23.1 MJ/m^2) of the same year (JAPAN METEOROLOGICAL AGENCY, 2008).

KISHINO (1993) reported that relative PAR beneath 33 cm thick ice was about 0.7% under natural conditions and about 4% after the removal of snow that had accumulated on the ice in Lagoon Saroma-ko, about 100 km north of Lagoon Notoro-ko. Although this demonstrates that light penetration through ice is largely obstructed by snow accumulation, such heavy accumulation was not recorded on any occasion in the present investigation in Lagoon Notoro-ko. The reason for this difference between lagoons is not clear at present.

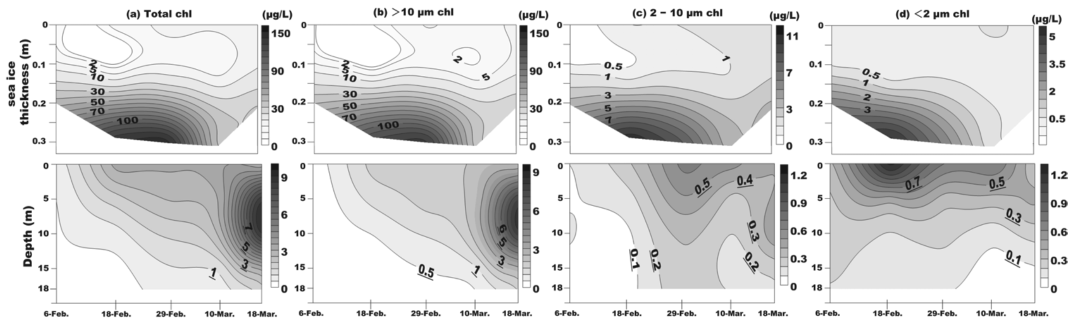

Fig. 3 Vertical section of total chlorophyll *a* over time (a), large-sized chlorophyll *a* > 10 µm (b), medium-sized chlorophyll *a* 2–10 µm (c) and small-sized chlorophyll *a* < 2 µm (d) in 20–31 cm thick sea ice (upper) and the underlying water column down to 18 m (lower) from February 6 to March 18, 2008. The bottom depth was about 20 m.

3.2 Chlorophyll a (Fig. 3)

Chlorophyll *a* concentration in the ice was 2.2–8.4 µg/L in the upper part, 2.8–13.4 µg/L in the middle part and 21.8–163.6 µg/L in the lower part. This demonstrates that so-called ice algae (microalgal communities within sea ice) can attain very high densities particularly in the lower part of the ice. Fig. 3 shows that their density gradually increased during the course of ice development until the end of February, but suddenly decreased when the ice started melting in early March. Among the ice algae, the large size class (> 10 µm) always predominated, while intermediate (2–10 µm) and small (< 2 µm) size classes usually contributed less than 20%. The exclusive dominance of the large size class was constant throughout the survey period. Similar trends of vertical and temporal variations of the ice algal chlorophyll *a* had been observed in a preliminary survey done in the preceding winter; while absolute concentration was apparently different between deep central area (this station) and shallow near-shore area, the trends were essentially the same in different areas. Similarity in concentration between several ice cores collected from the area of ca. 1 m^3 had also been confirmed.

The sudden decrease in chlorophyll *a* in the ice from February 29 to March 10 is remarkable and interesting. Because the ice was approximately the same thickness in this period, it is unlikely that the lower layer of the ice holding dense algae had melted. It must be noted that chlorophyll *a* in the middle part also dropped markedly from 13.4 to 3.3 µg/L in the same period. One possible explanation for this decrease is as follows: As solar radiation and air temperature increased (data not shown), the ice might start melting internally before the surface temperature of the underlying water increased to the melting temperature of the sea ice (−1.8℃). The internal melt probably progressed around brine pockets, which are characteristic of sea ice. The pockets gradually expanded and the ice algae inside were released into the underlying water. During this, the thickness of the ice might have remained unchanged.

Released ice algae partly contributed to an increase in phytoplankton in the underlying water column. As seen in Fig. 3, such a contribution to phytoplankton increase was positive in the smaller size classes but less so in the large size class. The latter indicates that the large-sized ice algae, probably in the form of colonies or aggregates,

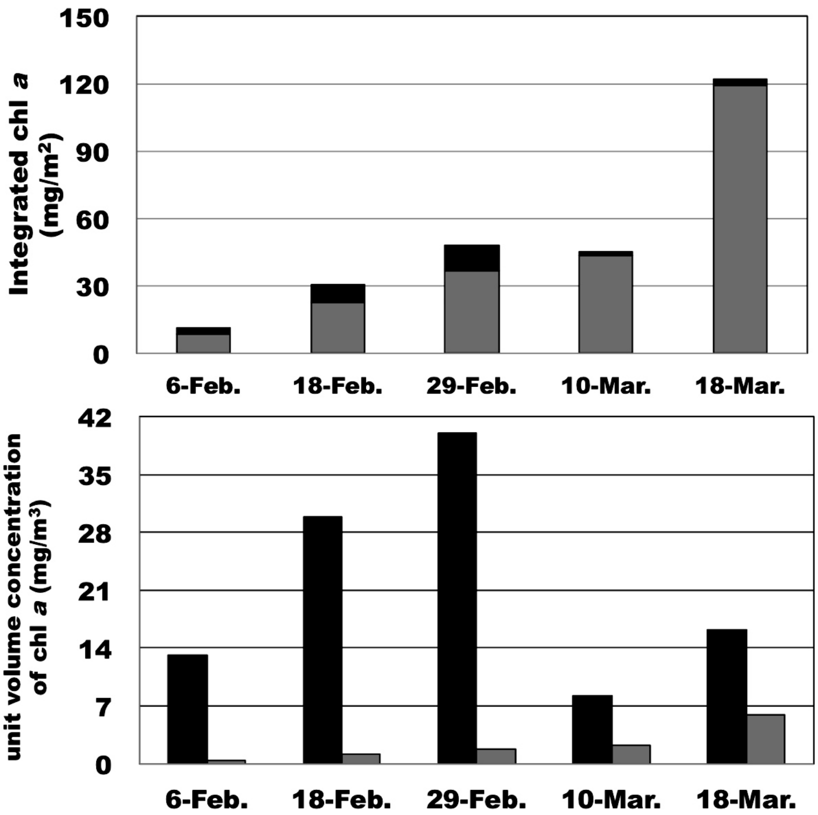

Fig. 4 Temporal changes in chlorophyll *a* stocks in the ice cover (■) and the underlying water column (■) in total amount (upper: mg/m^2) and average concentration (lower: mg/m^3) observed during the ice-covered period from February 6 to March 18, 2008, in Lagoon Notoro-ko, Hokkaido, Japan.

sunk down to the sea bottom rapidly and were hardly sampled with a Van Dorn bottle. If so, a large proportion of the ice algae contributed to the benthic rather than planktonic community. A bloom of the larger phytoplankton occurred on March 18, well after the major decrease of large-sized ice algae and took place in subsurface layer (5–10 m) instead of the surface layer underneath the melting ice (Fig. 3b). Since PAR at 10 m on March 18 was 1.15% (Table 1), blooming in the 5–10 m layer was natural. It is interesting to note that the larger phytoplankton avoided the low salinity surface water underneath the melting ice but the smaller size classes did not. This demonstrates that ice algae and phytoplankton populations interact differently in different size classes.

3.3 Integrated chlorophyll *a* in ice and water column (Fig. 4)

The amount of integrated chlorophyll *a* through the ice cores was 2.5 mg/m^2 at beginning, increased steadily to a maximum of 11.6 mg/m^2 on February 29 and dropped to 1.7 and 2.7 mg/m^2 on March 10 and 18, respectively. During this period, since ice thickness was more or less constant at 20–31 cm (Fig. 3), accumulation and loss of chlorophyll *a* should have occurred in the bottom part of the ice. The sudden decrease in chlorophyll *a* on March 10, when the thickness of the ice was still increasing, albeit marginally, is interesting (Fig. 3). This implies that release of the ice algae into the underlying water column is triggered by the widening of the brine pockets inside the ice, not because of the collapse of the sea ice, as discussed in the preceding chapter.

Integrated chlorophyll *a* through water column to 20 m depth differed from that in the ice over time. Chlorophyll *a* continually increased in the water column from 8.7 mg/m^2 on February 6 to 43.7 mg/m^2 on March 10 and finally reaching 119.1 mg/m^2 on March 18. Consequently, the ratio of the ice algae to phytoplankton in total chlorophyll *a* was relatively high before March 10 with a maximum of about 25% on February 29, but decreased sharply to about 2% in March. Nevertheless, the average chlorophyll *a* concentration in the ice was always higher than in the water column even on March 18 when the phytoplankton bloom occurred. Because it is generally known that the density of dietary microalgae positively affects herbivore feeding efficiency, the sea ice provides herbivores with efficient grazing areas, especially on its under surface exposed to the water. Benthopelagic mysids and shrimps were occasionally observed with abundant copepods in the surface layer at the present investigation site (data not shown).

4. Conclusions

The present study site, Lagoon Notoro-ko, is located in the southern half of the northern hemisphere. This makes the light conditions in the water column under ice cover essentially different to that in high arctic seas. In the high arctic, because solar radiation in winter is generally low and largely reflected by snow and ice, underwater light conditions are very poor and thus phytoplankton production is negligibly low. In contrast, except on the occasional heavy snow days, phytoplankton photosynthetic production in Lagoon Notoro-ko is not limited in this way. The present results evidently show that, in the water column covered with 20–31 cm ice, the 1% PAR depth (compensation depth) was as deep as 6.5–10.7 m (cf. Table 1). The phytoplankton chlorophyll *a* concentration was well over 1.0 μg/L to the depths throughout winter (Fig. 3). This level of chlorophyll *a* is comparable to those in warm seasons (Kurata and Nishihama, 1987; Nishino *et al*., 2014). The brackish nature of the lagoon water might benefit this; the water column is easily stratified and holds phytoplankton in the shallower layers.

Stocks of chlorophyll *a* within the ice (ice algae) were also notably large. Integrated chlorophyll *a* was comparatively smaller than in the underlying water column but its concentration was very high (Fig. 4). A certain proportion of the ice algal populations is continuously released into the water. This might form an efficient forage site of filter feeders in the underlying water, because they prefer dense food suspension to phytoplankton distributed over wide water column (Parsons and Takahashi, 1973; Taniguch, 1975). Since major part of the ice algae is concentrated into the bottom-most part of the ice, their products are partly available to grazers including benthopelagic organisms on the under-surface of the ice. We also suggest that most of the large-sized ice algae sink directly to the sea bottom in late February (Fig. 3), which might be consumed by benthic grazers. Such contribution of the ice algae could be determined by collecting the sinking colonies with e.g. sediment traps in future survey.

In summary, sea ice is a unique ecological platform, where microalgae perform three primary producer roles, i.e. produce nutrient rich products (pasture), allow grazers to feed on the products (meadow) and transport products to the benthic community (feeder).

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Seasonal variations in the population structure and depth distribution of *Calanus sinicus* in northern Kagoshima Bay

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Abstract: We investigated seasonal variations of population structure and depth distribution of *Calanus sinicus* in northern Kagoshima Bay. Animals were abundant during April to June when chlorophyll *a* concentrations were high. Young copepodites or adults appeared over the seasons, however, copepodite stage 5 dominated when the population abundance was the lowest during August 2009 and July 2010. We found little indication of seasonal vertical migration since all developmental stages occurred above 50 m and below 100 m throughout the year. RNA:DNA ratios revealed no significant decline throughout the year. These results suggest that *Calanus sinicus* reproduces throughout the year and does not experience a deep-water dormancy period in northern Kagoshima Bay.

Keywords : *Calanus sinicus*, population structure, depth distribution, nucleic acids

Introduction

Calanoid copepods are among the most diverse groups of crustacean zooplankton (more than 2000 species; Razouls *et al.*, 2005–2013), contributing significantly to marine biomass (Verity and Smetacek, 1996) with greater than half of the global abundance of zooplankton (Longhurst, 1985). These copepods integrate carbon flows from lower trophic levels of both the classical and microbial food webs because they consume phytoplankton, heterotrophic microzooplankton, and sinking detrital particles (Dagg, 1993; Gifford, 1993; Kobari *et al.*, 2003). They represent a major food resource for epi- and mesopelagic fishes (Brodeur *et al.*, 1999; Moku *et al.*, 2000; Yamamura *et al.*, 2002), marine mammals (Kawamura, 1982), and seabirds (Russell *et al.*, 1999). Thus, an understanding of trophodynamics in marine ecosystems demands careful study of the population dynamics of calanoid copepods.

Calanus sinicus Brodsky (1965) is widely distributed around coastal areas in East Asia (e.g., Hulsemann, 1994) where it contributes the biomass of zooplankton communities (Uye and Shimizu, 1997; Uye *et al.*, 1999). However, the life history of *Calanus sinicus* is quite variable. For example, reproduction occurs throughout the year in the Inland Sea of Japan (Huang *et al.*, 1992,

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1993a, b), whereas stage 5 copepodites (C5) are found in abundance at depth in Sagami Bay (NONOMURA *et al*., 2008) and the Yellow Sea (PU *et al*., 2004a, b), indicating a dormant life history phase. In the Yellow Sea, they produce dormant stock residing at depth during the food-scarce summer and increase their abundance during the food-rich seasons (PU et al., 2004a, b; ZHANG *et al*. 2007). UYE (2000) reviewed that this species prospered in the shelf ecosystem with not only suitable ambient temperature and food supply for reproduction and development but also enough depth for diel vertical migration and egg hatching before sink to bottom. However, there is little information on the life cycle prospering in the region with suitable temperature, food availability and depth.

Kagoshima Bay is a large semi-enclosed embayment located at the southernmost part of Kyushu, Japan. This embayment is characterized by deep (deeper than 200 m) bathymetry. The deep and semi-enclosed nature of the embayment in the northern area promotes deep-water hypoxia during autumn to winter period. Although we know that *C. sinicus* occurs in the northern area of Kagoshima Bay (NOZAWA and SAISYO, 1980), there is little knowledge of seasonal variations in their population structure and depth distribution. We expect the specific life cycle with continuous reproduction and without dormancy in the northern area of Kagoshima Bay due to 1) the sufficient depth for vertical migration and egg hatching, 2) the limited water exchange in the semi-enclosed embayment and 3) the suitable temperatures and food supply for growth and egg production (KOBARI *et al*. 2002, 2009).

The objective of this study was to clarify a year-round reproduction and dormant stock of *C. sinicus* in the northern area of Kagoshima Bay. Our hypothesis is that the population's life cycle is adapted to the high temperature, high food availability and deep water column, and is characterized by year-round reproduction with no dormant stock. We tested our hypothesis by monitoring seasonal changes in population structure and depth distribution with monthly sampling. In addition, we measured nucleic acids contents of the C5s in order to evaluate the potential for dormancy similar to other subarctic Pacific copepod groups (KOBARI *et al*., 2013).

Materials and Methods

Oceanographic observations and zooplankton sampling

Oceanographic observations and zooplankton sampling in Kagoshima Bay were carried out on a monthly basis, between April 2009 to December 2010 at S16 (31° 39.9´N, 130° 41.9´E: 140-m deep; Fig. 1). All sampling was carried out during research cruises of the T/S Nansei-Maru. Temperature and salinity profiles down to 135 m were carried out with CTD system (Seabird SBE-9). Water samples for chlorophyll *a* and dissolved oxygen measurements were collected from 8 depths (10, 20, 30, 50, 75, 100, 125 and 135 m) with a CTD-CMS system and from the sea surface with a plastic bucket. These samples were filtered through a Whatman GF/F filter (0.7-μm nominal pore size) under vacuum pressure <20kPa. Chlorophyll pigments were immediately extracted from material retained on filter papers by direct immersion into *N, N*-dimethylformamide (DMF) at –5°C in darkness for more than 24 hours (SUZUKI and ISHIMARU, 1990). Chlorophyll *a* concentration was measured with a fluorometer (Turner Designs Co., TD-700) by the non-acidified fluorometric method (WELSCHMEYER, 1994). Dissolved oxygen was determined by the Winkler titration method.

Zooplankton collections and identification

Zooplankton samples for enumeration were col-

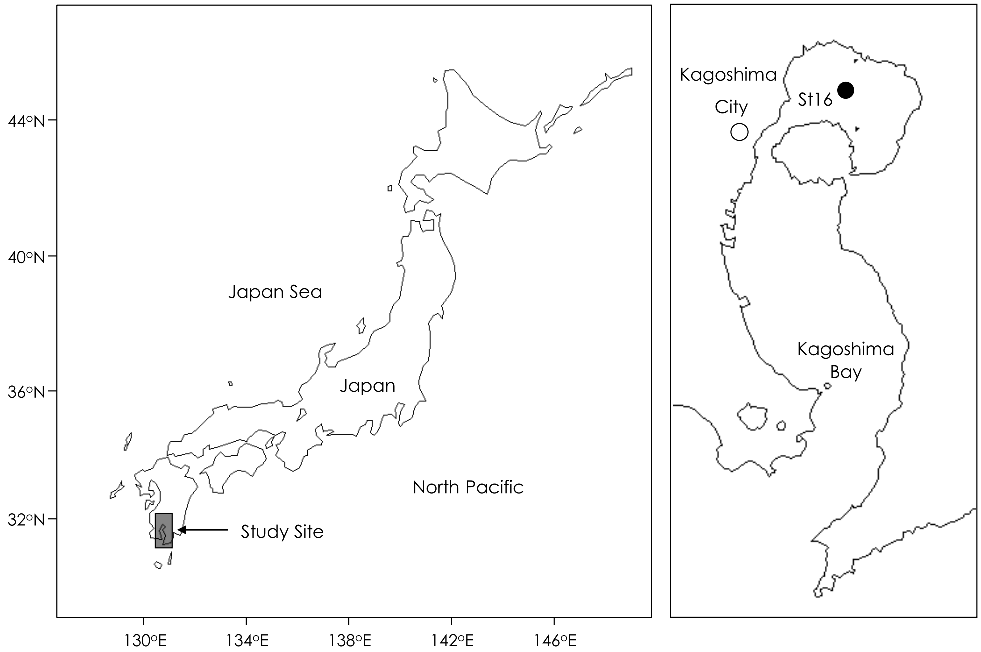

Fig. 1. Location of oceanographic observations and zooplankton sampling in northern area of Kagoshima Bay (S16: 31°40.2'N, 130°41.6'E).

lected with a Vertical Multiple Plankton Sampler (0.25-m^2 mouth square, 0.1-mm mesh size; TERAZAKI and TOMATSU, 1997) hauled at 1 m sec^{-1} during the day time (09:00-11:00) for each cruise. The following discrete depth intervals were sampled on the upcast: 0–50, 50–100 and 100–135 m. Subsamples for enumeration were preserved in a 5% borax-buffered formaldehyde seawater solution. Individual *C. sinicus* were identified by stage for copepodites (C1-C5) and by sex (i.e., male or female) for adults (C6). All animals were examined under a stereo dissecting microscope (Nikon SMZ1200).

Fresh zooplankton samples for biochemical analyses were collected with vertical net hauls (0.5 m sec^{-1}) from near bottom to sea surface using a modified North Pacific Standard net (MOTODA, 1957: diameter 45 cm, mesh size 0.335 mm) equipped with a large cod end (2L). On deck, individual specimens were quickly identified to species and developmental stage under a dissecting microscope. *C. sinicus* C5s picked for biochemical analyses were placed in 2 mL vials, stored at –80℃, and transported back to land for laboratory analyses of nucleic acids contents.

Nucleic acids analyses

We measured RNA and DNA with the microplate fluorescent assay (MFA) developed by WAGNER *et al.* (1998). The MFA assay is a modification of the sequential fluorometric method of BENTLE *et al.* (1981), in which DNA and RNA in a single sample are determined sequentially by the addition of DNase and RNase using Ethidium Bromide as fluorescent dye (see CALDARONE *et al.*, 2006 for details). WAGNER *et al.* (1998) modified the sequential fluorometric method to the MFA with 96-well microtiter plates by adopting a sarcosyl extraction technique and eliminating the DNase step, thus allowing application of the assay to small samples (single copepods) without extended working time.

Each specimen was thawed and then homogenized by vigorous shaking with 5 zirconia beads in 200 μL of a 1% sarcosyl extraction buffer. Samples were shaken for 5 minutes at room temperature on a vortex mixer equipped with a multiple-vial head. Following the initial homogenization, samples were then diluted with Tris buffer to reduce the sarcosyl concentration to 0.1%, and then shaken for an additional 10 minutes. Finally, sampled were centrifuged (15000 g) for 10 min at 4℃ to separate insoluble copepod remains.

In each run, 75 μL aliquots of sample supernatant and 8 replicates from 0.01 to 0.5 μg mL^{-1} DNA (calf-thymus, Sigma-Aldrich D4522) and from 0.02 to 3 μg mL^{-1} RNA (bakers-yeast, Sigma-Aldrich R7125) were transferred to 96-well microplates (Nunc). Zero concentrations of the standard solutions were also treated as reagent blanks (containing all chemicals but no copepod homogenate). Here, we used RiboGreen (Invitrogen R11491) as a fluorescent dye instead of Ethidium Bromide (used by Wagner *et al.* 1998) because of its greater nucleic acid sensitivity and efficacy (Gorokhowa and Kyle, 2002). We added 100 μL of 0.2% RiboGreen to each well, and the plates were then kept at room temperature for 5 minutes. The fluorescence of RiboGreen was then scanned using a microplate reader (Perkin-Elmer, ARVO MX1420) with 485 nm (excitation) and 535 nm emission) filters (First scan). The RNase solution (10 μL) was then added to each well. The microplate was kept at room temperature for another 20 minutes and RiboGreen fluorescence was scanned (Second scan). The concentrations of RNA (μg mL^{-1}) were calculated as the differences between first (DNA + RNA) and second (DNA) scans, and the standard curve of RNA versus the fluorescence established from the first scan of the same plate. DNA concentrations (μg mL^{-1}) were computed from the second scan and the standard curve of DNA versus fluorescence established from the second scan (RNase treated) of the same plate.

Results

Environmental variables

Sea surface temperature ranged from 16.3 to 29.0℃ (Fig. 2). The thermocline and halocline were developed above 30 m during May to August 2009 and during May to October 2010. Surface waters during the summer of 2010 were much less saline than for the same period in 2009. Over the course of the study period, seasonal variations in temperature (16.1 to 18.3℃) below

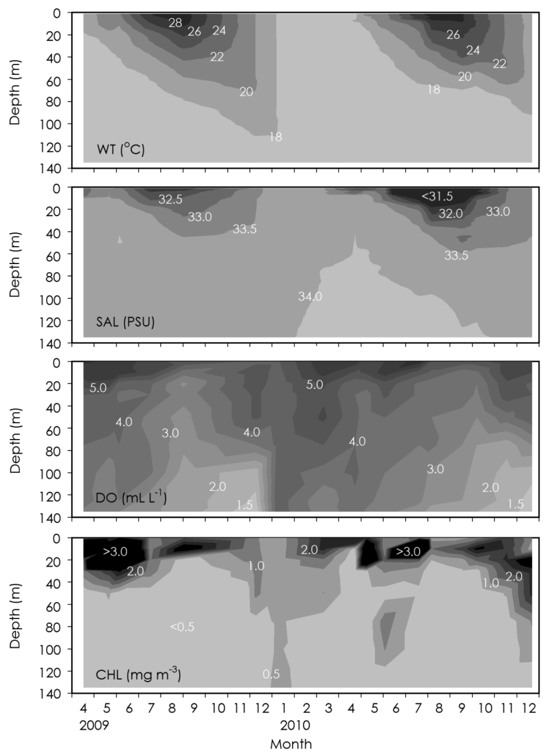

Fig. 2. Seasonal changes in vertical profiles of temperature (WT: ℃), salinity (SAL: PSU), dissolved oxygen (DO: mL L^{-1}) and phytoplankton biomass (CHL: mg chlorophyll *a* m^{-3}) at S16 in Kagoshima Bay.

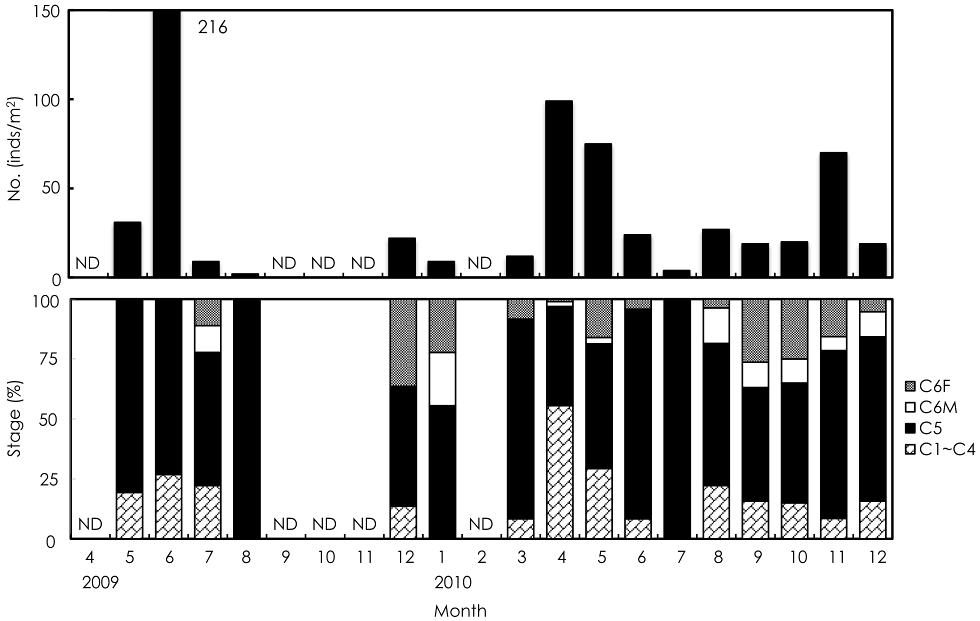

Fig. 3. Seasonal changes in abundance (individuals m^{-2}) and stage composition (%) of *Calanus sinicus* in the water column from 135 m to sea surface at S16 in Kagoshima Bay. ND: No data.

100 m were less pronounced than variation of salinity (33.9 to 34.1PSU) in the same depths. The dissolved oxygen concentrations above 50 m were greater than 3.0 mL L^{-1} during the entire study period. However, the dissolved oxygen concentration below 100 m gradually declined after July 2009 and 2010 and reached to 1.1 mL L^{-1} near the base of the water column in December 2009. Chlorophyll *a* concentrations were greater than 5 mg m^{-3} above 30 m during April to July in both years, but were 0.5 to 1.0 mg m^{-3} throughout the water column during December 2009 to January 2010.

Population structure

Peak abundance values for *C. sinicus* in the water column were measured in June 2009 (216 individuals m^{-2}), April 2010 (99 individuals m^{-2}) and in November 2010 (70 individuals m^{-2}) (Fig. 3) , when phytoplankton biomass above 50 m was high. *C. sinicus* C5s were typically the most abundant stage and were present throughout the study period. The population was composed entirely of C5s in August 2009 and July 2010 when the water column abundance of *C. sinicus* was the lowest (< 10 individuals m^{-2}). Young copepodites from C1 to C4 composed less than 30% of the population throughout the study period, except in April 2010 (~50% of the total abundance). Adult males and females were sampled during the most months, however, their seasonal pattern was not clear.

Depth distribution

We generally measured a high abundance of *C. sinicus* both above 50 m and below 100 m, excepted for November 2010 when the relative abundance was the greatest in the 50–100 m layer (Fig. 4). Over the course the year, *C. sinicus* was abundant above 50 m during June to July and

Fig. 4. Seasonal changes in relative depth distributions of *Calanus sinicus* developmental stages at S16 in Kagoshima Bay. C1–C4: Copepodite stage 1 to 4. C5: Copepodite stage 5. C6: Copepodite stage 6 (adult male and female). Note that some months are missing due to no sampling.

below 100 m in December but seasonal migration was not apparent for the population. Moreover, we noted no clear seasonal pattern when we considered each developmental stage separately. Young copepodites (C1 to C4) appeared abundantly in the layers above 50 m as well as below 100 m. Adults and C5s were abundant both above 50 m and/or below 100 m, except for November 2010 when they appeared abundantly in the 50–100 m layer.

Nucleic acids ratio

Individual DNA and RNA contents both decreased during August to October and then increased from November to December (Fig. 5). The RNA:DNA ratio was relatively stable during the summer with values increasing toward December.

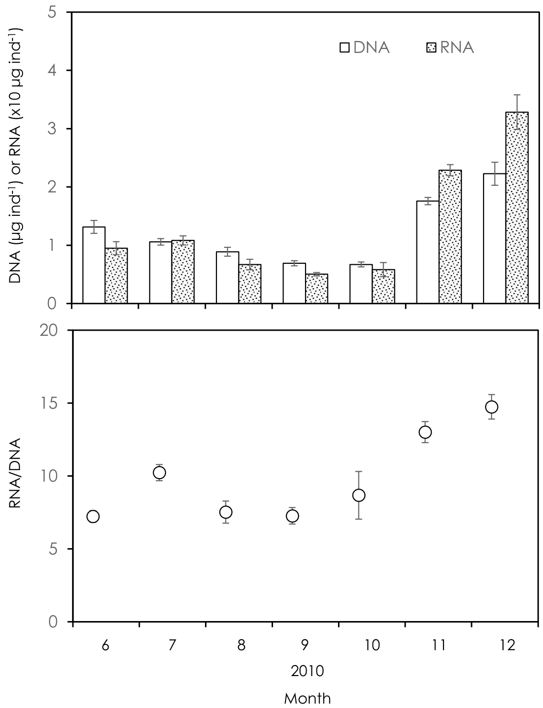

Fig. 5. Seasonal changes in individual RNA and DNA content (μg individual^{-1}) and RNA:DNA ratios of copepodite stage 5 for *Calanus sinicus* at S16 in Kagoshima Bay. Error bars represent ±1SE.

Discussion

While *C. sinicus* reproduction takes place throughout the year in the Inland Sea of Japan, the population follows a clear seasonal pattern with high abundance during June to August and low during September to March (HUANG *et al.*, 1992, 1993a, b). Studies by Huang et al. (HUANG *et al.*, 1992, 1993a, b) found no evidence of a dormant stock in the Inland Sea of Japan and concluded that the population was able to produce three generations a year because ambient temperatures and food availability were suitable. However, UYE (2000) has pointed out that *C. sinicus* prospers in shelf waters with enough depth to perform full-scale vertical migration and to avoid embedding at bottom before egg hatching. On the other hand, a different life history was found for the Sagami Bay (NONOMURA *et al*., 2008) and Yellow Sea (PU *et al*., 2004a, b; ZHANG *et al*., 2007) populations. While all developmental stages were abundant above 100 m during May in Sagami Bay, C5s were found in the layers below 200 m (NONOMURA *et al*., 2008). Such a deep appearance of C5 was also evident for the *C. sinicus* population in Yellow Sea (PU *et al*., 2004a, b; ZHANG *et al*., 2007). While all development stages including nauplii occurred in the water column during August, C5s were concentrated at depth in the central part of Yellow Sea, indicating a dormant stock. These latter studies suggest that the Yellow Sea population of *C. sinicus* produces dormant stock during the summer when food availability is low and temperatures are high because their reproductive and development timings fit the more favorable seasons (PU *et al*., 2004a, b; ZHANG *et al*., 2007). These findings indicate that a variety of the life histories for *C. sinicus* is characterized by presence or absence of dormancy. Also, they seem to result from the combined effects of food availability, thermal regime, and deep bathymetry.

Population abundance was high during April to June and low during July to August in the northern area of Kagoshima Bay. The seasonal changes in abundance corresponded to those in chlorophyll *a* concentrations in the surface layer. A similar seasonal pattern was observed for the *C. sinicus* population in the Kii Channel of the Inland Sea of Japan (HUANG *et al*., 1993a). Young copepodites and adults were present during most of the study period and year-round reproduction was also evident for the populations in the Inland Sea of Japan and the neighboring waters. In the present study, seasonal migration was not clear for all development stages. While only C5 was found in summer when the population abundance was the lowest, they appeared in both surface and bottom layers. These results suggest that *C. sinicus* conducts a year-round reproduction and does not produce a dormant stock in the northern area of Kagoshima Bay. However, the timing of greatest abundance was earlier in northern area of Kagoshima Bay (April to June) compared to that of the Inland Sea of Japan (June to August) and the regional variations may be due to differences in seasonal temperature and phytoplankton biomass patterns.

Laboratory studies on the growth and development of the congeneric species, *Calanus pacificus* (VIDAL, 1980a, b, c, d), demonstrated that growth rate varied with temperature only under food-saturated conditions. Similar interactive effects of food availability and temperature have not been demonstrated for *C. sinicus* growth and development rates. However, egg production rates have been demonstrated to increase logistically with phytoplankton biomass (UYE, 2000) while both growth and development rates appear to be temperature-dependent (UYE, 1988). Sea surface temperatures greater than 20℃ were evident during July in the Inland Sea of Japan (HUANG *et al*., 1993a) and from May through December in the northern area of Kagoshima Bay. High phytoplankton concentrations were measured during August and September in the Inland Sea of Japan (>5 mg m^{-3}: HUANG *et al*., 1993a) and during May and June in the present study (>10 mg m^{-3}). Thus, it is appears that *C. sinicus* abundance increases during the spring when thermal and food (i.e., phytoplankton biomass) conditions are optimal for development and growth. This optimal period occurs earlier in the northern area of Kagoshima Bay relative to the Inland Sea of Japan.

In the northern area of Kagoshima Bay, year-to-year variations were found for the environmental conditions such as ambient temperature, salinity and chlorophyll *a* from spring to summer.

As seen in less abundance for *C. sinicus* under the low food availability in 2010, environmental conditions during spring to summer are likely important for their life history strategy. However, even if they increased their abundance during spring to early summer like in 2009, the population abundance was lowest during summer when the population was composed entirely of C5s. In the Yellow Sea and Sagami Bay, C5s found in deep layers are considered to be dormant (PU *et al*., 2004a, b; ZHANG *et al*., 2007, NONOMURA *et al*., 2008). In the present study, however, we find no evidence for dormancy in the northern area of Kagoshima Bay. For marine calanoid copepods, dormancy has been identified by an empty and reduced gut (MILLER *et al*. 1984) or by the shape and/or structure of diapause eggs (BAN, 1997). More recently, dormancy for copepods has also been identified biochemically by low aminoacyl-tRNA synthetase activities (YEBRA *et al*., 2006) or low RNA:DNA ratios (KOBARI *et al*., 2013). We did not measure a significant decline in RNA:DNA ratios for our study population. Based on the equation developed by Kobari *et al*. (KOBARI *et al*., 2013), the RNA: DNA ratios measured for *C. sinicus* were much higher than ratios measured for "active" copepods (1.0 to 1.6). These findings suggest that no dormant stock is formed for the *C. sinicus* population in the northern area of Kagoshima Bay. Why then is the population abundance low and composed of C5s during the summer in the northern area of Kagoshima Bay? Summer phytoplankton biomass never dropped below 1 mg chlorophyll *a* m^{-3}, indicating that clutch size and spawning frequency were probably food-saturated (UYE, 2000). It is possible that hatching and development failures (i.e., embryonic and naupliar malformations) were enhanced with high summer surface temperatures (>25℃) as suggested by ZHANG *et al*. (2007), resulting in elevated mortality for early life stages in Kagoshima Bay. On the other hand, copepod mortality increases with high thermal regimes since predation activity is enhanced (HUNTLEY and LOPEZ, 1992; HIRST and KIØRBOE, 2002). The naupliiar and young copepodite stages of *C. sinicus* are known to reside in surface layers throughout the day (UYE *et al*., 1990; HUANG *et al*. 1992, 1993b). UYE (2000) pointed out that the C5 and adult stages can, however, avoid visual predators in the shelf waters where they are able to carry out a full-scale diel vertical migration. The water column depth at our study site was 140 m, deeper than Kii Channel where the full-scale diel vertical migration has been observed (UYE, 2000). Taking into account for the predominance of C5s even under the cold thermal regime without the growth inhibition (i.e., winter to spring), we suggest that the predominance of C5s occurs (especially in summer) as a result of high predation mortality on early life stages. However, how do they sustain their population with quite low abundance of the early life stages even in the year-round reproduction and equiproportional development (UYE, 1998)? Indeed, the abundances of C1 to C4 were lower than those in the previous studies (UYE *et al*., 1990; HUANG *et al*. 1992, 1993b). Based on the results in the Yellow Sea (PU *et al*., 2004b), *C. sinicus* exhibited different life history strategies to conduct summer dormancy at depth in the deepest area and to reproduce throughout the year in the neighboring shallow area. Since there are basin areas deeper than 200 m in northern and southern Kagoshima Bay, *C. sinicus* might be sustained by recruitment of dormant stock forming in the basin areas.

UYE (2000) pointed out that shelf waters might provide a suitable habitat for *C. sinicus* due to the ideal temperature, food supply and depth. These conditions of a sufficiently deep water column, the high thermal regime, and suitably high food supply appear to be met for the *C. sinicus* population in the northern area of Kagoshima Bay. The importance of both ambient temperature and food supply in copepod life cycles has been well studied (HUANG *et al.*, 1993a; PU *et al.*, 2004a, b; ZHANG *et al.*, 2007). Our study also emphasizes that water column depth plays an important role in calanoid copepod life cycles because of the potential limits imposed vertical migrants. It has been hypothesized that coastal populations of *C. sinicus* are supplied by estuarine circulation transporting populations flourishing in shelf waters (UYE, 2000). However, such circulation was limited in the northern area of Kagoshima Bay due to the presence of a narrow channel (TAKAHASHI, 1977). We suggest that *C. sinicus* can complete their life cycle in the northern area of Kagoshima Bay where food availability and depth are suitable, even in the high thermal regime.

Acknowledgement

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学 会 記 事

1. 第16回日仏海洋学シンポジウム報告

日仏海洋学会および仏日海洋学会は1983年にフランスのモンペリエで第1回日仏海洋学シンポジウムを開催して以来，日仏交互にシンポジウムを重ね，本年，第16回日仏海洋学シンポジウムを日本で開催した．“The sea under human and natural impacts: challenge of oceanography to the future Earth”をテーマとし，第1部を2015年11月19-20日に宮城県塩竈市公民館本庁分室，第2部を21日に東京都恵比寿日仏会館で行なう2部構成とした．本シンポジウムの前には三陸沿岸の復興，後には岡山県日生海域の里海に関するエクスカーションがフランス人参加者中心で行われた．

三陸のエクスカーションでは，11月17日に陸前高田市の巨大防潮堤の見学，気仙沼市唐桑のかき小屋での地元漁業者との懇談会を行い，11月18日に南三陸町立サケふ化場，漁業協同組合の協力で志津川湾におけるギンザケとカキ養殖の現場視察を行った．その後，宮城県水産総合技術センターで水産業の復興状況についての紹介と議論を行い，松島湾の宮城県漁協鳴瀬支所カキ部会長渡辺茂氏のカキ処理場で意見交換を行った後，塩竈に移動した．

第1部では，パリでのテロで亡くなった犠牲者とフランス国民に対する黙祷を行ない，小松会長およびセカルディー会長の挨拶の後，震災の影響および復興に関する5題の基調講演が行われた．続いて口頭セッション19演題およびポスターセッション16演題が発表された．第1部終了後，参加者は東京へ移動し，11月20日19時からフランス大使公邸での本シンポジウムを記念した大使主催のレセプションに招待された．レセプションでは海洋学水産学関係者も招待され，大使の代理であるフランス公使，小松会長の挨拶の後，セッカルディ会長の乾杯の挨拶があり，美味なワインと食事が振る舞われ，参加者の会話も弾み，予定時間を過ぎた21時30分に散会した．

第2部では口頭セッション5演題が発表された．その後，シンポジウムを総括し，今後の活動の方向性について検討した．午後には市民公開セミナーが“Historical relationship between France and Japan on oyster culture, for the renovation of aquaculture in Sanriku”をテーマとして行われた．多数の参加者があり，多くの議論が行われた．その後ワインと日本酒の試飲会とカキと蒲鉾の試食がフォワイエで行われ，室内楽の演奏も行われた．

11月22日に朝から岡山県日生町に移動し，日生漁協が取り組んでいる里海活動について漁業協同組合の中心メンバーとNPO法人里海づくり研究会田中丈裕氏と意見交換し，岡山で宿泊した．翌日東京に移動した．

シンポジウム参加者数は延べ100名（内フランス側参加者18名）に達した．シンポジウムでは終始活発な議論と意見交換が行われ，大変な盛会となり，参加者にとって有意義なものとなった．本シンポジウムの講演論文集は2016年の出版を目指して準備を進める．

本シンポジウムは笹川日仏財団，日仏会館，東北区水産研究所の共催で行われ，さらにフランス大使館をはじめとして多数の団体の後援，協賛，展示，広告のご支援を受けた．各団体に厚くお礼申し上げる．

以下に第16回シンポジウムを企画・実行した委員，各種参加団体およびプログラムを掲載する．

Organizational committee

Prof. Teruhisa Komatsu (President SFJO Japan), Prof. Hubert-Jean Ceccaldi (President SFJO France), Prof. Shiro Imawaki (JAMSTEC), Dr. Yves Henocque (IFREMER/SFJO France), Dr. Patrick Prouzet (IFREMER/SFJO France), Prof. Tsutomu Morinaga (SFJO Japan), Prof. Jiro Yoshida (TUMSAT), Prof. Hiroshi Kouno (TUMSAT), Prof. Yasuyuki Koike (ex. TUMSAT), Prof. Jota Kanda (TUMSAT), Prof. Yuji Tanaka (TUMSAT), Prof. Hisayuki Arakawa (TUMSAT), Prof. Yujiro Kitade (TUMSAT), Prof. Takeyoshi Nagai (TUMSAT), Prof. Daigo Yanagimoto (Univ. Tokyo), Prof. Toshiki Nakano (Tohoku Univ.), Dr. Hiroshi Uchida (JAMSTEC), Prof. Kaoru Ichikawa

(Kyushu Univ.), Prof. Mitsuru Hayashi (Kobe Univ.), Prof. Tomoharu Senjyu (Kyushu Univ.), Dr. Yutaka Okumura (FRA), Dr. Hideki Takami (FRA), Dr. Tetsuo Seki (SFJO Japan), Prof. Kenji Ookoshi (Toho Univ.)

Scientific committee

Prof. Teruhisa Komatsu (President SFJO Japan), Prof. Hubert-Jean Ceccaldi (President SFJO France), Prof. Shiro Imawaki (JAMSTEC), Dr. Yves Henocque (IFREMER/SFJO France), Dr. Patrick Prouzet (IFREMER/SFJO France), Prof. Tsutomu Morinaga (SFJO Japan) Prof. Jiro Yoshida (TUMSAT), Prof. Hiroshi Kouno (TUMSAT), Prof. Yasuyuki Koike (ex. TUMSAT), Prof. Jean-Claude Dauvin (Université Caen), Dr. François Galgani (IFREMER/SFJO France), Dr. Sandrine Ruitton (IFREMER), Dr. Hervé Thébault (IRSN)

Organaizer : Société franco-japonaise d'Océanographie Japan & France

Sponser : La Maison franco-japonaise, Fondation Franco-Japonaise Sasakawa, Tohoku Nashonal Fisheries Reseach Institute

Support : The Japanese Society of Fisheries Science, Tohoku branch of the JSFS, The Oceanographic Society of Japan, The Society of Fisheries Oceanography, Miyagi Prefecture Fisheries Technology Institute, Iwate Fisheries Technology Center, Fukushima Prefectual Fisheries Experimental Station, Akita Prefectural Fisheries Promotion Center, Aomori industry technology center fisheries research institute, Fisheries Experimental Station of Ibaraki, Tohoku University (Tohoku Ecosystem-Associated Marine Sciences), Tohoku University (Graduate school of agricultural science), Alliance Francaise de Sendai, Japan Agency for Marine-Earth Science and Technology, L'Ambassade de France au Japon, Cable TV Marinet

Co-support : HUMANWEB Inc., Sanyo Techno Marine Inc., K-Engineering Co. LTD., IDEA Consaltants Inc., Kokusai Kogyo Co. LTD., Toyo Corporation, Saikai Laboratory of Aquaculture and Technology Co. LTD., JFE Advantech Co. LTD., SEA-Plus Inc.

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Cooperation : Japan Kotsu Co. LTD., Ojima-Kamabokoten Co. LTD., Saura Co. LTD., Pernod Ricard Japan K.K.

Program

17–18 November

- **Excursion**
  Tokyo-Ichinoseki-Rikuzentakada-Ishinomaki
  Ishinomaki-Shizugawa-Shiogama

19 November, The Shiogama public hall

09h00 Opening address

09h00–09h15 Teruhisa KOMATSU President of SFJO Japan
Challenge to resolve problems in the ocean and coastal waters in future Earth with stronger cooperation between the two Sociétés franco-japonaises d'Océanographie

09h15–09h30 Hubert-Jean CECCALDI President of SFJO France
Evolution and progress accomplished during previous French-Japanese Symposiums of Oceanography

Key note

Chairpersons Teruhisa KOMATSU & Hubert-Jean CECCALDI

09h30–9h50 : Key note 1–1 Hideki TAKAMI (FRA)
Challenges to revitalize the abalone *Haliotis discus hannai* fishery damaged by the 2011 mega-earthquake and tsunami in Iwate prefecture, northeastern Japan
Key note 1–2 Yutaka OKUMURA (FRA)
Influence of the Tsunami on the Coastal Area of Miyagi Prefecture, Japan

09h50–10h10 : Key note 2 Patrick PROUZET (IFREMER)
Ecological status of Atlantic salmon (*Salmo salar*) in France

10h10–10h30 : Key note 3 Hisayuki ARAKAWA (TUMSAT)
Explaining the reasons for the slower decrease in radioactive concentrations in some fish species after the Fukushima Daiichi Nuclear Power Plant Disaster

10h30–10h50 : Key note 4 Hubert-Jean CECCALDI (SFJO France)
Future essential orientations in marine sciences and technology and cooperations between the two Sociétés franco-japonaises d'Océanographie

Oral session

Session 1 Natural impacts and recovery of aquaculture

Chairpersons Yujiro KITADE (TUMSAT) & Sandrine RUITTON (Mediterranean Inst. Ocean.)

11h05–11h20 Com–01 Mitsuru HAYASHI (Kobe Univ.)
Shift of water quality in Osaka Bay by the resuspension of marine sediment caused by tsunami

11h20–11h35 Com–02 François POISSON (IFREMER)
By-catch monitoring programme of the French Bluefin tuna longline fishery.

11h35–11h50 Com–03 Shinnosuke KAGA (Iwate Fish.Tech.Ctr.)
On-site depuration of paralytic shellfish poisoning toxins accumulated in the oyster *Crassostrea gigas* in Ofunato Bay, Japan

11h50–12h05 Com–04 Patrick PROUZET (IFREMER)
The European eel (*Anguilla anguilla*) in France: An example of close cooperation among researchers and fishers to study and manage an endangered species.

12h05–12h20 Com–05 Yoshifumi TAKAHASHI (Kyushu Univ.)
An analysis of the potential success for an improved

Poster session

14h00–15h00

P–01 Mathias GIRAULT (Kanagawa Academy Sci. & Tech.) : Automatic sorting system and incubation at single plankton level using microfluidic devices

P–02 Miwa YATSUYA (FRA) : Clearance rates of Crassostrea spp. on oyster reef in temperate semi-enclosed Ariake Bay, western Japan

P–03 Hidekazu SHIRAI (Sanyo Techno Marine, Inc.) : A high-resolusion unstructured grid finite volume model for currents around narrow straits of Matsushima Bay

P–04 Toshiki NAKANO (Tohoku Univ.) : Quantitative metabolome profiling of growth hormone transgenic Coho Salmon

P–05 Ken HIGUCHI (TUMSAT): Development of an underwater NaI (Tl) scintillation spectrometer to monitor seabed radioactivity

P–06 Haruka SUZUKI (Tohoku Univ.): Distributional changes in the kelp ***Eisenia bicyclis*** resulting from the subsidence and the landfill for breakwater restoration after the 2011 Tohoku Earthquake

P–07 Minoru TOMIYAMA (Aichi Fisheries Research Institute): Factor analysis of upstream migrating Ayu in the Yahagi River using machine learning

P–08 Yutaka OKUMURA (FRA): Suitable quantity of oyster culture in Oginohama Bay, Miyagi, Japan

P–09 Hikaru ENDO (Tohoku Univ.): Combined effects of nutrient availability, light intensity, and temperatureon the photosynthetic pigments and color of the brown alga ***Undaria pinnatifida***

P–10 Keiichi YAMAZAKI (TUMSAT): Amplification of near-inertial period fluctuation associated with passage of typhoon around the Tango Peninsula, Japan

P-11 Hiroyuki TOGASHI (FRA): The use of stable isotopes for food web analyses: An example of food webs in a coastal ecosystem in Sendai Bay

P-12 Yuki KUBO (Tohoku Univ.): Seasonal movements of the herbivorous gastropod *Omhalius rusticus*

P-13 Takuro NAKAGAWA (TUMSAT): Relationship between patterns of fish behavior and concentration of radioactive materials after nuclear accident by the 2011 Great East Japan Earthquake.

P-14 Yoshichika IKEDA (TUMSAT): Development of a de-oiling process for seabed sediments

P-15 Teruhisa KOMATSU (Univ. Tokyo): Trophic cascade of seaweed forests in Sanriku Coast after the huge tsunami on 11 March 2011

P-16 Gerard FOURNEAN (Aquitaine Landes Récifs): Implantation of artifi cial reefs on the French Atlantic Coast

Session 2 Human impacts

Chairpersons Hisayuki ARAKAWA (TUMSAT) & Yves HENOCQUE (IFREMER)

15h00-15h15 Com-06 Akira MATSUMOTO (TUMSAT)
A feasibility study of an in situ fluorescence spectroscopy system for the detection of deposited oil

15h15-15h30 Com-07 Hervé THÉBAULT (IRSN)
137Cs and Tritium Concentrations in Seawater off the Fukushima Prefecture:
Results from the SOSO 5 Rivers Cruise (October 2014)

15h30-15h45 Com-08 Jun SHOJI (Hiroshima Univ.)
Do species diversity and productivity of fisheries resources increase around submarine groundwater seepages in coastal area?: possible effects of global warming

15h45-16h00 Com-09 François GALGANI (IFREMER)
Plastic in the Mediterranean Sea

Session 3 Promotion of cooperative research on fisheries/oceanography between Japan and France

Chairpersons Ryo KIMURA (FRA) & Sandrine VAZ (IFREMER)

16h20-16h30 Opening address of the session: Executive Director Fuminari ITOH (FRA)

16h30-16h45 Yves HENOCQUE (IFREMER)
Do our ocean policies make any difference to the wellbeing of coastal communities?

16h45-17h00 Masahito HIROTA (FRA)
Fish and seafood value chains and the wellbeing for local community

17h00-17h15 Franck LAGARDE (IFREMER)
Synthesis of new knowledge about determinism of Pacific oysters (*Crassostrea gigas*) larval recruitment in the Mediterranean Thau Lagoon

17h15-17h30 Masakazu HORI (FRA)
Challenge to harmonize sustainable fishery with water-quality improvement using seagrass-oyster interaction in oligotrophic coastal ecosystems

Banquet

18h00-20h00 Ground palace Shiogama

20 November, The Shiogama public hall

Session 4 Challenge of oceanography

Chairpersons Shiro IMAWAKI (JAMSTEC) & Hervé THÉBAULT (IRSN)

09h00-09h15 Com-10 Yujiro KITADE (TUMSAT)
Recent research results and future project in Antarctic Ocean by Umitaka-Maru research group for physical oceanography

09h15-09h30 Com-11 Mathias GIRAULT (Kanagawa academy of Sci. & Tech.)
Automatic sorting system and incubation at single plankton level using microfluidic devices

09h30-09h45 Com-12 Daigo YANAGIMOTO (Univ. Tokyo)

Observation of near-bottom current on the continental shelf off Sanriku

09h45–10h00 Com–13 Jean-Claude DAUVIN (Université Caen)
The English Channel: towards a new Japanese Sea

Session 5 Coastal ecosystem and management
Chairpersons Yasuyuki KOIKE (SFJO Japan) & Jean-Claude DAUVIN (Université Caen)

10h15–10h30 Com–14 Sandrine RUITTON (Mediterranean Inst. Ocean.)
Japanese vs. French artificial reefs: high technology vs. design to enhance ecological services

10h30–10h45 Com–15 Satomi TAKAGI (Tohoku Univ.)
Improvement of gonad quality of the sea urchin *Mesocentrotus nudus* by short-term cage culture

10h45–11h00 Com–16 Nelly FERROU & Gérard FOURNEAU (Aquitaine Landes Récifs)
Artificial Reefs Installation along the Aquitaine Coast

11h15–11h30 Com–17 Sandrine VAZ (IFREMER)
Quantitative mapping of fish habitat: from knowledge to spatialised fishery management

11h30–11h45 Com–18 Kazumi WAKITA (Tokai Univ.)
Perceptions of marine ecosystem services: A case study from remote islands, Taketomi Town

11h45–12h00 Com–19 Catherine BOISNEAU (UMR CITERES)
Amphidromous Fishes Management in Continental Waters. The Need for an Integrated Approach

Reception at The Embassy of France in Japan (11–44, Minami Azabu–4, Minato, Tokyo)

21 November, The hall of Nichifutsu Kaikan (La Maison Franco-Janonaise) in Ebisu

Session 6 Aquaculture
Chairpersons Tetsuo SEKI (AFFTIS) & François GALGANI (IFREMER)

10h00–10h15 Com–20 Hirokazu ABE (FRA)
Larval and Juvenile Dynamics of the Manila Clam *Ruditapes philippinarum* in Matsushima Bay and Mangoku-ura Inlet, Northeastern Japan, Following 2011 Tsunami Disaster

10h15–10h30 Com–21 Catherine MARIOJOULS (AgroParisTech)
Certification Schemes for Sustainable Aquaculture and Feeding

10h30–10h45 Com–22 Waka SATO-OHKOSHI (Tohoku Univ.)
Ecological impacts of the 2011 earthquake and tsunami on the subtidal macrobenthic community in Onagawa Bay, northeastern Japan

10h45–11h00 Com–23 Jean-Claude DAUVIN (Université Caen)
One year colonisation by zoobenthic species on an eco-friendly artificial reef in the English Channel intertidal zone

11h00–11h15 Com–24 Rena SHIBATA (FRA)
Retinomotor and stress responses of marbled sole *Pleuronectes yokohamae* under the LEDs

11h30–12h00 Summarize of Symposium
Chairpersons Presidents of SFJO Japan & France

Group photograph

Open Seminar for Public (with interpretation)

PM, 21 November, The hall of Nichifutsu Kaikan (La Maison Franco-Janonaise) in Ebisu

Historical Relationship between France and Japan on Oyster Culture, for the renovation of aquaculture in Sanriku

13h30-13h40 Opening address

Teruhisa KOMATSU (President of SFJO-J)

13h40-14h10 History and Solidarity on Oyster Culture in both countries

Yasuyuki KOIKE (ex. Prof. of TUMSAT)

14h10-14h40 Situation of Oyster culture in France.

Dr. Catherine MARIOJOULS (Agro.Paris.Tech)

15h00-15h30 Situation and new trial on Oyster culture in Japan. Tetsuo SEKI (AFFTIS)

15h30-16h00 New challenge on commercialization and culture technique of Oyster in Japan:

Ms. Kyoko WASHIASHI

(Oyster innovation Co. Humanweb)

16h00-16h30 Cooporation between France and Japon on Oyster culture and future prospects.

Franck LAGARDE (IFREMER)

16h30-17h00 Discussion

17h00-17h15 Closing address

Prof. Hubert-Jean CECCALDI

(President of SFJO-F)

17h30 Cocktail (with concert of the flute)

2. 幹事会議事録

・第 1 回幹事会議事録

日　時：2015 年 4 月 6 日（月）10 時 30 分～ 12 時00分

場　所：東京海洋大学　9 号館 207 号室

参加者：小松，今脇，森永，小池，河野，荒川，内田，柳本，本多（事務）

(1) 報告事項

① 総会，評議員会，研究発表会　6 月 27 日（土）に決定した.

② 日仏工業技術会の研修に関してその見学地として JAMSTEC が挙げられている．その協力依頼に関して，今脇顧問の紹介により見学が行なわれる予定である.

(2) 協議事項

① 研究発表の締め切り日程，参加費などについて日付などの修正ののち承認した．懇親会場は次回までに決定.

② 学会賞受賞規則変更案を原案の通り承認した.

・第 2 回幹事会議事録

日　時：2015 年 5 月 1 日（金）15 時 00 分～ 16 時45分

場　所：東京海洋大学　9 号館 203 号室

参加者：小松，森永，小池，荒川，内田，奥村，田中，本多（事務）

(1) 報告事項

① 日本水産学会誌「水産研究のフロントから」が紹介された.（小松）

(2) 協議事項

① 総会議題および評議員議題の確認

1) 2014 年度収支決算および 2015 年度予算案について確認した.

2) 学会賞規定の今脇修正案について検討し，一部の文言修正し承認した.

3) 2015 年度日仏海洋学会役員リストを確認した.

4) 学会費滞納者リストを確認した．事務局から入金依頼を再度行うことにした.

5) 会員には総会議案，評議員には総会議案と評議員会議案を委任状と一緒に送付することとした.

② Yves HENOCQUE 博士の受章記念講演を学会賞記念講演の前の時間帯に 30 分間お願いすることにした.

・第 3 回幹事会議事録

日　時：2015 年 6 月 2 日（火）15 時 00 分～ 16 時 45 分

場　所：東京海洋大学　9 号館 203 号室

参加者：小松，河野，森永，小池，吉田，荒川，内田，奥村，本多（事務）

(1) 報告事項

① 日仏海洋学会総会と評議員会の案内状に議案と委任状を添付して事務局より発送済みの報告がされた.

(2) 協議事項

① 総会議案　第一号議案 2014 年度事業報告（その他）に評議員会での決定事項（賞規定の改訂および会員の除名）を追加するかについてメール幹事会議をすることとした.

② 一般社団法人学術著作権協会より電子的複製権の管理委託の承認について，荒川庶務幹事より他学会の対応策を聞いてもらい，メール幹事会議をすることとした.

・第 4 回幹事会議事録

日　時：2015 年 7 月 28 日（火）10 時 00 分～

場　所：東京海洋大学　9 号館 203 号室

参加者：小松，今脇，關，小池，荒川，内田，奥村，本多（事務）

(1) 報告事項

① 6/27（土）日仏海洋学会総会および学術研究発表会を行なった．議事録は，La mer 次号へ掲載予定.

② 一般社団法人学術著作権協会より電子的複製権の管理委託の承認についてメール持ち回り会議にて審議し，承認を得たので委託することとした.

(2) 協議事項

① 日仏海洋学会誌「うみ」投稿規定について，一部の不明瞭な文言や古い表現を改めることとした．吉田編集委員長と庶務幹事で原案を作成することとした.

② 日仏海洋学会会則の一部改正について，第7条に会計年度を追記する件が提案され次回までに改定案を検討することとした.

③ 日仏海洋学会賞および日仏海洋学会論文賞の英語表記について検討し，以下のように決定した.

学会賞：La Societe franco-japonaise d'oceanographie Prize

論文賞：La Societe franco-japonaise d'oceanographie Excellent Article Award

・第5回幹事会議事録

日　時：2015年9月17日（木）10時30分～12時45分

場　所：東京海洋大学　9号館203号室

参加者：小松，今脇，森永，河野，小池，荒川，奥村，本多（事務）

(1) 報告事項

① 日本学術会議水産・海洋研究連絡協議会より名古屋議定書により生じる水産・海洋分野の問題点の洗い出しに関する WG の立ち上げに際し日仏海洋学会は参加，（幹事持ち回りメール会議）することとし，推薦された奥村裕委員に WG 委員を委嘱した．第1回は8月27日に東京海洋大学で開催されたが，出張のため出席できなかった．本会議の報告は後日行なうこととする．（奥村）

② 2015年度賞委員長選考依頼を行なった．（小松会長）

(2) 協議事項

① 投稿規程などの改定について日本語版，英語版が提案された．投稿が誰でもできるように変更することが提案されているが会員に限定するべき．その代わりに論文が印刷されたらすぐにホームページでオープンにする方が会員の獲得につながるのではないか？（河野）再度，編集委員長と庶務幹事で相談することとした.

② 会則に学会の会計年度を明記する旨の改定案が示されたが，事業年度として明記する方がよいのではないかとの意見があり（今脇），次回幹事会に再提案することとした.

3. 2015年度（第56回）日仏海洋学会総会議事録

日　時：2015年6月27日（土）14時40分～15時50分

場　所：公益財団法人 日仏会館　会議室501号室

議事に先立ち総会の成立要件の確認を行ない，出席87名（会議参加22名，委任状による出席65名）により本総会は成立（会員数130名の1/6の出席）が確認された.

議　長：小松会長

第1号議案　2014年度事業報告（荒川庶務幹事）

(1) 庶務関係

会員異動状況について2014年度会員数は不変.

(2) 活動状況

① 評議員会1回（6/14　日仏会館），幹事会7回（4/30, 10/3, 11/4, 12/12, 1/15, 2/9, 3/2　東京海洋大学）），総会1回（6/14），学術研究発表会1回（6/14），第16回日仏海洋学シンポジウム実行委員会4回（12/12, 1/15, 2/9, 3/2　東京海洋大学）を開催.

② 日仏関連学会連絡協議会（6/16　日仏会館－小松会長出席，12/8　日仏会館－小松会長，荒川庶務幹事出席），水産・海洋科学研究連絡協議会（5/21　東京海洋大学－小松会長出席，11/17　東京海洋大学－河野副会長，荒川庶務幹事出席）

③ 学会賞選考委員半数改選を実施

④ 論文賞2件を授与

(3) 編集関係

学会誌「La mer」52巻1-2号，52巻3号，52

巻4号を発刊
(4) その他
① 学会賞規定の一部改正
② 会費未納により会員一名を除名（会則第8条(2)）
各報告と質疑ののち，第1号議案は承認された.
第2号議案　2014年度収支決算報告および監査報告
(1) 2014年度収支決算が会計幹事代理（荒川庶務幹事）より資料1に従って報告された.
(2) 宮崎監事から監査の結果，会計が適正であると報告された.
質疑ののち，第2号議案は承認された.
第3号議案　2015年度事業案（(1)－(5) 荒川庶務幹事，(6) 吉田編集委員長）
(1) 総会1回，学術研究発表会1回，評議員会1回，幹事会4回，第16回日仏海洋学シンポジウム実行委員会8回　開催（予定）
(2) 第16回日仏海洋学シンポジウム開催（2015年11月16～21日）
(3) 2015年度学会賞，論文賞の授与
(4) 2016年度学会賞，論文賞の候補者の推薦
(5) 評議員選挙，会長選挙，学会賞委員半数改選
(6) 学会誌「La mer」53巻1-4号の発刊予定と編集状況報告
各項目の説明と質疑ののち，第3号議案は承認された.
第4号議案　2015年度予算案
2015年度予算案が会計幹事代理（荒川庶務幹事）により資料2に従って説明された.
審議ののち，第4号議案を承認された.
第5号議案　2014-2015年度役員，評議員，学会賞推薦委員（荒川庶務幹事）
学会賞選考委員半数改選の結果について報告された.
学会賞選考委員として当選した小松委員から辞退の申し出があり，次点の千手会員を選出した. 第5号議案は承認された.
第6議案　第16回日仏海洋学シンポジウム（小松会長）
第16回日仏海洋学シンポジウムの概要および準備の進捗状況の説明を行なった.
(1) テーマ：“The sea under human and natural impacts: challenge of oceanography to the future Earth”
(2) 市民シンポジウムテーマ：「日仏　海の幸文化—三陸の復興に向けて—（仮）」
(3) 開催時期：2015年11月17-18日　エクスカーション
2015年11月19-20日　日仏海洋学シンポジウム Part 1（塩竈）
2015年11月21日　日仏海洋学シンポジウム Part 2，日仏市民シンポジウム（日仏会館）
(4) 開催場所：塩釜市役所公民館本町分室／塩竈市杉村惇美術館，日仏会館（東京）
(5) 内容：
① エクスカーション（宮城県沿岸見学，カキ養殖復旧状況，巨大防波堤，沿岸の現況調査，漁業者との意見交換等）
② 塩釜市役所公民館本町分室にて基調講演とシンポジウム
③ フランス大使館にてレセプション
④ 日仏会館にて市民シンポジウム
(6) 主催：日仏海洋学会，仏日海洋学会
(7) 共催：公益財団法人日仏会館，笹川日仏財団，水産総合研究センター東北区水産研究所
(8) 後援：日本海洋学会，日本水産学会，日本水産学会東北支部，水産海洋学会，福島県水産試験場，岩手県水産技術センター，秋田県水産振興センター，宮城県水産技術総合センター（決定済みのみ）
質疑を行った後，第6号議案は承認された.
報告事項
第15回日仏海洋学シンポジウムの概要の記事が，日本水産学会誌81巻3号に掲載されたことについて中野俊樹会員より報告された.

4. 2014年度学術研究発表会
日　時：2015年6月27日（土）9時30分~14時30分
場　所：日仏会館501会議室
プログラムは以下の通り.
9：30～10：00　座長　飯淵敏夫（海生研）
① 福島県いわき市沿岸の海藻群落の放射性物質濃度
○重岡柚[1]，浅田みなみ[1]，松本陽[1]，荒川久幸[1]，榎本昌宏[2]（[1]海洋大院，[2]福島水試）
② 高効率NaI（Tl）結晶を用いた曳航型放射性物質センサー（S-RAM）の開発
○樋口謙[1]，荒川久幸[1]，松本陽[1]，

守岡良晃[2]（[1]海洋大院，[2]福島水試）
10：00~10：30　座長　中野俊樹（東北大学）
③　千葉県館山湾における温帯性サンゴ *Alveopora japonica* の短期個体群動態
○橋本匠平，松本陽，荒川久幸（海洋大院）
④　クロミンククジラとミンククジラ頭骨における形態学的新知見
○中村玄[1]，藤瀬良弘[2]，加藤秀弘[1]
（[1]東京海洋大学大学院，[2]（一財）日本鯨類研究所）
10：30 ～ 11：00　フランス勲章受章記念講演
"The bumpy road from science to policy"
Dr. Yves Hénocque（Ifremer）
13：00 ～ 13：30　座長　内田　裕（JAMSTEC）
⑤　Introduction to microfluidic sorting system in Oceanography
○ M. Girault, A. Hattori, H. Kim, K. Matsuura, M. Odaka, H. Terazono, K. Yasuda
（Kanagawa academy of science and technology）
⑥　Spatial and temporal variations in the micro-scale vertical distributions of plankton in upper layers　○ J. Zhang[1]・T. Akiba[2]・Y. Tanaka[1]（[1]TUMSAT,[2]AIST）
13：30 ～ 14：30　座長 千手智晴（九州大学）
⑦　サメ類を漁獲対象とした調査用縦延縄採集具の開発について
○上嶋紘生[1]，戸高耀介[2]，生井沢知佳[2]，栗原芳恵[1]，宮崎唯史[1]，塩出大輔[2]，吉田次郎[2]，根本雅生[2]
（[1]海洋大練習船，[2]海洋大院）
⑧　南西諸島東方海域における浮延縄試験操業
○戸高耀介[1]，古見拓郎[1]，梶浦俊樹[1]，塩出大輔[1]，上嶋紘生[2]，萩田隆一[2]，林 敏史[2]，吉田次郎[1]，根本雅生[1]（[1] 海洋大院，[2] 海洋大練習船）
⑨　A Note on GK filter: Contamination of double diffusive convection in　overturning
○ Haruka Nakano and Jiro Yoshida（TUMSAT）
⑩　相模湾北部における表層循環流関する研究
○陳 禕寧，中野知香，根本雅生，吉田次郎（海洋大院）
14：40 ～ 15：50　総会
16：00 ～ 16：10　2015 年度日仏海洋学会賞および論文賞授与式
≪学会賞受賞≫ 千手智晴会員（九州大学）「日本海の深層水の形成・循環・変質過程に関する研究」
≪論文賞受賞≫ 大村卓朗会員（東大大海研）「Current status of ballast water and aquatic organisms transferred from and to Japan」50 巻 1-2 号，11-22，2012
≪論文賞受賞≫ 中野知香会員（海洋大院）「Parameterization of the eddy diffusivity due to double diffusive convection」51 巻 1-2 号，13-29，2013
16：10 ～ 16：50　2015 年度日仏海洋学会賞記念講演　千手智晴会員
17：00 ～ 19：00　懇親会（オトラ アネックスにて）

5. 訃報

本学会名誉会員，佐伯和昭先生は 2015 年 2 月にご逝去されました．長年にわたって庶務や渉外幹事を歴任し，2008 年度より名誉会員となられました．心より哀悼の意を表し，謹んでご報告申し上げます．

6. 新入会員

氏　名	所　属	紹介者
阿部　博和	国立研究開発法人水産総合研究センター　東北区水産研究所	奥村　裕
上嶋　紘生	東京海洋大学　船舶運航センター青鷹丸	吉田　次郎
秋葉　龍郎	産業技術総合研究所	田中　祐志
Mathias GIRAULT	公益財団法人　神奈川科学技術アカデミー	荒川　久幸
張　峻德	東京海洋大学　応用環境システム学専攻　浮遊生物研究室	田中　祐志
髙橋　義文	九州大学大学院　農学研究院　農業資源経済学部門	奥村　裕
小針　統	鹿児島大学　水産学部　水圏科学分野	吉田　次郎
樋口　謙	東京海洋大学　海洋環境保全学専攻　環境測定学研究室	荒川　久幸
大草　駿	東京海洋大学　海洋環境保全学専攻　環境測定学研究室	荒川　久幸
重岡　柚	東東京海洋大学　海洋環境保全学専攻　環境測定学研究室	荒川　久幸
劉　軒禹	東京海洋大学　海洋環境保全学専攻　環境測定学研究室	荒川　久幸

7. 所属および住所変更

氏　名	新しい所属先・住所
谷田　巖	東京大学大学院農学生命科学研究科水圏生物環境学研究室　特任研究員
渡部　俊広	国立研究開発法人　水産総合研究センター
中村　真由子	国立研究開発法人　海洋技術安全研究所
JFE アドバンテック株式会社	兵庫県西宮市高畑町 3-48

8. 退会（逝去者含む）

佐伯和昭，有木瑞紀，明瀬太志，戸口和貴，那須野陽平，信幸建設株式会社（賛助）

9. 寄贈図書

Ocean Newsletter（海洋政策研究財団）；No. 350-367
RESTEC News（一般財団法人リモート・センシング技術センター）；第 6 号
なつしま（JAMSTEC）；通巻 349 号～ 353 号
農工研ニュース（農村工学研究所）；No. 95-99
増養殖研究レター（水産総合研究センター）；第 5 号
国立科学博物館研究報告 A 類（動物学）；第 401 巻第 1 号-第 3 号
Ocean Breeze（東京大学大気海洋研究所）；第 18 号-第 20 号
気候システムニュース；2015. 2, No. 4
CIC NEWSLETTER（東京大学）；No. 12
FRANEWS（水産総合研究センター）；No. 41-44
神奈川県立博物館研究報告自然科学（神奈川県立生命の星・地球博物館）；44 号
水産技術（独立行政法人水産総合研究センター）；第 7 巻第 2 号-第 8 巻第 1 号
水産総合研究センター研究報告；No. 39-40
Techno-ocean News（テクノオーシャンネットワーク）；No.　56-57
海洋白書 2015　日本の動き　世界の動き「海洋立国」のための海洋政策の具体的実施に向けて（海洋政策研究財団）
日仏生物学会　会報；No. 54, 2014
東京大学大気海洋研究所　要覧・年報　2015
農村工学研究所報告（農村工学研究所）；第 54 号
広島日仏協会報　BULLETIN　No. 197
国立研究開発法人産業技術総合研究所地質調査総合センター 2015　沖縄島北部周辺海域海洋地質図
国立研究開発法人産業技術総合研究所地質調査総合センター 2015　室蘭沖表層堆積図
PEOGRESS IN FISHERY SCIENCES（中国水産学会）；第 16 巻第 4 期
Oceanologia et Limnologia Sinica（中国海洋湖沼学会・中国科学院海洋研究所）；第 46 巻第 1 期～第 3 期
農村工学研究所成果情報（農村工学研究所）；平成 26 年度

平成 26 年度収支決算

収入の部

費　　目	予算額（A）	決算額（B）	増減（B）－（A）	摘　　要
前年度繰越金	1,464,206	1,464,206	0	
正会員会費	880,000	872,000	−8,000	8,000 円× 109 名
特 別 会 員	96,000	102,000	6,000	6,000 円× 17 名
学生会員会費	24,000	12,000	−12,000	4,000 円× 3 名
賛助会員会費	80,000	110,000	30,000	10,000 円× 11 口（7 社）
学会誌売上金	150,000	161,201	11,201	
広　告　費	20,000	0	−20,000	
論文印刷費・カラー印刷費	600,000	548,000	−52,000	9 論文
別刷り印刷費	90,000	125,300	35,300	7 論文
雑　収　入	100,000	116,600	16,600	学術著作権使用料他
寄　付　金	0	0	0	
収入合計	3,504,206	3,511,307	7,101	

支出の部

費　　目	予算額（A）	決算額（B）	増減（B）－（A）	摘　　要
学会誌印刷費	1,800,000	969,286	−830,714	52（1.2），52（3），52（4）
送料・通信費	100,000	44,893	−55,107	
事　務　費	700,000	695,492	−4,508	事務用品，人件費（通勤手当含む）
交　通　費	20,000	2,202	−17,798	事務局～日仏会館
会　議　費	5,000	1,308	−3,692	
学会賞経費	30,000	19,850	−10,150	賞状他
雑　　　費	25,000	26,224	1,224	振込手数料他
次年度繰越	824,206	1,752,052	927,846	
支出合計	3,504,206	3,511,307	7,101	

平成 27 年度予算

収入の部

費目	2015 年度予算（B）	2014 年度予算（A）	増減（B）－（A）	摘要
前年度繰越金（銀行残高）	1,752,052	1,464,206	287,846	
正会員会費	888,000	880,000	8,000	8,000 円× 111 名
特別会員	108,000	96,000	12,000	6,000 円× 18 名
学生会員会費	28,000	24,000	4,000	4,000 円× 7 名
賛助会員会費	80,000	80,000	0	10,000 円× 8 口（7 社）
学会誌売上金	150,000	150,000	0	
広告費	20,000	20,000	0	
論文印刷費・カラー印刷費	600,000	600,000	0	
別刷り印刷費	90,000	90,000	0	
雑収入	100,000	100,000	0	
寄付金	1,700,000	0	1,700,000	シンポジウム助成（笹川日仏財団 100 万円，日仏会館 70 万円）
収入合計	5,516,052	3,504,206	2,011,846	

支出の部

費目	2015 年度予算（B）	2014 年度予算（A）	増減（B）－（A）	摘要
学会誌印刷費	1,020,000	1,800,000	−780,000	53（1.2）340,000 円請求予定，年 3 回発行で積算
送料・通信費	100,000	100,000	0	
事務費	700,000	700,000	0	事務用品，人件費（通勤手当含む）
交通費	10,000	20,000	−10,000	事務局～日仏会館
会議費	5,000	5,000	0	
学会賞経費	30,000	30,000	0	
雑費	25,000	25,000	0	
シンポジウム事業費	1,800,000	0	1,800,000	
次年度繰越（予備費）	1,826,052	824,206	1,001,846	
支出合計	5,516,052	3,504,206	2,011,846	