

## Variation in a color pattern of white patch on the flippers of North Pacific common minke whales: Potential application for their interoceanic difference.

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**Abstract** : We investigated growth related changes, sex-based differences, and variation in the white flipper patches of 240 North Pacific minke whales *Balaenoptera acutorostrata*. Previously reported photographic data of North Atlantic minke whales ( $n = 13$ ) were also used for interoceanic comparison. In the North Pacific specimens the size of the white patch was larger in males (33.8%) than in females (31.8%). The relative area of the white patch decreased during development, and tended to be larger in the males. The relative length of white patch to flipper length (33.4%) and area of the white to flipper area (38.8%) in North Pacific specimens were significantly smaller than the corresponding length (40.7%) and area (55.5%) in North Atlantic specimens. Although the proximal boundary contour of the white patch was straight in North Atlantic specimens, it was meandering in North Pacific specimens. The findings in this study suggest that the morphology of the white flipper patch can be applicable to the elucidation of common minke whale speciation.

**Keywords** : Common minke whales, *Balaenoptera acutorostrata*, flipper, morphology

### Introduction

The common minke whale, *Balaenoptera acutorostrata*, is the smallest species in family Balaenopteridae. They are widely distributed

in the world and are considered to be an important marine resource, especially given their large stock size. North Atlantic minke whales are a commercial whaling target species in Norway and Iceland, and North Pacific minke whales have a long history of sustainable use in Japan. This species is currently the subject of whale research programs conducted in accordance with Article VIII of the International Convention for the Regulation of Whaling.

Common minke whales are currently classified into two subspecies: *B. a. scammoni* in the North Pacific and *B. a. acutorostrata* in the North Atlantic. In the Southern Hemisphere there is a distinctive population of "dwarf" minke whales *B. a.* subsp., however, its taxonomical classification is still debated (RICE, 1998). It has also been recommended that the North Pacific minke whales be further divided into several subspecies (KATO *et al.*, 1992, KANDA *et al.*, 2009), which demonstrates

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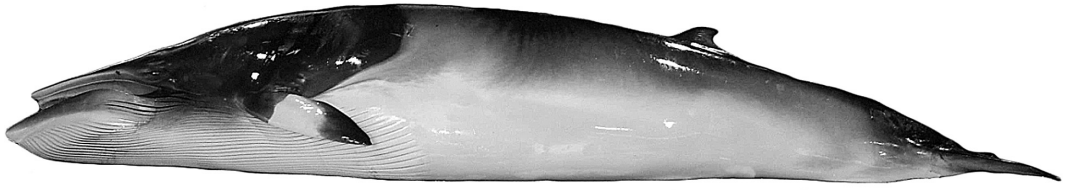


Fig. 1. Lateral view of the North Pacific common minke whale with a clear white patch on the flipper

the complexity associated with the classification of *B. acutorostrata*. Minke whales have a white patch on their pectoral flippers, a feature that has not been observed in any other whale species (Fig. 1). External appearance is an important classification criterion, and previous studies have investigated intra-oceanic variation (KATO *et al.*, 1992) and made interoceanic comparisons (OMURA and SAKIURA, 1956) of these white flipper patches. Compared with North Pacific minke whales, white patches in dwarf minke whales are much larger, reaching the shoulder, and thereby significantly differentiate the subspecies (ARNOLD *et al.*, 1987; KATO and FUJISE, 2000; ARNOLD *et al.*, 2005). Furthermore, preliminary studies have shown that the boundary contour of the white patch at the base of the flipper varies between the North Pacific and North Atlantic minke whales (OMURA and SAKIURA, 1956; HORWOOD, 1989).

Despite the preliminary investigation of interoceanic variation of white patches in common minke whales, such findings have not been used to identify their subspecies, because of the lack of fundamental information such as the extent of intra-oceanic variation and growth related changes in the North Pacific minke whales. In this study, we therefore investigated the features, variation, and sex-based differences in the morphology of the white flipper patch of North Pacific minke whale specimens, with the aim of establishing classification indexes from our findings for the North Pacific stock in future studies. We also compared North Pacific and North Atlantic specimens to reveal the morphological variation in white patches within the same species and to evaluate the utility of using white patch morphological features to identify common minke whale

populations.

## Materials

### *North Pacific minke whales*

We used 237 North Pacific minke whales (151 males, body length: 3.70–8.16 m; 86 females, body length: 3.84–8.68 m) collected from offshore waters near Japan in 2012 and off Sanriku and Kushiro, Japan, in 2012–2013 during the Japanese Whale Research Program under Special Permit in the Western North Pacific-Phase II (commonly known as JARPN II) survey, which was conducted in accordance with Article VIII of the International Convention for the Regulation of Whaling and Japanese law (Fig. 2). Even for minke whales inhabiting the same ocean, it is necessary to investigate intra-species variation among the subspecies inhabiting Pacific coastal regions and those offshore. In this study, however, we placed priority on the comparison between larger geographical regions to elucidate interoceanic species variation and will investigate intra-oceanic variation in future studies.

### *North Atlantic minke whales*

In this study, comparative analysis was performed using photographs of North Atlantic minke whales taken in the ocean, which were available online. We made efforts to provide all specific locations where photographs of whales were taken; however, some whales were considered to be North Atlantic minke whale for the purposes of this study even if that information was unavailable. We selected 13 whales where the front of the flipper was photographed (Table 1).

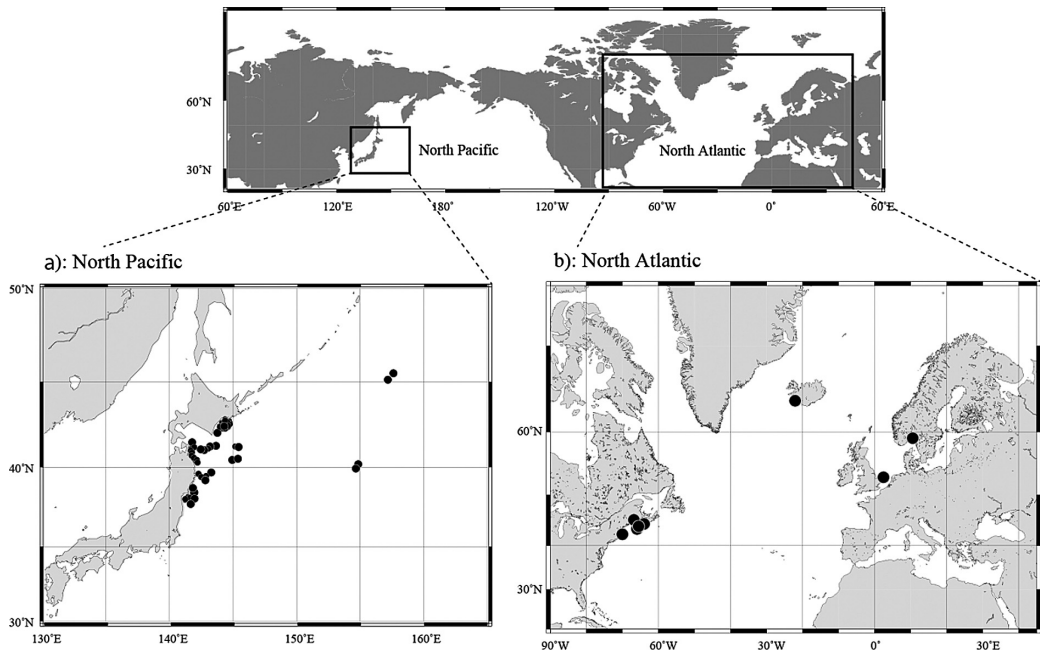


Fig. 2. Geographical locations (a) where North Pacific common minke whales were collected and (b) where North Atlantic common minke whales were photographed

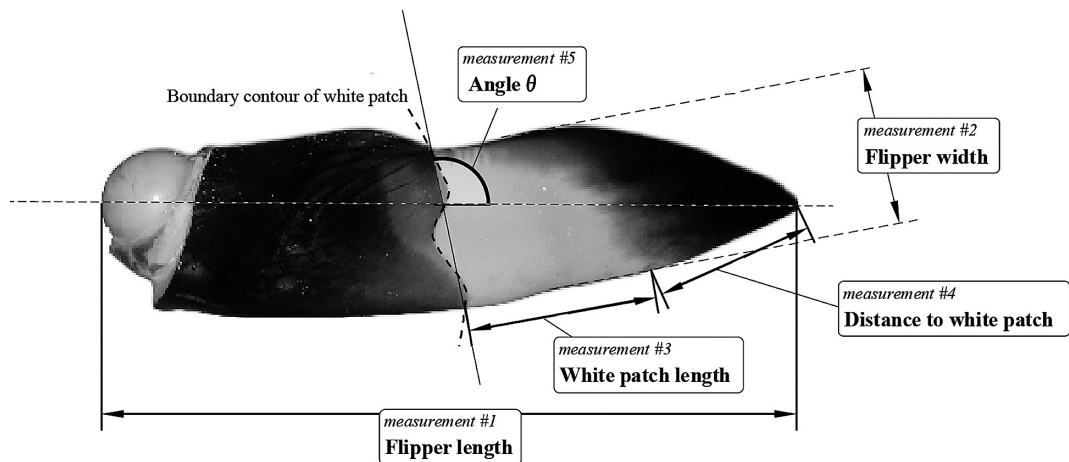


Fig. 3. Measurement points on the flipper

## Methods

### *Measurements of the length of each measurement points*

Body length of North Pacific minke whales were measured in a straight line between the tip of the snout and the notch of the flukes

down to the centimeter scale. Another measurement points on the flipper, *measurement #1* through *4* were conducted on resected flippers down to the millimeter scale using a stainless steel caliper or a measurement tape as described in Fig. 3. In the North Atlantic specimens,

Table 1. URLs of various websites with published photographs of North Atlantic common minke whales and the shooting locations

| ID    | Location                                 | URL   |
|-------|--|---|
| NA-1  | North Atlantic                           | <a href="http://www.projectminke.com/pgiminkesco02.jpg">http://www.projectminke.com/pgiminkesco02.jpg</a>   |
| NA-2  | Campobello Island, New Brunswick, Canada | <a href="http://1.bp.blogspot.com/-syZ_usMTayM/ThoKVNng4DCI/AAAAAAAAAAD14/pDbvidzmCnc/s400/265932_624155920585_1214036622_3430023_7497371_o.jpg">http://1.bp.blogspot.com/-syZ_usMTayM/ThoKVNng4DCI/AAAAAAAAAAD14/pDbvidzmCnc/s400/265932_624155920585_1214036622_3430023_7497371_o.jpg</a>   |
| NA-3  | North Atlantic                           | <a href="http://uk.whales.org/sites/default/files/styles/flexslider_full/public/species/balaenoptera_acutorostrata-aishling_hefferna.jpg?itok=WTOTd5iN">http://uk.whales.org/sites/default/files/styles/flexslider_full/public/species/balaenoptera_acutorostrata-aishling_hefferna.jpg?itok=WTOTd5iN</a>   |
| NA-4  | Stellwagon Bank, Cape Cod, Massachusetts | <a href="http://fc05.deviantart.net/fs70/i/2011/219/e/9/the_oceanic_puppy_by_silvervulpine-d45skfn.jpg">http://fc05.deviantart.net/fs70/i/2011/219/e/9/the_oceanic_puppy_by_silvervulpine-d45skfn.jpg</a>   |
| NA-5  | Gulf of Maine, Canada                    | <a href="http://www.healthywildlife.ca/wp-content/uploads/2012/07/minke-whale-in-fishing-gear.jpg">http://www.healthywildlife.ca/wp-content/uploads/2012/07/minke-whale-in-fishing-gear.jpg</a>   |
| NA-6  | Stellwagen Bank, Massachusetts           | <a href="http://www.wheretowatchbirdsandotherwildlifeintheworld.co.uk/images/minke.jpg">http://www.wheretowatchbirdsandotherwildlifeintheworld.co.uk/images/minke.jpg</a>   |
| NA-7  | Norway                                   | <a href="http://www.marefa-whaleresearch.org/wp-content/uploads/2012/12/minke3-copyright.jpg">http://www.marefa-whaleresearch.org/wp-content/uploads/2012/12/minke3-copyright.jpg</a>   |
| NA-8  | Gorleston, Norfolk, United Kingdom       | <a href="http://whalesandmarinefauna.files.wordpress.com/2013/07/minke-whale-norfolk.jpg">http://whalesandmarinefauna.files.wordpress.com/2013/07/minke-whale-norfolk.jpg</a>   |
| NA-9  | Norway                                   | <a href="http://www.bulandet-grendalag.org/images/Kval/BrukKval2.jpg">http://www.bulandet-grendalag.org/images/Kval/BrukKval2.jpg</a>   |
| NA-10 | Norway                                   | <a href="http://awionline.org/sites/default/files/imagecache/awi-quarterly-cover/images/press-releases/minke%20on%20Norwegian%20boat%20steve%20morgan%20pic.jpg">http://awionline.org/sites/default/files/imagecache/awi-quarterly-cover/images/press-releases/minke%20on%20Norwegian%20boat%20steve%20morgan%20pic.jpg</a>   |
| NA-11 | Reychabic, Iceland                       | <a href="http://online.wsj.com/news/articles/SB121984941913476621?mg=reno64-wsj&amp;url=http%3A%2F%2Fonline.wsj.com%2Farticle%2FSB12198494191346621.html&amp;fpid=2.7.121.122.201.401.641.1009#5">http://online.wsj.com/news/articles/SB121984941913476621?mg=reno64-wsj&amp;url=http%3A%2F%2Fonline.wsj.com%2Farticle%2FSB12198494191346621.html&amp;fpid=2.7.121.122.201.401.641.1009#5</a> |
| NA-12 | Martinique Beach, HRM, Nova Scotia       | <a href="http://i235.photobucket.com/albums/ee253/Accentor/Mammals/Minke-Whale-deceased-06.jpg">http://i235.photobucket.com/albums/ee253/Accentor/Mammals/Minke-Whale-deceased-06.jpg</a>   |
| NA-13 | North Atlantic                           | <a href="http://whalesenseblog.files.wordpress.com/2013/03/2927_70869334631_4497029_n.jpeg?w=604&amp;h=314">http://whalesenseblog.files.wordpress.com/2013/03/2927_70869334631_4497029_n.jpeg?w=604&amp;h=314</a>   |

measurement values on flipper were calculated using image processing software Canvas X, because their measurement values were not available online.

- i) measurement #1:* Flipper length (a straight line connecting the tip of flipper and the head of the humerus)
- ii) measurement #2:* Flipper width (the widest point of the flipper)
- iii) measurement #3:* The length of the white

patch along the anterior margin of the flipper

- iv) measurement #4:* The length between the tip of flipper and the starting point of the white patch along the anterior margin of the flipper
- v) measurement #5:* The angle between the axis of the flipper and the mean black/white borderline between the flipper base and the white patch (Angle  $\theta$ )

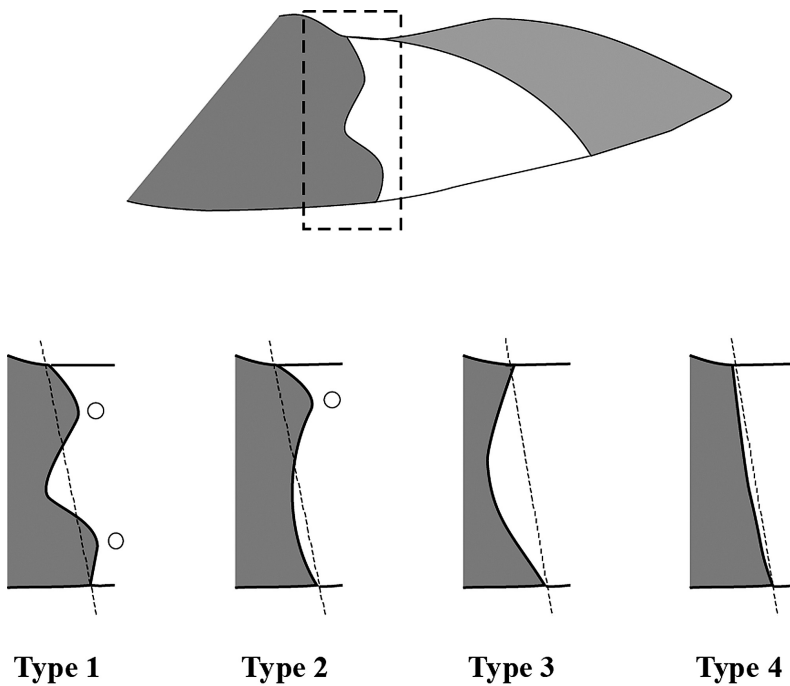


Fig. 4. Morphological typing of the boundary contours at the flipper base

#### *Photographic recording*

To measure the angle (angle  $\theta$ ) and area of white patch, the photographic recording of flippers was performed using the raw image function of Nikon D70 and D100 digital cameras, with the Kodak Gray Scale chart to the side, and efforts were taken not to overexpose the black area with flash. The raw image processing program, RAWTherapee (<http://www.rawtherapee.com>), was used to perform white balance of photographic images and to adjust exposure, and the RGB values at the midpoint of the Kodak Gray Scale chart were also adjusted to R=119, G=119, and B=119. After saving the images as TIFF files, image processing software (Image J; <http://imagej.nih.gov/ij/>) was used to construct 8-bit grayscale images, and Otsu's binarization method was used to determine the threshold value for discriminating white from black and gray and thus produce binary images. When it was difficult to determine a correct threshold value due to the presence of shadows and light grays, variable thresholding was performed with Open CV in

Microsoft Visual C++. After this preprocessing, Image J was used to determine the area of the flipper and white patch. The flipper area was defined as the area between the tip of the flipper and the white patch, and the area of the white patch was defined as the white area after binarization. The area of the white patch relative to the flipper was expressed as a percentage. Angle  $\theta$  was determined using Canvas X (<http://www.poladigital.co.jp/canvas/>). Measurement and photographic recording were performed bilaterally; however in general, only left side measurements were used in this study.

#### *Classification of the boundary contour of the white patch*

The boundary contours of the white patches at the base of the flipper were grouped based on the pattern of the boundary of the curves along the mean black/white borderline connecting the dorsal and anterior margins (Fig. 4). White patches with an unclear boundary pattern were excluded from this study.

- Type 1: 2 curves crossing the mean black/white borderline
- Type 2: 1 curve crossing the mean black/white borderline
- Type 3: No curves crossing the mean black/white borderline, but a large concave curve toward the base of the flipper
- Type 4: The actual boundary being nearly straight and parallel to the mean black/white borderline

#### *Analysis on growth dependent change*

The following allometric equation was used to extract growth- and sex-related patterns at each measurement point :

$$Y = \beta X^\alpha$$

where  $X$  defines flipper length (cm) or body length (m) ;  $Y$ , the length at each measurement point (cm) ;  $\alpha$ , the allometric coefficient; and  $\beta$ , initial growth constant. To reveal sex-based differences, individual allometric equations were converted into a logarithmic form, and the slope and intercept were compared using the  $t$  test. Results were considered statistically significant at  $p < 0.05$ . Following YOSHIDA *et al.* (1993), the  $t$  test was also conducted to classify growth features at each anatomical point into three patterns: hyperallometry (positive allometry) when the allometric coefficient was significantly greater than 1, isometry (isometric allometry), and hypoallometry (negative allometry) when the allometric coefficient was less than 1.

## Results and discussion

### 1. Growth related changes and sex-based differences in the North Pacific minke whales.

#### *Length of the flipper and body length*

237 North Pacific specimens (151 males; 86 females) were divided into different groups based on body length: groups divided every 50 cm between 3.5–8.0 m and a group of 8.0–9.0 m due to the small sample number. The minimum, maximum, and mean flipper length and the flipper length relative to body length in individual groups are shown in Table 2. Flipper length increased as growth in both sexes. In males, the mean length increased from 63.0 cm (c.v.=0.03,  $n=2$ ) in the 3.5 m group (3.5–4.0 m) to 127.1 cm (c.v.=0.02,  $n=3$ ) in the

8.0 m group (8.0–9.0 m), whereas the mean length of female whales increased from 59.5 cm ( $n=1$ ) to 134.1 cm (c.v.=0.03,  $n=6$ ), respectively.

The mean proportion of the flipper length to the body length dropped from 16.3% (c.v.=0.04,  $n=2$ ) in the 3.5 m group to 15.5% (c.v.=0.03,  $n=16$ ) in the 4.5 m group in males and from 16.2% (c.v.=0.04,  $n=7$ ) in the 4.0 m group to 15.7% (c.v.=0.03,  $n=17$ ) in the 4.5 m group in females. The mean proportion peaked at 16.5% (c.v.=0.03,  $n=35$ ) for males and 17.3% ( $n=1$ ) for females in the 7.0 m group before decreasing again, showing that the proportional length of the flipper changes with body length. No statistically significant difference by sex was observed in any of the body length groups (Mann-Whitney's  $U$ -test,  $p < 0.01$ ).

In mammals, the relative growth patterns of the four limbs reflect the ecology and life history of individual species and may vary between sexes or over different developmental stages. In *Homo sapiens*, the length of four limbs relative to the body increases during development (BOGIN and VARELA-SILVA, 2010). However, the relative proportion of leg length decreases in crab-eating macaques, (*Macaca fascicularis*), and at age 3 years, male-female differences in relative growth pattern starts to emerge, with a lower or higher relative proportion in females and males, respectively (SHIMIZU *et al.*, 1991). Although the length between the tip and base of the flipper relative to the body decreases in the Dall's Porpoise (*Phocoenoides dalli*), another marine mammal, the corresponding measurement in fin whales (*B. physalus*), which belong to the same genus as common minke whales, is constant (OHSUMI, 1960; AMANO and MIYAZAKI, 1993). In common minke whales, the relative length of the flipper to the body decreased by approximately 0.8% during the 3.5–4.5 m developmental stages, but peaked at the 7.0–8.0 m developmental stage before making another decline, demonstrating an inconsistent growth pattern. Such fluctuation in the proportions is thought to be due to differences in the growth rates of the flipper and body. Whales use their flippers to acquire buoyancy and change direction (FISH *et al.*,

Table 2. Actual length of the flipper in *measurement #1* and the length relative to the body length in the North Pacific common minke whales

| Body length class (m) | Male                |         |      |                               |         |      | Female              |             |       |                               |           |      | Male v.s. Female |      |
|-----------------------|---------------------|---------|------|-------------------------------|---------|------|---------------------|-------------|-------|-------------------------------|-----------|------|------------------|------|
|                       | Flipper length (cm) |         |      | Proportion of body length (%) |         |      | Flipper length (cm) |             |       | Proportion of body length (%) |           |      |                  |      |
|                       | Min-Max             | Average | c.v. | Min-Max                       | Average | c.v. | Min-Max             | Average     | c.v.  | Min-Max                       | Average   | c.v. |                  | n    |
| 3.5-3.9               | 61.2-64.7           | 63.0    | 0.03 | 15.6-16.9                     | 16.3    | 0.04 | 2                   | 59.5        | 59.5  | 0.00                          | 15.5      | 15.5 | 1                | n.s. |
| 4.0-4.4               | 64.0-77.8           | 68.7    | 0.06 | 15.2-17.4                     | 16.0    | 0.04 | 7                   | 63.8-72.6   | 69.0  | 0.04                          | 14.7-17.1 | 16.2 | 7                | n.s. |
| 4.5-4.9               | 67.2-79.4           | 73.5    | 0.05 | 14.3-16.5                     | 15.5    | 0.03 | 16                  | 69.2-79.0   | 74.8  | 0.04                          | 14.8-16.9 | 15.7 | 17               | n.s. |
| 5.0-5.4               | 74.6-87.3           | 82.1    | 0.04 | 14.9-16.3                     | 15.6    | 0.03 | 18                  | 77.0-89.7   | 83.3  | 0.04                          | 14.9-16.8 | 15.8 | 22               | n.s. |
| 5.5-5.9               | 82.4-99.8           | 92.2    | 0.06 | 14.7-16.7                     | 15.9    | 0.04 | 9                   | 84.3-95.5   | 91.3  | 0.04                          | 14.7-16.2 | 15.8 | 12               | n.s. |
| 6.0-6.4               | 93.2-107.1          | 99.3    | 0.04 | 15.1-17.1                     | 15.9    | 0.04 | 18                  | 93.0-105.6  | 100.2 | 0.05                          | 15.2-17.0 | 16.1 | 9                | n.s. |
| 6.6-6.9               | 103.0-117.1         | 110.1   | 0.03 | 15.6-17.3                     | 16.4    | 0.03 | 21                  | 104.0-114.0 | 110.8 | 0.03                          | 16-17.1   | 16.8 | 5                | n.s. |
| 7.0-7.4               | 106.2-128.8         | 119.5   | 0.04 | 15.1-17.6                     | 16.5    | 0.03 | 35                  | 122.6       | 122.6 | 0.00                          | 17.3      | 17.3 | 1                | n.s. |
| 7.5-7.9               | 118.1-133.0         | 126.1   | 0.03 | 15.4-17.6                     | 16.5    | 0.03 | 22                  | 122.7-135.0 | 129.0 | 0.03                          | 16.1-17.3 | 16.7 | 6                | n.s. |
| 8.0-9.0               | 123.4-130.7         | 127.1   | 0.02 | 15.3-16.3                     | 15.7    | 0.03 | 3                   | 128-140.6   | 134.1 | 0.03                          | 15.9-17   | 16.4 | 6                | n.s. |
| Total                 | 61.2-133.0          |         |      | 14.3-17.6                     | 16.1    | 0.04 | 151                 | 59.5-140.6  |       |                               | 14.7-17.3 | 16.0 | 86               | n.s. |

Table 3. Actual and relative values in *measurement #3-5* and the relative area of the white patches in the North Pacific common minke whales

| Body length class<br>(m) | <i>measurement #3</i> |         |                                  |           |             |      |                                  |           |           |         | <i>measurement #4</i>                       |      |             |         |                                  |         |           |      |   |         | <i>measurement #5</i> |         |                                  |      |           |         |   |         |         |      | Area of white patch |  |  |
|--------------------------|-----------------------|---------|----------------------------------|-----------|-------------|------|----------------------------------|-----------|-----------|---------|---|------|-------------|---------|----------------------------------|---------|-----------|------|---|---------|-----------------------|---------|----------------------------------|------|-----------|---------|---|---------|---------|------|---------------------|--|--|
|                          | Length (cm)           |         | Proportion of flipper length (%) |           | Length (cm) |      | Proportion of flipper length (%) |           | Angle (°) |         | Coverage of white patch to flipper area (%) |      | Length (cm) |         | Proportion of flipper length (%) |         | Angle (°) |      | Coverage of white patch to flipper area (%) |         | Length (cm)           |         | Proportion of flipper length (%) |      | Angle (°) |         | Coverage of white patch to flipper area (%) |         |         |      |                     |  |  |
|                          | Min-Max               | Average | c.v.                             | Min-Max   | Average     | c.v. | Min-Max                          | Average   | c.v.      | Min-Max | Average                                     | c.v. | Min-Max     | Average | c.v.                             | Min-Max | Average   | c.v. | Min-Max                                     | Average | c.v.                  | Min-Max | Average                          | c.v. | Min-Max   | Average | c.v.  | Min-Max | Average | c.v. |                     |  |  |
| 3.5-3.9                  | 16.2-27.1             | 21.7    | 0.25                             | 26.5-41.9 | 34.2        | 0.23 | 2                                | 19.6-20.4 | 20.0      | 0.02    | 30.3-33.3                                   | 31.8 | 0.05        | 2       | 73.1-87.1                        | 80.1    | 0.09      | 2    | 34.8-43.7                                   | 39.2    | 0.11                  | 2       | 34.8-43.7                        | 39.2 | 0.11      | 2       | 34.8-43.7                                   | 39.2    | 0.11    | 2    |                     |  |  |
| 4.0-4.4                  | 17.8-27.6             | 23.4    | 0.12                             | 24.8-38.7 | 34.2        | 0.12 | 7                                | 15.0-24.4 | 20.2      | 0.16    | 23.0-35.5                                   | 29.4 | 0.13        | 7       | 74.6-97.2                        | 86.5    | 0.08      | 7    | 35.6-48.7                                   | 43.5    | 0.11                  | 7       | 35.6-48.7                        | 43.5 | 0.11      | 7       | 35.6-48.7                                   | 43.5    | 0.11    | 7    |                     |  |  |
| 4.5-4.9                  | 18.0-31.1             | 24.2    | 0.15                             | 24.2-44.6 | 32.8        | 0.17 | 14                               | 12.8-30.2 | 21.7      | 0.20    | 19.0-38.5                                   | 29.4 | 0.18        | 16      | 77.8-104.5                       | 89.1    | 0.08      | 16   | 32.5-61.5                                   | 43.7    | 0.18                  | 13      | 32.5-61.5                        | 43.7 | 0.18      | 13      | 32.5-61.5                                   | 43.7    | 0.18    | 13   |                     |  |  |
| 5.0-5.4                  | 25.0-35.8             | 28.5    | 0.10                             | 29.6-44.5 | 34.8        | 0.12 | 18                               | 16.1-28.7 | 23.0      | 0.13    | 20.8-32.9                                   | 27.9 | 0.11        | 18      | 73.4-100.3                       | 88.1    | 0.09      | 18   | 24.7-55.5                                   | 43.7    | 0.19                  | 16      | 24.7-55.5                        | 43.7 | 0.19      | 16      | 24.7-55.5                                   | 43.7    | 0.19    | 16   |                     |  |  |
| 5.5-5.9                  | 18.7-38.9             | 29.1    | 0.20                             | 22.1-40.5 | 31.4        | 0.17 | 8                                | 22.5-36.8 | 28.4      | 0.16    | 25.3-39.3                                   | 30.8 | 0.13        | 9       | 75.6-98.4                        | 86.6    | 0.10      | 9    | 24.7-47.1                                   | 34.3    | 0.24                  | 6       | 24.7-47.1                        | 34.3 | 0.24      | 6       | 24.7-47.1                                   | 34.3    | 0.24    | 6    |                     |  |  |
| 6.0-6.4                  | 24.2-41.0             | 33.1    | 0.14                             | 25.4-41.7 | 33.4        | 0.14 | 18                               | 19.3-39.0 | 30.1      | 0.18    | 19.8-36.4                                   | 30.2 | 0.15        | 18      | 67.2-98.0                        | 86.1    | 0.10      | 18   | 23.3-57.3                                   | 41.9    | 0.25                  | 12      | 23.3-57.3                        | 41.9 | 0.25      | 12      | 23.3-57.3                                   | 41.9    | 0.25    | 12   |                     |  |  |
| 6.6-6.9                  | 27.9-45.7             | 36.2    | 0.12                             | 24.5-42.3 | 33.0        | 0.14 | 21                               | 25.9-44.5 | 33.7      | 0.14    | 24.0-38.9                                   | 30.6 | 0.13        | 21      | 71.3-104.0                       | 87.7    | 0.09      | 21   | 14.5-58.2                                   | 39.6    | 0.28                  | 17      | 14.5-58.2                        | 39.6 | 0.28      | 17      | 14.5-58.2                                   | 39.6    | 0.28    | 17   |                     |  |  |
| 7.0-7.4                  | 30.1-55.7             | 42.4    | 0.15                             | 23.6-46.5 | 35.6        | 0.16 | 34                               | 25.3-50.7 | 36.2      | 0.17    | 22.7-41.7                                   | 30.2 | 0.15        | 35      | 67.2-104.1                       | 86.9    | 0.11      | 35   | 16.9-57.4                                   | 35.4    | 0.27                  | 26      | 16.9-57.4                        | 35.4 | 0.27      | 26      | 16.9-57.4                                   | 35.4    | 0.27    | 26   |                     |  |  |
| 7.5-7.9                  | 30.8-55.3             | 41.5    | 0.16                             | 24.8-42.7 | 32.8        | 0.16 | 22                               | 31.7-54.2 | 40.7      | 0.13    | 24.6-45.9                                   | 32.3 | 0.14        | 22      | 69.7-99.4                        | 86.9    | 0.10      | 22   | 7.7-58.5                                    | 35.4    | 0.34                  | 16      | 7.7-58.5                         | 35.4 | 0.34      | 16      | 7.7-58.5                                    | 35.4    | 0.34    | 16   |                     |  |  |
| 8.0-9.0                  | 33.7-41.8             | 38.8    | 0.09                             | 27.3-32.2 | 30.5        | 0.07 | 3                                | 43.7-48.0 | 45.2      | 0.04    | 34.4-36.7                                   | 35.5 | 0.03        | 3       | 82.2-90.1                        | 86.5    | 0.04      | 3    |   |         |                       | 0       |                                  |      |           |         |   |         |         |      |                     |  |  |
| Total                    | 16.2-55.7             |         |                                  | 22.1-46.5 | 33.8        | 0.15 | 147                              | 12.8-54.2 |           |         | 19.0-45.9                                   | 30.3 | 0.15        | 151     | 67.2-104.5                       | 87.2    | 0.10      | 151  | 7.7-61.5                                    | 39.3    | 0.26                  | 115     | 7.7-61.5                         | 39.3 | 0.26      | 115     | 7.7-61.5                                    | 39.3    | 0.26    | 115  |                     |  |  |
| 3.5-3.9                  | 15.6                  | 15.6    |                                  | 26.2      | 26.2        |      | 1                                | 19.2-19.2 | 19.2      |         | 32.3  | 32.3 |             | 1       | 97.4-97.4                        | 97.4    | 0.00      | 1    |   |         |                       | 0       |                                  |      |           |         |   |         |         |      |                     |  |  |
| 4.0-4.4                  | 18.4-23.8             | 21.4    | 0.08                             | 28.8-33.8 | 31.1        | 0.05 | 7                                | 19.4-25.0 | 21.5      | 0.08    | 26.7-36.0                                   | 31.2 | 0.09        | 7       | 86.2-96.1                        | 91.1    | 0.04      | 7    | 17.2-48.3                                   | 32.2    | 0.27                  | 7       | 17.2-48.3                        | 32.2 | 0.27      | 7       | 17.2-48.3                                   | 32.2    | 0.27    | 7    |                     |  |  |
| 4.5-4.9                  | 17.2-39.2             | 24.6    | 0.20                             | 22.5-53.5 | 32.9        | 0.21 | 17                               | 9.6-25.4  | 20.8      | 0.18    | 13.1-34.1                                   | 27.8 | 0.18        | 17      | 70.4-102.6                       | 90.9    | 0.10      | 17   | 9.7-52.3                                    | 41.1    | 0.25                  | 16      | 9.7-52.3                         | 41.1 | 0.25      | 16      | 9.7-52.3                                    | 41.1    | 0.25    | 16   |                     |  |  |
| 5.0-5.4                  | 16.6-39.8             | 28.4    | 0.20                             | 20.1-47.0 | 34.2        | 0.19 | 20                               | 16.0-33.4 | 22.8      | 0.17    | 20.4-38.6                                   | 27.4 | 0.16        | 22      | 75.8-98.9                        | 88.0    | 0.08      | 22   | 24.9-55.7                                   | 45.1    | 0.20                  | 19      | 24.9-55.7                        | 45.1 | 0.20      | 19      | 24.9-55.7                                   | 45.1    | 0.20    | 19   |                     |  |  |
| 5.5-5.9                  | 23.0-40.2             | 28.7    | 0.17                             | 24.2-44.7 | 31.4        | 0.17 | 12                               | 23.0-34.1 | 28.1      | 0.14    | 25.6-39.7                                   | 30.7 | 0.14        | 12      | 65.5-100.2                       | 87.9    | 0.10      | 12   | 8.6-50.9                                    | 30.5    | 0.42                  | 9       | 8.6-50.9                         | 30.5 | 0.42      | 9       | 8.6-50.9                                    | 30.5    | 0.42    | 9    |                     |  |  |
| 6.0-6.4                  | 17.5-40.4             | 28.4    | 0.25                             | 16.6-42.7 | 28.6        | 0.27 | 9                                | 19.5-39.6 | 30.2      | 0.09    | 20.6-38.2                                   | 30.0 | 0.16        | 9       | 77.8-100.6                       | 90.2    | 0.09      | 9    | 28.5-43.6                                   | 36.6    | 0.16                  | 8       | 28.5-43.6                        | 36.6 | 0.16      | 8       | 28.5-43.6                                   | 36.6    | 0.16    | 8    |                     |  |  |
| 6.6-6.9                  | 28.4-42.1             | 33.4    | 0.14                             | 25.0-37.2 | 30.2        | 0.13 | 5                                | 28.7-46.4 | 36.5      | 0.16    | 27.6-40.9                                   | 32.8 | 0.14        | 5       | 75.1-99.0                        | 87.0    | 0.10      | 5    | 26.5-43.9                                   | 33.1    | 0.20                  | 5       | 26.5-43.9                        | 33.1 | 0.20      | 5       | 26.5-43.9                                   | 33.1    | 0.20    | 5    |                     |  |  |
| 7.0-7.4                  | 30.8                  | 30.8    |                                  | 25.1      | 25.1        |      | 1                                | 45.0      | 45.0      |         | 36.7  | 36.7 |             | 1       | 102.9-102.9                      | 102.9   | 0.00      | 1    | 36.1-36.1                                   | 36.1    | 0.00                  | 1       | 36.1-36.1                        | 36.1 | 0.00      | 1       | 36.1-36.1                                   | 36.1    | 0.00    | 1    |                     |  |  |
| 7.5-7.9                  | 37.5-44.3             | 41.3    | 0.07                             | 28.8-34.1 | 32.0        | 0.06 | 6                                | 36.6-46.3 | 40.8      | 0.08    | 27.6-34.3                                   | 31.6 | 0.07        | 6       | 71.4-98.7                        | 89.8    | 0.10      | 6    | 30.9-44.9                                   | 37.4    | 0.14                  | 5       | 30.9-44.9                        | 37.4 | 0.14      | 5       | 30.9-44.9                                   | 37.4    | 0.14    | 5    |                     |  |  |
| 8.0-9.0                  | 25.9-51.5             | 39.9    | 0.19                             | 19.5-38.5 | 29.8        | 0.19 | 6                                | 35.8-51.8 | 45.0      | 0.12    | 27.9-39.0                                   | 33.5 | 0.11        | 6       | 72.1-104.5                       | 92.7    | 0.11      | 9    | 17.2-27.9                                   | 22.5    | 0.24                  | 2       | 17.2-27.9                        | 22.5 | 0.24      | 2       | 17.2-27.9                                   | 22.5    | 0.24    | 2    |                     |  |  |
| Total                    | 15.6-51.5             |         |                                  | 16.6-53.5 | 31.8        | 0.02 | 84                               | 9.6-51.8  |           |         | 13.1-40.9                                   | 29.8 | 0.16        | 86      | 65.5-104.5                       | 89.9    | 0.10      | 89   | 8.6-55.7                                    | 38.1    | 0.28                  | 72      | 8.6-55.7                         | 38.1 | 0.28      | 72      | 8.6-55.7                                    | 38.1    | 0.28    | 72   |                     |  |  |
| Total                    | 15.6-55.7             |         |                                  | 16.6-53.5 | 33.4        | 0.18 | 231                              | 9.6-54.2  |           |         | 13.1-45.9                                   | 30.1 | 0.15        | 237     | 65.5-104.5                       | 86.6    | 0.12      | 240  | 74.7-61.5                                   | 38.8    | 0.27                  | 186     | 74.7-61.5                        | 38.8 | 0.27      | 186     | 74.7-61.5                                   | 38.8    | 0.27    | 186  |                     |  |  |



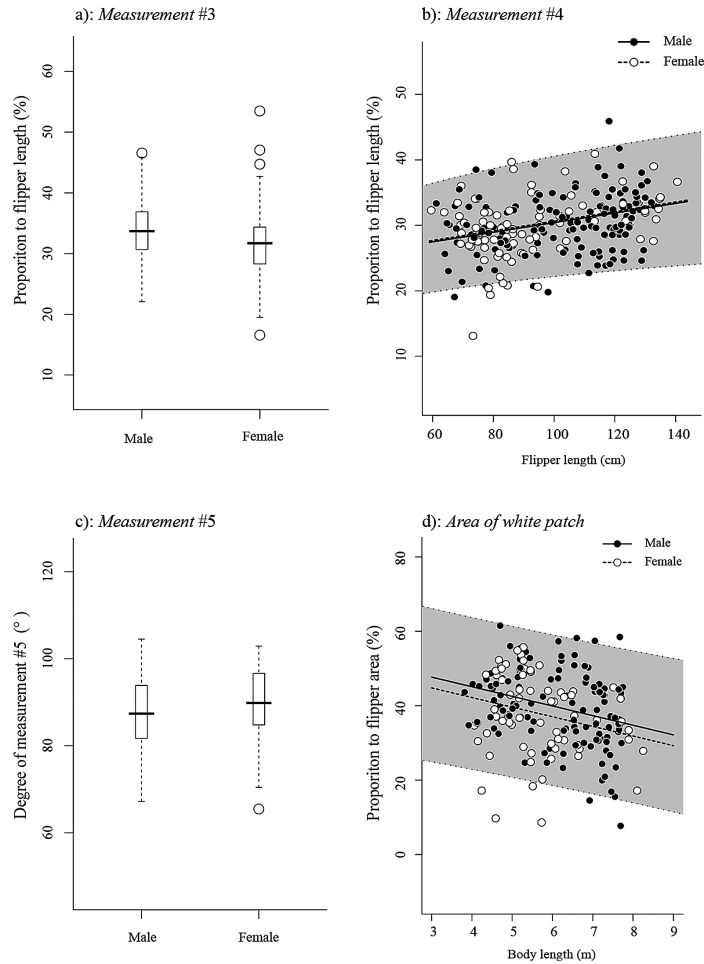


Fig. 5. Growth related changes and sexual differences of each measurement points on the flipper. *Measurement #3* (a), *measurement #4* (b), *measurement #5* (c) and white patch area (d). Boxplots are shown with whiskers extending from minimum (bottom) to maximum (top) values, with a horizontal line as the median value and outliers as circles. Black circle with solid regression line denotes male; white circle with broken line, female and gray area, 95% confidence interval.

2008). The difference in the relative length was approximately 1% in this study, and it is unclear to what extent such a small difference affects flipper function. We plan to investigate this further in a future study by using, for example, computational fluid dynamics simulation.

#### *Anterior white patch on the flipper (measurement #3)*

The correlation coefficient ( $r$ ) was larger for

flipper length ( $r = 0.636$ ) than for body length ( $r = 0.628$ ), indicating that the values of *measurement #3* and therefore growth related changes are affected more by flipper length than by body length (Table 5). We therefore used flipper length as a criterion to assess growth related changes and sex-based differences in *measurement #3*. The allometric equation for each sex is shown below :

$$\text{Males } (n=147) : \quad y = 0.47x^{0.93}$$

Table 4. White patch boundary contour type in North Pacific and North Atlantic common minke whales. In the North Pacific common minke whales, the predominant type was type 1 (two curves), followed by type 2 (one curve) and type 3 (concave boundary contour). None of the common minke whales were classified as type 4 (straight borderline). Conversely, all North Atlantic common minke whales were classified as type 4 (straight borderline), but not types 1–3.

|       | North Pacific         |               |               |               |               |               |               |               |               |              |               | Total         | North Atlantic |                |
|-------|-----------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|--------------|---------------|---------------|----------------|----------------|
|       | Body length class (m) |               |               |               |               |               |               |               |               |              | Sex           |               |                |                |
|       | 3.5–3.9               | 4.0–4.4       | 4.5–4.9       | 5.0–5.4       | 5.5–5.9       | 6.0–6.4       | 6.5–6.9       | 7.0–7.4       | 7.5–7.9       | 8.0–9.0      | Male          |               |                | Female         |
| Type1 | 2<br>(66.7%)          | 10<br>(71.4%) | 22<br>(68.8%) | 26<br>(68.4%) | 15<br>(75.0%) | 16<br>(61.5%) | 21<br>(80.8%) | 24<br>(70.6%) | 13<br>(50.0%) | 6<br>(66.7%) | 99<br>(68.8%) | 56<br>(66.7%) | 155<br>(68.0%) | 0<br>(0.0%)    |
| Type2 | 1<br>(33.3%)          | 3<br>(21.4%)  | 8<br>(25.0%)  | 8<br>(21.1%)  | 3<br>(15.0%)  | 7<br>(26.9%)  | 2<br>(7.7%)   | 8<br>(23.5%)  | 10<br>(38.5%) | 1<br>(11.1%) | 33<br>(22.9%) | 18<br>(21.4%) | 51<br>(22.4%)  | 0<br>(0.0%)    |
| Type3 | 0<br>(0.0%)           | 1<br>(7.1%)   | 2<br>(6.3%)   | 4<br>(10.5%)  | 2<br>(10.0%)  | 3<br>(11.5%)  | 3<br>(11.5%)  | 2<br>(5.9%)   | 3<br>(11.5%)  | 2<br>(22.2%) | 12<br>(8.3%)  | 10<br>(11.9%) | 22<br>(9.6%)   | 0<br>(0.0%)    |
| Type4 | 0<br>(0.0%)           | 0<br>(0.0%)   | 0<br>(0.0%)   | 0<br>(0.0%)   | 0<br>(0.0%)   | 0<br>(0.0%)   | 0<br>(0.0%)   | 0<br>(0.0%)   | 0<br>(0.0%)   | 0<br>(0.0%)  | 0<br>(0.0%)   | 0<br>(0.0%)   | 0<br>(0.0%)    | 15<br>(100.0%) |
| Total | 3                     | 14            | 32            | 38            | 20            | 26            | 26            | 34            | 26            | 9            | 144           | 84            | 228            | 15             |

$$\text{Females } (n=84) : \quad y=0.43x^{0.93}$$

Here,  $x$  and  $y$  define flipper length (cm) and *measurement #3* (cm), respectively. The initial growth constants were significantly different between sexes, demonstrating that the values of the length of the white patch along the anterior margin relative to the flipper differ by sex ( $t$ -test,  $p < 0.01$ ). Moreover, the allometric coefficient (0.93) was close to 1 in both sexes, indicating that the proportion of the length of *measurement #3* to flipper length does not change during development ( $t$ -test,  $p = 0.89$ ). In fact, the mean proportion in males (33.8%, c.v. = 0.15) was about 2% larger than that in females (31.8%, c.v. = 0.20), indicating that the relative length of the white patch along the anterior margin in male specimens was higher than the corresponding length in females (Mann-Whitney's  $U$ -test,  $p < 0.01$ ). However, due to large individual variability of the minimum-maximum values in males (16.2–55.7%) and females (15.6–51.5%), the difference in the length of white patches was not clear enough to discriminate between sexes (Fig. 5-a, Table 3).

*The length of flipper from the tip to the white patch along the anterior margin (measurement #4)*

The correlation coefficient ( $r$ ) was larger for the flipper ( $r = 0.834$ ) than for the body ( $r = 0.829$ ), suggesting that *measurement #4* was

affected more by the flipper length (Table 4). Therefore, the length of the flipper was used as the denominator in *measurement #4* to investigate sex-related changes during development. The allometric equation is shown below :

$$\begin{aligned} \text{Males } (n=151) : & \quad y=0.09x^{1.26} \\ \text{Females } (n=86) : & \quad y=0.12x^{1.19} \\ \text{Both sexes } (n=237) : & \quad y=0.11x^{1.22} \end{aligned}$$

where  $x$  and  $y$  define the flipper length (cm) and the value of *measurement #4* (cm), respectively.

No significant sex-based differences were observed in the allometric equations or in the initial growth constants ( $t$ -test,  $p = 0.49$ ). In addition, the allometric equation was larger than 1 in both sexes (1.22) ( $t$ -test,  $p < 0.01$ ), indicating that the length relative to the flipper of *measurement #4* increases as growth. The 95% prediction interval of the relative values relative to the flipper increased from 19.8–36.4% for a 60 cm flipper to 23.9–43.7% for a 140 cm flipper (Fig. 5-b).

*Angle of the mean black/white borderline to the axis of the flipper (Angle  $\theta$ ) (measurement #5)*

To investigate growth related changes in the angle between the black/white borderline connecting the anterior and posterior margins of the flipper and the axis of the flipper

connecting the tip of the flipper and the head of the humerus (*measurement #5*), 240 North Pacific specimens (151 males; 89 females) were divided into different groups based on body length described above. The minimum, maximum, and mean flipper length and the flipper length relative to body length in individual groups are shown in Table 2.

No difference were observed between body length class both in males and females (*Kruskal-Wallis* test,  $p=0.971$ ). The mean angle of the *Angle*  $\theta$  was  $87.2^\circ$  (c.v.=0.10,  $n=151$ ) and  $89.9^\circ$  (c.v.=0.10,  $n=89$ ) in males and female, respectively (Fig. 5-c). In female the angle was about  $2.7^\circ$  greater than males (*ANOVA* test,  $p<0.05$ ).

#### *Boundary contour of the white patch*

Growth related changes and sex-based difference in the boundary contour of the white patch were investigated after dividing the contours into the four types defined earlier and dividing specimens into groups based on body length (Table 4). Type 1, with two curves was the predominant type in the North Pacific specimens (99 males; 56 females), accounting for 68.0%, followed by 22.4% (33 males; 18 females) for type 2 with one curve and 9.6% (12 males; 10 females) for type 3 with no curves. None of the North Pacific specimens were type 4, with a straight boundary contour. The chi-squared test revealed no sex-based difference ( $\chi^2$ -test,  $p=0.67$ ).

Comparisons by body length showed that type 1 was predominant type during development, followed by types 2 and 3. The Pearson's chi-squared test did not reveal any difference in compositions between the different developmental stages (Pearson's  $\chi^2$ -test,  $p=0.83$ ).

#### *Relative area of white patch*

To investigate growth related changes and sex-based differences in the area of the white patch relative to the flipper area, we first analyzed whether the relative area was affected more by the length of the body or the flipper. The single regression analysis with the length of body or flipper as the explanatory variable and the relative area of white patch as the objective variable revealed that the correlation

coefficient was larger for the body ( $r = -0.254$ ) than for the flipper ( $r = -0.256$ ), indicating that the area of the white patch is affected more by the body length. Therefore, body length was used as the denominator to investigate the growth related changes by sex (Fig 5-d). The intercept on the regression line appeared to be larger for males than that for females, but not significantly so (*t*-test,  $p=0.08$ ) :

$$\begin{aligned} \text{Males } (n=115) : & \quad y = -2.58x + 55.5 \\ \text{Females } (n=72) : & \quad y = -2.59x + 52.6 \\ \text{Both sexes } (n=187) : & \quad y = -2.24x + 52.3 \end{aligned}$$

Here,  $x$  and  $y$  define the body length (m) and the relative area of the white patch (%), respectively.

The significantly smaller coefficient ( $-2.24$ ) indicates that the relative area of the white patch decreases during development (*t*-test,  $p<0.01$ ). In addition, the 95% confident interval of the relative values to the flipper length decreased from 23.3–63.9% for a 60 cm flipper to 12.8–53.6% for a 140 cm flipper (Fig. 5-d).

Among whales, the white flipper patch is unique to common minke whales, and is thought to play a role in feeding or in recognition of species or sex. We previously investigated the potential contribution of the white patch to the species or sex recognition. Whales are excellent swimmers and migrate long distances across the open ocean. Although the breeding waters of common minke whales have not been fully elucidated, their white patches, which are very visible in the water, may serve as a visual indicator for locating a breeding partner. This study showed that the mean lengths of the white patch differ between sexes. However, the minimum and maximum lengths of the white patch ranged from 22.1–46.5% in males and 16.6–53.3% in females, and because of the large individual variability seen in each sex, sexual dimorphism was not supported by this study. In our analysis, we also combine all specimens collected off the North Pacific coasts of Japan, without investigating intra-oceanic variation. Moreover, the number of large ( $>7$  m) female specimens in this study was

Table 5. Relative values of *measurement #3-5* and actual angles of *measurement #5* of the North Atlantic common minke whales

|                                  | Min-Max   | Average | c.v. | <i>n</i> |
|----------------------------------|-----------|---------|------|----------|
| <i>measurement #3</i> (%)        | 32.7–53.9 | 40.7    | 0.15 | 13       |
| <i>measurement #4</i> (%)        | 16.6–35.6 | 29.7    | 0.19 | 13       |
| <i>measurement #5</i> (°)        | 45.6–70.6 | 60.0    | 0.13 | 13       |
| Relative area of white patch (%) | 43.4–62.2 | 55.5    | 0.09 | 13       |

relatively small. Therefore, to clarify the actual situation, further studies are needed that include a higher number of female common minke whales and that perform interoceanic comparisons using genetic techniques.

With regard to the role of the white patch in feeding, North Pacific minke whales are known to prefer schooling fish to planktonic crustaceans such as copepods and krill (MURASE *et al.*, 2007). North Atlantic minke whales and dwarf minke whales are also known to prey on a large number of fishes (KATO and FUJISE, 2000; Pierce *et al.*, 2004). In addition, Antarctic minke whales (*B. bonaerensis*), a close relative of minke whales that mainly feed on Antarctic krill, do not have a white patch on the flipper. A previous study investigating schooling behavior in fish has shown that their schooling behavior can be controlled by a short light-dark cycle presented as a stimulus (ARIMOTO, 1991). Because the dorsal region of common minke whales is dark gray or black, when they spread their flippers, the white patch is clearly visible from the rear. Because of the high visibility of the white color in water and the high contrast between the white patch and the darker body color, minke whales may be able to use their patch to surprise fish when feeding and induce clumping behavior. Comparative observational studies of feeding behaviors between common minke whales and Antarctic minke whales and the investigation of response behavior of krill and schooling fish toward an artificial whale flipper with a white patch may provide insight into the patch's significance.

## 2. Comparison between two subspecies.

The above data were used to perform the comparison of common minke whale in two subspecies. Since the values of each measurement showed a significant growth related changes or sex-based difference in the North Pacific minke whales, it would have been appropriate to perform similar measurements considering growth or sex for the North Atlantic minke whales. However, because the information of their body length and sex were not available alongside their photographs, mean values of all specimens were combined and used for comparison. Also the flipper length (the length from the tip of flipper to the end of humer) is not available in the North Atlantic minke whales, this value was estimated from the ratio of flipper width and length in the North Pacific minke whales. In the North Pacific minke whales, the relationship between width and length of the flipper is explained by following equation;

$$y = 4.48x^{0.99} \quad (n = 224)$$

where *x* defines the flipper width (cm) and *y* defines the flipper length. No difference by sex was observed in the initial growth constants or allometric coefficients (*t*-test, *p*>0.05). Furthermore, the allometric coefficient (0.99) was close to 1 (*t*-test, *p*>0.05), indicating that the flipper width was constant throughout development in both sexes. When both sexes were combined in analysis, the ratio of the length to the width was 4.41 (c.v.=0.04). So, in the North Atlantic specimens the length of flipper was determined by multiplying flipper width

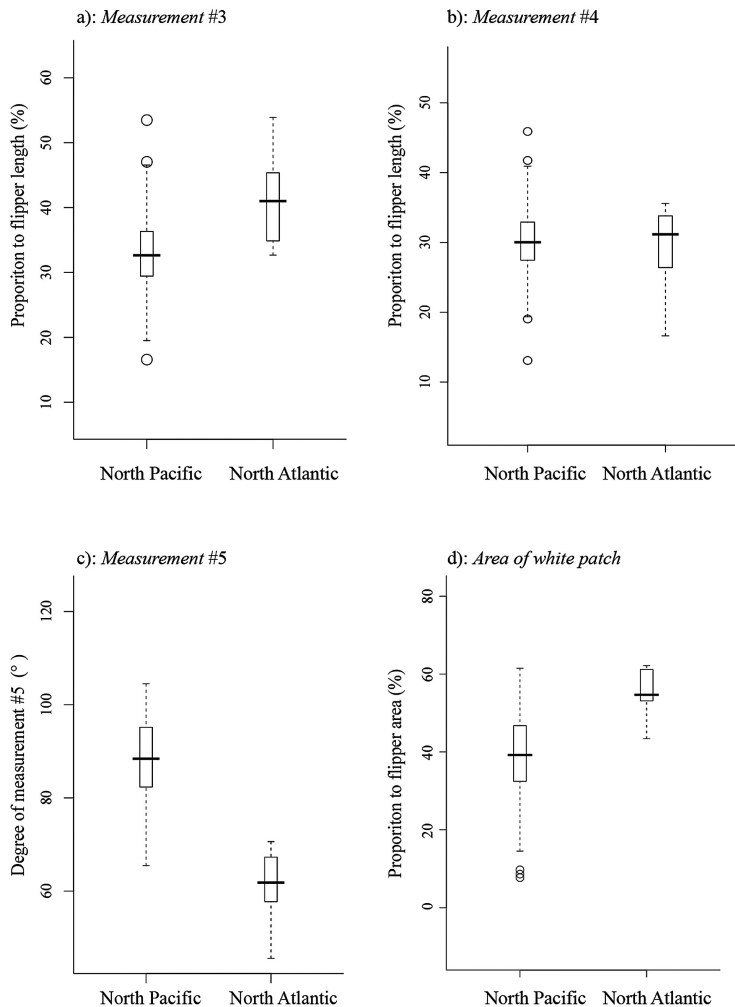


Fig. 6. Interoceanic differences of each measurement points on the flipper. *Measurement #3* (a), *measurement #4* (b), *measurement #5* (c) and white patch area (d). Boxplots are shown with whiskers extending from minimum (bottom) to maximum (top) values, with a horizontal line as the median value and outliers as circles.

by the ratio of length to width (4.41).

#### *Anterior white patch on the flipper (measurement #3)*

The relative length of the white patch along the anterior margin of the flipper was 40.7% (c.v.=0.15) in the North Atlantic specimens, which was significantly larger than 33.0% (c.v.=0.17) in the North Pacific specimens (Mann-Whitney's  $U$ -test,  $p < 0.01$ ) (Fig. 6-a, Table 5).

#### *The length of flipper from the tip to the white patch along the anterior margin (measurement #4)*

The relative length of the flipper from the tip to the white patch along the anterior margin was 29.7% (c.v.=0.19) and 30.1% (c.v.=0.15) in the North Atlantic and North Pacific specimens, respectively, with no significant difference (Mann-Whitney's  $U$ -test,  $p > 0.01$ ) (Fig. 6-b and 7, Table 5).

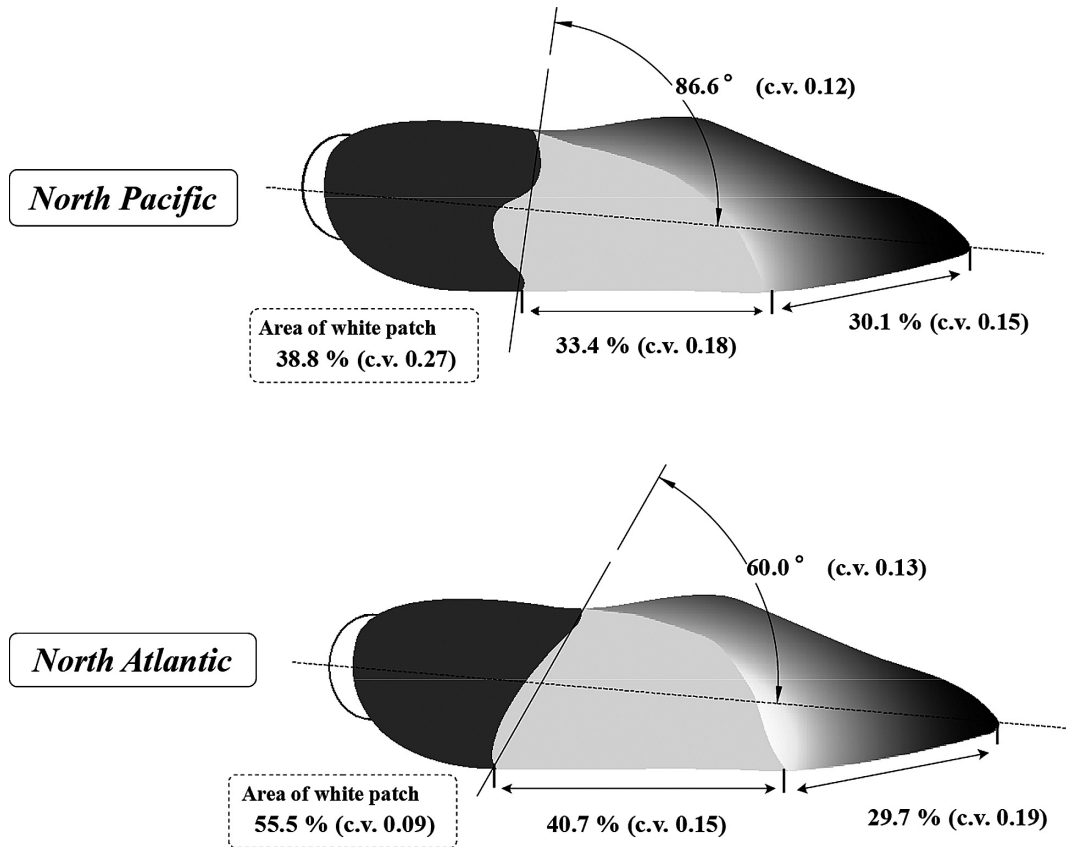


Fig. 7. Relative length of different parts of the flipper, the angle of the mean black/white borderline to the axis of the flipper, and the relative area of the white patch in the North Pacific (top) and North Atlantic (bottom) common minke whales

*Measurement # 5: Angle of the mean black/white borderline to the axis of the flipper (Angle  $\theta$ )*

The mean angle was  $60.0^\circ$  (c.v.=0.13) in the North Atlantic specimens and  $86.6^\circ$  (c.v.=0.12) in the North Pacific specimens. This difference in angle by  $26.6^\circ$  indicates that the angle of the mean black/white borderline in the North Atlantic was much more acute in *measurement #5* (Mann-Whitney's  $U$ -test,  $p < 0.01$ ) (Fig 6-c and 7, Table 5).

*Relative area of white patch*

The mean area of the white patch was 55.5% (c.v.=0.09) in the North Atlantic specimens, which was significantly larger than 38.8% (c.v.=0.27) in the North Pacific specimens

(Mann-Whitney's  $U$ -test,  $p < 0.01$ ) (Fig. 6-d and 7).

*Boundary contour of the white patch*

To reveal the difference between whales in the two oceans, the above finding was compared with the boundary contour of the white patch in the North Atlantic specimens. In these specimens, the boundary contour was type 4 with a straight boundary contour, suggesting a clear difference between the two habitats ( $\chi^2$ -test,  $p < 0.01$ ) (Fig. 7). The characteristic features of the boundary contours in North Pacific and North Atlantic whales are summarized in Table 6.

Except for *measurement #4*, which measured

Table 6. Summary of the results and interoceanic comparison

| Measurement items  | North Pacific |   | North Atlantic |
|--|---------------|---|----------------|
| Anterior white patch on the flipper (measurement #3)   | 33.4%         | < | 40.7%          |
| The length of flipper from the tip to the white patch along the anterior margin (measurement #4)       | 30.1%         | ≈ | 29.7%          |
| Relative area of white patch   | 38.8%         | < | 55.5%          |
| Angle of the mean black/white borderline to the axis of the flipper (Angle $\theta$ ) (measurement #5) | 86.6°         | > | 60.0°          |
| Boundary contour of the white patch  | Types 1, 2, 3 |   | Type 4         |

the relative length of the flipper from the tip to the white patch, all other measurements were clearly different between subspecies. Compared with the North Pacific specimens, the white patch in the North Atlantic specimens was large and well developed at the flipper base. Furthermore, the boundary contours clearly differ between the two subspecies, and no growth related changes were observed in the North Pacific specimens. These findings suggest that the white patch on flipper is an effective anatomical part to use when comparing subspecies, even when those subspecies are geographically distinct.

Because the white patch is a feature unique to common minke whales and unseen in other whale species, it has been useful as a trait for classification. However, it has never been investigated in detail, and this is therefore the first study to quantitatively evaluate the morphology of the white flipper patch. The results revealed growth- and sex-related differences even within the North Pacific species as well as larger-than-expected differences between the North Pacific and North Atlantic subspecies, suggesting that the white flipper patch may serve as a useful feature in common minke whale identification. In particular, the boundary contour of the white patch did not change during development, and the North Pacific and North Atlantic specimens did not share boundary contour features, further supporting the usefulness of the white patch for classification. Although the length of the flipper from the tip to the white patch did not

differ between the two subspecies, the clear differences in boundary contour, angle  $\theta$ , and the length of the white patch between the two subspecies demonstrate that the morphology of the flipper near its base clearly indicates the subspecies of common minke whale. This study showed that North Atlantic minke whale has larger white patch area than North Pacific minke whales. The white patch area of Dwarf minke whales is much larger than that of North Pacific and North Atlantic minke whales, it covers shoulder/flipper region (BEST, 1985; KATO and FUJISE, 2000; ARNOLD *et al.*, 2005). Dwarf minke whales are genetically closer to the North Atlantic minke whales more than North Pacific minke whales (PASTENE *et al.*, 2007). The result that North Atlantic minke whales have large white patch area, might also suggesting that Dwarf minke is evolutionally closer to North Atlantic minke whales. In cetacean, Dall's porpoise *Phocoenoides dalli* shows external difference greater than genetics (HAYANO *et al.*, 2003), therefore external character might changes much faster than genetics. Although genetic variation in North Atlantic minke whales has been reported (PASTENE *et al.*, 2007), differences in the boundary contours of the white patch as shown in this study may serve as a tool equivalent or even superior to genetic testing to elucidate the speciation of common minke whales. It is necessary to further clarify the differences between common minke whale subspecies in different oceans through careful investigation and data collection during commercial whaling of North Atlantic minke

whales. Furthermore, crosschecking of the morphological findings and genetic findings regarding the white patch in the North Pacific stock will greatly contribute to the elucidation of the speciation process in the common minke whale clades and their population structure, which can be used for bio resource management.

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# Influence of river discharge on seasonal and interannual variability of remotely sensed chlorophyll-*a* concentration in Toyama Bay, the Sea of Japan

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**Abstract :** It is often reported that increase of phytoplankton biomass in Toyama Bay coastal area in summer is a cause of water quality degradation as measured by Chemical Oxygen Demand. Satellite chlorophyll-*a* concentration (Chl-*a*) and river discharge from 1998 to 2009 were compared to study the influence of land-based sources of nutrients on seasonal and interannual variability of Chl-*a* in Toyama Bay. Toyama Bay was divided into three sub-areas (A, B and C, from innermost to outermost) by taking level, trend and peak timing of satellite Chl-*a* into consideration. In sub-area A, satellite Chl-*a* increased towards summer and its increasing interannual trend was detected. From the comparison of variability in satellite Chl-*a* with river discharge and nutrient data in Toyama Bay, it was suggested that a high concentration of total nitrogen from the Jinzu River was a compelling cause of potential eutrophication in sub-area A. In both sub-areas B and C, a positive correlation was found between satellite Chl-*a* and river discharge from May to July ( $p < 0.01$ ,  $r = 0.47$  in sub-area B;  $p < 0.01$ ,  $r = 0.47$  in sub-area C) and August to October ( $p < 0.01$ ,  $r = 0.51$  in sub-area B;  $p < 0.01$ ,  $r = 0.47$  in sub-area C). It was considered that there were excessive nutrients not used by phytoplankton in sub-area A, and they were delivered to sub-areas B and C from May to October then contributed to increase in phytoplankton biomass. The influence of river discharge on satellite Chl-*a* was obvious in the sub-area A throughout the year, but it also occasionally extends to sub-areas B and C from May to October. Monitoring the peak pattern and level of seasonal variability in Chl-*a* was suggested for assessment and management of water quality, because a single and long summer peak pattern is correlated with symptoms of eutrophication.

**Keywords :** *phytoplankton; river discharge; ocean color radiometry; chlorophyll-a; coastal environment*

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## 1. Introduction

Rivers that supply nutrients and sediments to coastal waters are essential to maintaining high productivity and biodiversity in coastal ecosystems. While rivers provide nutrients that are essential for primary production of phytoplankton, excessive nutrients cause eutrophication and often result in degradation of water quality, occurrence of red tides, hypoxia and anoxia, and benthic mortality (RABALIS *et al.*, 1996). As coastal waters tend to be influenced by anthropogenic sources, it is necessary to understand seasonal changes in phytoplankton biomass in order to conserve the coastal

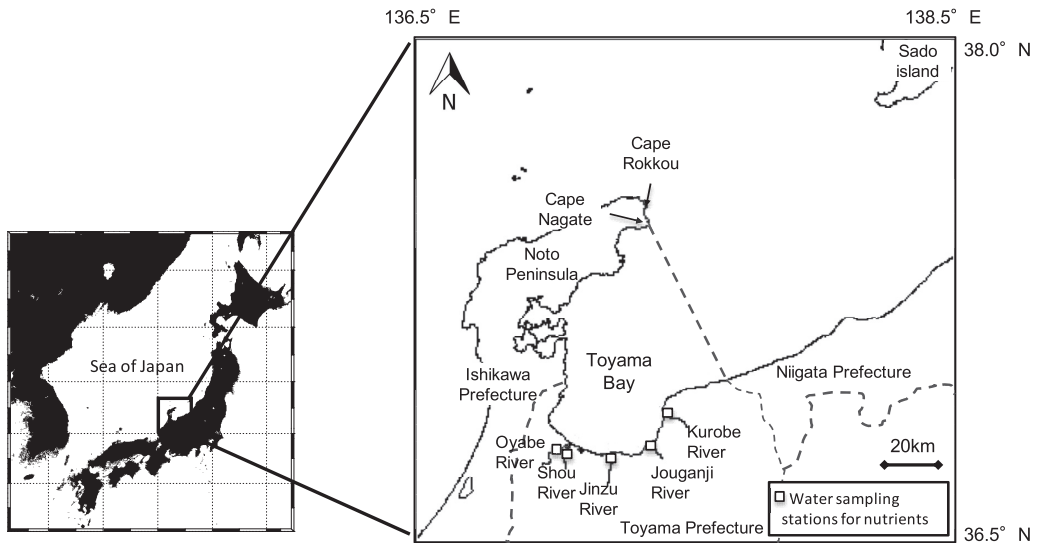


Fig. 1. Location of Toyama Bay.

environment.

The environment of Toyama Bay (Fig. 1), a semi-enclosed bay in the Sea of Japan, is strongly influenced by nutrients provided from fresh water discharged from surrounding rivers (NAGATA *et al.*, 1988; NAGATA and NAKURA 1993; TSUJIMOTO 2009). The TOYAMA BAY WATER QUALITY CONSERVATION RESEARCH COMMITTEE (2001) reported that riverine input of nutrients contribute to an increase of phytoplankton biomass in the summer in Toyama Bay, and results in degradation of water quality measured by Chemical Oxygen Demand (COD) in coastal area.

River discharge influence on the variability of chlorophyll-*a* concentration (Chl-*a*, a proxy for phytoplankton biomass) in Toyama Bay was first reported by NAGATA and NAKURA (1993). They observed a remarkable increase of Chl-*a* after spring in the region that is most affected by river discharge. OHNISHI *et al.* (2007) observed high satellite Chl-*a* in summer at the Jinzu River estuary and detected a correlation between high satellite Chl-*a* and lower sea-surface salinity, whereas spring and fall peaks of satellite Chl-*a* were associated with thermal stratification in the Sea of Japan as reported by YAMADA *et al.* (2004). TERAUCHI *et al.*

(2014) illustrated potential eutrophic zones in the Toyama Bay coastal area by combining 12 years satellite Chl-*a* level and trend data and suggested that a long term increasing trend in total nitrogen input from the Jinzu River from 1986 to 2008 is the greatest contributor to high and increasing Chl-*a* in the detected potential eutrophic zone. The detected potential eutrophic zone by TERAUCHI *et al.* (2014) includes the Jinzu River mouth, where TSUJIMOTO (2012) reported that nutrients were not limiting phytoplankton growth from analysis of monthly observation data of dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP) and dissolved silica (DSi) from April 2006 to February 2008. Tsujimoto (2012) also reported that nutrient limitation was altered from nitrogen limitation in 2006 to phosphorus limitation in 2007 at a water sampling station located outside of the potential eutrophic zone detected by TERAUCHI *et al.* (2014). Nevertheless, there is no study illustrating the effect of land-based sources of nutrients from rivers on the variability of Chl-*a* in Toyama Bay utilizing long term spatial and temporal scales of data.

Wider spatial coverage and higher temporal frequency in monitoring of sea surface Chl-*a*

by ocean color satellite have been utilized in many studies. ACKER *et al.* (2005) observed significantly higher satellite Chl-*a* in 2003 than in 2002 at the Chesapeake Bay mouth that was consistent with strong forcing by freshwater flow and nutrient loading in the nutrient-limited region. WALKER and RABALAIS (2006) found positive correlations between satellite Chl-*a* and river discharge at the west of the Mississippi Delta with 0 to 1 month time lags. YAMAGUCHI *et al.* (2012) detected high satellite Chl-*a* in summer in the Yellow and East China Seas associated with movement of Changjiang diluted water with a 0–2 month time lag. TERAUCHI and ISHIZAKA (2007) detected radical changes in satellite Chl-*a* in several days in Toyama Bay coastal area that monthly based shipboard measurements were not able to detect.

Objective of this paper is to analyze the influence of river discharge on seasonal and interannual variability of Chl-*a* in Toyama Bay using long-term ocean-color satellite data. Causes of potential eutrophication in the Toyama Bay coastal area will then be discussed.

## 2. Data and methods

### 2.1 Location of study area

Toyama Bay is located to the east of Noto Peninsula, at the center of the eastern part of the Sea of Japan (Fig. 1). Toyama Bay's surface area is approximately 2,120 km<sup>2</sup>, with a maximum depth of 1,250 m and volume of approximately 1,280 km<sup>3</sup> following the boundary definition by IMAMURA *et al.* (1985) - east of an imaginary line running between Cape Nagate in Ishikawa Prefecture and the border of Toyama-Niigata Prefectures. Toyama Bay consists of three layers of water masses; Japan Sea Proper Water flows in areas deeper than 300 m, Tsushima Warm Current in areas of depth less than 300 m and coastal waters mixed with fresh waters provided from five Class-A rivers (the Oyabe, Shou, Jinzu, Joganji and Kurobe River) and 29 Class-B rivers that flow into the bay (UCHIYAMA, 2005). Annual average runoff from the five Class-A rivers are 60.37, 33.05, 172.77, 19.31, and 86.48 m<sup>3</sup> s<sup>-1</sup> in Oyabe, Shou, Jinzu, Joganji, and Kurobe Rivers, respectively

(JAPAN RIVER ASSOCIATION, 2004), and contribute significantly to nutrient loads in Toyama Bay (TSUJIMOTO, 2009).

### 2.2 Satellite Chl-*a* data

Satellite Chl-*a* data of two ocean color sensors were obtained for this study: 2,700 images of the Sea-viewing Wide Field-of-view Sensor on board the Orbview-2 satellite (SeaWiFS) and 3,766 images of the Moderate Resolution Imaging Spectroradiometer on board the Aqua satellite (MODIS-A). Data were obtained for the area defined by 36.5 to 38.0° N and 136.5 to 138.5° E from 1998 to 2009. Daily composite data were computed after a quality screening process conducted by TERAUCHI *et al.* (2014). TERAUCHI *et al.* (2014) evaluated a set of variables called level 2 flags that report various potential errors at each pixel in comparison with *in situ* and satellite Chl-*a*, and showed more than 300% overestimation of *in situ* Chl-*a* was observed in 7 of 42 match ups flagged with both COASTZ and STRAYLIGHT flags. SeaWiFS Chl-*a* data so flagged was then excluded when computing the daily composite of SeaWiFS Chl-*a*. The daily composite of MODIS-A Chl-*a* was computed without level 2 flag screening per good agreement between *in situ* and MODIS-A Chl-*a* data; 32 out of 34 match ups were within the range of 33–300%.

TERAUCHI *et al.* (2014) also demonstrated pixel-to-pixel consistency in daily composite data between the quality screened SeaWiFS and MODIS-A Chl-*a* data during the observation-overlapping period, July 2002 to December 2004. With the quality screening of SeaWiFS, a comparison of SeaWiFS and MODIS-A data showed high correlation with a slope close to one described by the following formula:

$$\text{Log (MODIS-A Chl-}a\text{)} = -0.900 + 0.932 \text{ log (SeaWiFS Chl-}a\text{)}, \text{ with } r^2 = 0.81, N = 137,173.$$

Taking into account the pixel to pixel consistency between the quality screened SeaWiFS and MODIS-A, daily composites of SeaWiFS and MODIS-A Chl-*a* data in the overlapping period (from July 2002 to December 2004) were composited by averaging. Monthly mean data were then computed by Windows Image

Manager software (<http://www.wimsoft.com/>) from the daily composite data; SeaWiFS daily composite from January 1998 to June 2002, SeaWiFS and MODIS-A averaged daily composite from July 2002 to December 2004 and MODIS-A daily composite data from January 2005 to December 2009.

### 2.3 Defining sub-areas in Toyama Bay according to satellite Chl-*a* peak timing

Since past studies showed an increase of Chl-*a* after spring to summer in Toyama Bay coastal area, possibly due to the influence of land based sources of nutrients from rivers (NAGATA and NAKURA 1993; OHNISHI *et al.* 2007), the Julian day of annual Chl-*a* maximum was calculated during the period 1998 to 2009 (Fig. 2(a)). The earliest day of annual Chl-*a* maximum was day 58 and latest was day 230. The bay was then divided into two sub-areas: that area where the peak appears before the end of Julian day 121 (end of April; a spring peak) and that area where the peak appears later (a summer peak) (Fig. 2(b)).

Additionally, the summer peak area was divided into two sub-areas; the potential eutrophic zone detected by TERAUCHI *et al.* (2014), and outside this zone (Fig. 2(c)). Finally, Toyama Bay was divided into three sub-areas (sub-areas A, B and C; Fig. 2(d)). The coastal area along Noto Peninsula and Nanao Bay in Ishikawa Prefecture were excluded due to lack of *in-situ* Chl-*a* for validation of satellite Chl-*a* data. That area of the bay outside defined by a line from Cape Nagate in Ishikawa Prefecture to the border between Toyama Prefecture and Niigata Prefecture was also excluded for statistical analysis. Sub-area A is the potential eutrophic zone detected by TERAUCHI *et al.* (2014) located at the innermost part of Toyama Bay, where the satellite Chl-*a* value is higher than  $5 \text{ mg m}^{-3}$  in average and an increasing trend was observed in some spots during the study period. Sub-area B is located in between sub-area A and C, but a possible influence from land-based sources of nutrients from rivers is suspected. Sub-area C is located at the outermost part of Toyama Bay and satellite Chl-*a* is expected to increase with nutrients provided from deeper waters due to mixing and

thermal stratification. Furthermore, satellite Chl-*a* data at  $5 \times 5$  pixels around an offshore point located between Cape Rokkou in Ishikawa Prefecture and Sado Island in Niigata Prefecture were extracted as a reference site with negligible impact from land based sources of nutrient from rivers

### 2.4 River discharge data

Daily river discharges of five Class-A rivers (Oyabe, Sho, Jinzu, Jouganji and Kurobe Rivers) from 1998 to 2009 were obtained from the Water Information System of the Ministry of Land, Infrastructure and Transport, Japan. The sum of monthly means from these five Class-A rivers was then calculated for comparison with satellite Chl-*a* variability. Since the river discharge data of the Kurobe River was not available from January 1 to March 3, 2003 and November 4 to May 4, 2004, river discharge data during these periods was excluded from analysis.

### 2.5 Nutrients data

Total nitrogen (TN) and total phosphate (TP) concentrations have been monitored on a monthly basis from April 1985 to March 2006 and quarterly (February/May/August/November) since May 2006 at major river inflow points of Toyama Bay. These TN and TP data in the five Class-A rivers from 1998 to 2009 were obtained from the database of the National Institute for Environmental Studies, Japan.

## 3. Results

### 3.1 Seasonal variability of satellite Chl-*a* and river discharge

To visualize the typical seasonal variation of satellite Chl-*a* in Toyama Bay, monthly means from 12 years of satellite data were computed (Fig. 3). The monthly means clearly illustrated high satellite Chl-*a* from spring to fall in innermost part, and spring and fall peaks of satellite Chl-*a* in outermost part of Toyama Bay.

Monthly means of satellite Chl-*a* in each sub-area as well as the reference site were then computed from 1998 to 2009. To ensure the reliability of monthly means data in each sub-area, data with less than 80% valid values in

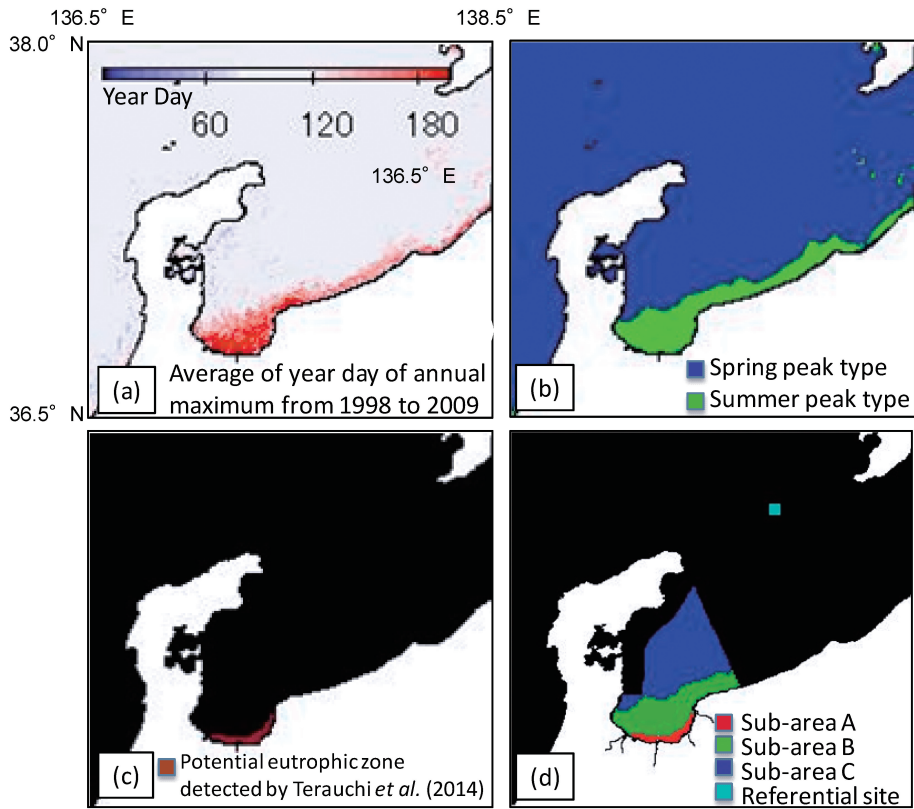


Fig. 2. Three sub-areas divided by the peak timing of satellite Chl-*a*.

(a) Average of year day of annual maximum from 1998 to 2009. (b) Spring peak and summer peak types in satellite Chl-*a*. (c) Potential eutrophication zone detected by Terauchi et al. (2014) using ocean color satellite data. (d) Sub-areas set by b and c, and location of referential site.

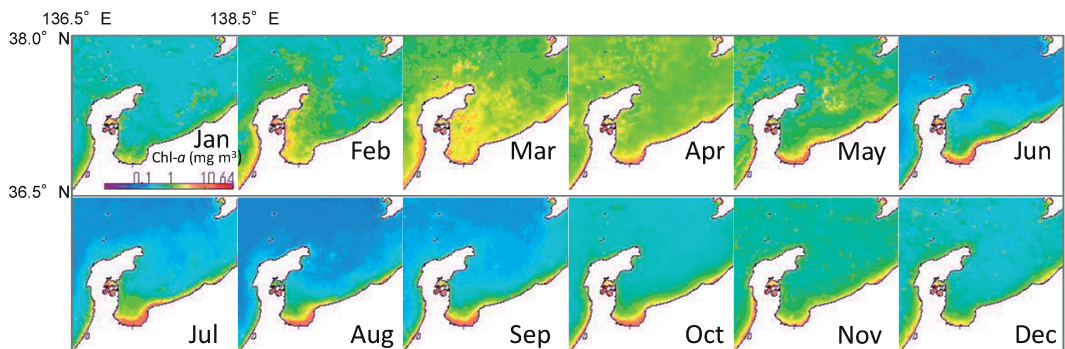


Fig. 3. Twelve years overall mean of monthly satellite Chl-*a* in Toyama Bay

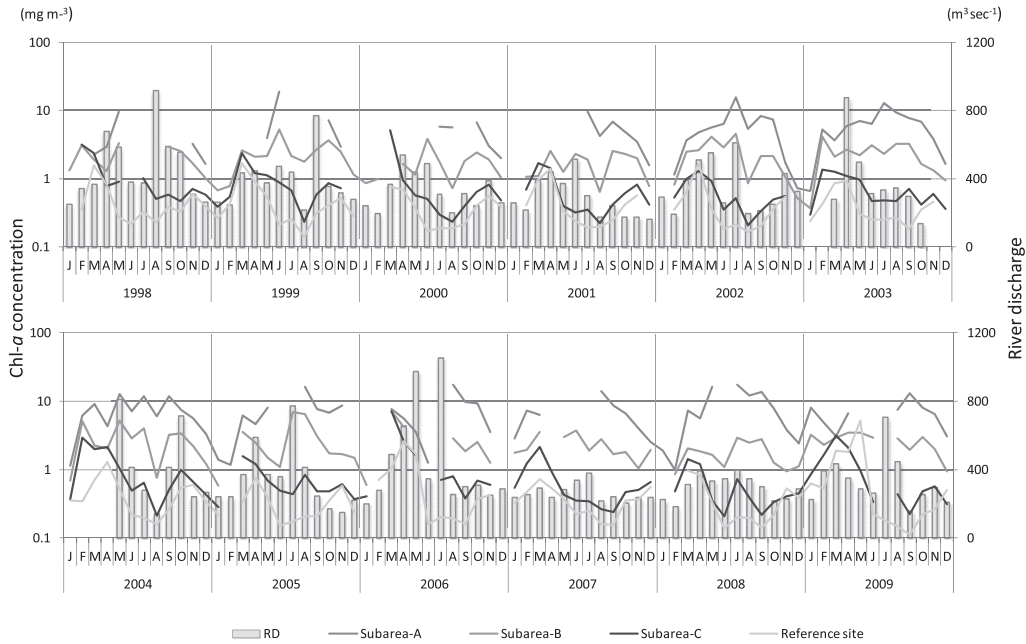


Fig. 4. Monthly means of satellite Chl-*a* in each sub-area and the reference site, and sum of monthly mean river discharge in the five Class-A rivers from 1998 to 2009.

each sub-area were excluded.

Satellite Chl-*a* in sub-area A were relatively higher than other sub-areas, and increased from spring to summer before decreasing in November (Fig. 4). A single and long summer peak pattern appeared in 2002, 2003 and 2008, but this pattern was not able to be detected due to lack of reliable data in other years such as 1998, 1999, 2000, 2001, 2005, 2006, 2007 and 2009. In contrast, satellite Chl-*a* in sub-area C was low in summer, there were spring and fall peaks almost every year, and its variation was similar to that of the reference site. In sub-area B, located in between sub-areas A and C, satellite Chl-*a* increased in spring, then did plateau in 2001, 2003, 2004, 2007 and 2009 or increased occasionally from May to October in 1999, 2000, 2002, 2005 and 2008 until it decreased every winter. As would be expected, river discharge was low in winter and increased towards spring every year. There were also increases of river discharge from summer to fall; however these increases appeared in different months each year.

To understand the extent of river discharge on Chl-*a* variation in Toyama Bay, monthly satellite Chl-*a* in each sub-area was compared with the sum of the five Class-A river monthly mean discharges from 1998 to 2009 (Fig. 5). Correlations between monthly satellite Chl-*a* and river discharge in sub-areas A, B and C were then derived. Correlated data were then sorted into four seasons (February to April, May to July, August to October and November to January) to see if there was any seasonal characteristic in the relationship between satellite Chl-*a* and river discharge (Fig. 5 (a) – (d)). There were positive significant correlations between satellite Chl-*a* and river discharge in sub-areas B and C in May to July and August to October (Table 1). Satellite Chl-*a* in sub-area A was often higher than  $10 \text{ mg m}^{-3}$  from May to October, but did plateau at river discharge amounts greater than  $500 \text{ m}^3 \text{ sec}^{-1}$ . Although there were no significant correlations between satellite Chl-*a* and river discharge in sub-area A in all seasons, a positive correlation ( $p < 0.05$ ) was found from August to October



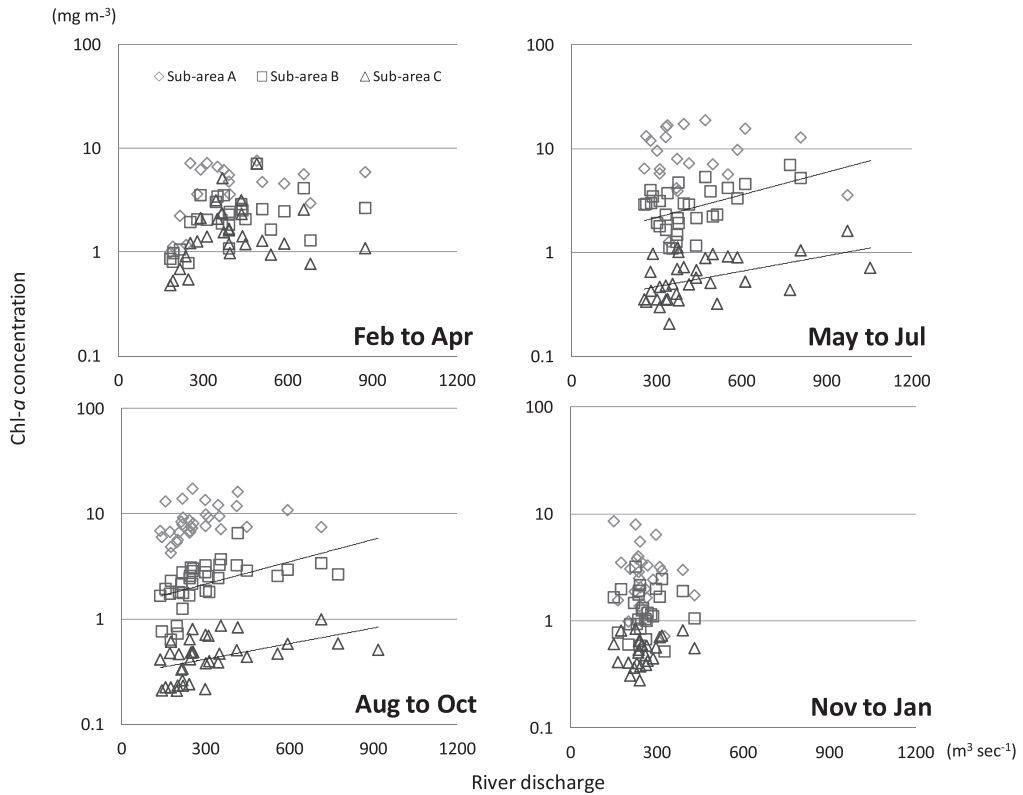


Fig. 5. Comparison of monthly means of satellite Chl-*a* and sum of monthly mean river discharge in the five Class-A rivers from 1998 to 2009. Matched data were sorted into four seasons (February to April, May to July; August to October, and November to January).

Table 1. Correlations between satellite Chl-*a* and river discharge in all sub-areas. Liner regression model was applied to logarithmically transformed satellite Chl-*a* value and river discharge to see significant relationship between them. Italic letters at column of sub-area A from August to October are *p* and *r* values when excluding two plots that have more than 500 m<sup>3</sup> sec<sup>-1</sup> in sum of monthly river discharge.

| Sub-area | Feb to Apr |      | May to Jul       |      | Aug to Oct       |             | Nov to Jan |      |
|----------|------------|------|------------------|------|------------------|-------------|------------|------|
|          | p value    | r    | p value          | r    | p value          | r           | p value    | r    |
| A        | 0.06       | 0.42 | 0.78             | 0.06 | 0.09             | 0.30        | 0.31       | 0.21 |
|          |            |      |                  |      | <i>&lt; 0.05</i> | <i>0.45</i> |            |      |
| B        | 0.17       | 0.45 | <i>&lt; 0.01</i> | 0.47 | <i>&lt; 0.01</i> | 0.51        | 0.83       | 0.04 |
| C        | 0.27       | 0.21 | <i>&lt; 0.01</i> | 0.47 | <i>&lt; 0.01</i> | 0.47        | 0.20       | 0.27 |

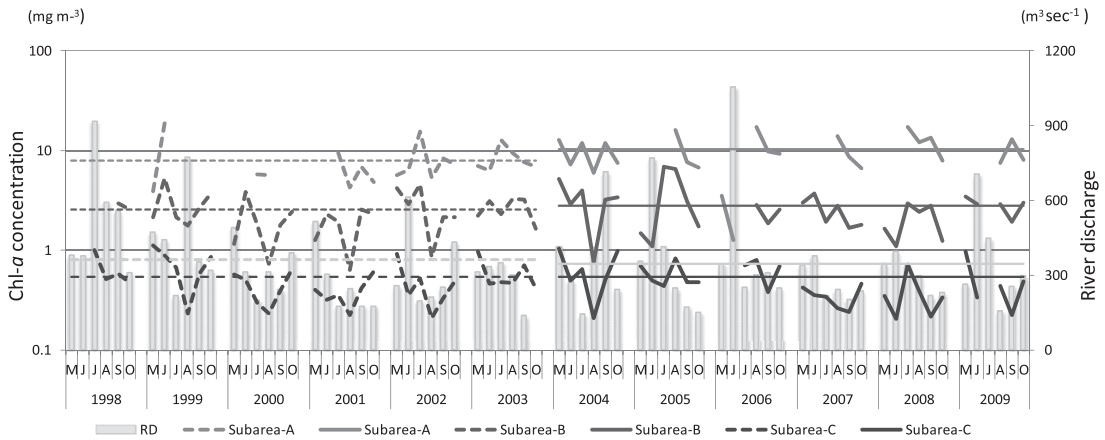


Fig. 6. Interannual variability of satellite Chl-*a* in each sub-area and sum of monthly mean in river discharge at the five Class-A rivers in May to October from 1998 to 2009. Dashed and solid lines indicate data in earlier years (1998 to 2003) and later years (2004 to 2009), respectively. Horizontal lines indicate mean values in each sub-area in earlier and later years.

when excluding two plots that have more than  $500 \text{ m}^3 \text{ sec}^{-1}$  amount of river discharge.

### 3.2 Interannual variability of satellite Chl-*a* and river discharge from 1998 to 2009

Since positive significant correlation between satellite Chl-*a* and river discharge was found in sub-areas B and C in two seasons (May to July and August to October), their interannual variability from 1998 to 2009 in each season were investigated (Fig. 6). In May to July, no significant trend was detected in satellite Chl-*a* in all sub-areas and river discharge amounts from 1998 to 2009. On the other hand, an increasing trend (Spearman's rank correlation,  $r_s = 0.44$ ,  $p < 0.05$ ) in satellite Chl-*a* was detected in sub-area A in August to October, whereas no significant trend was detected in satellite Chl-*a* in other sub-areas and river discharge amounts.

Since high Chl-*a* values more than  $10 \text{ mg m}^{-3}$  appeared more frequently in sub-area A in later years (2004 to 2009) than earlier years (1998 to 2003), averages of Chl-*a* in each sub-area and river discharge amount in earlier and later years were compared. Only in sub-area A, was the level of satellite Chl-*a* in the later years found to be higher ( $t$ -test,  $p < 0.05$ ) on average than that of the earlier years, while no

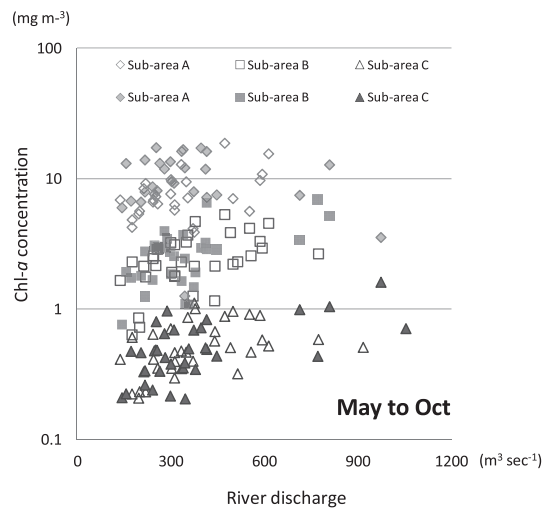


Fig. 7. Comparison of monthly means of satellite Chl-*a* and sum of monthly mean river discharge in the five Class-A rivers in May to October from 1998 to 2009. Open and filled plots indicate data in earlier years (1998 to 2003) and later years (2004 to 2009), respectively.

difference was detected in sub-areas B ( $p > 0.05$ ) and C ( $p > 0.05$ ). There were no difference in river discharge amounts between the earlier and the later years ( $p > 0.05$ ). To see if there was any bias in the relationship between

satellite Chl-*a* and river discharge amounts depending on earlier vs. later years, monthly means of satellite Chl-*a* in each sub-area from May to October in the earlier and later years were compared with the sum of monthly means of river discharge (Fig. 7). Satellite Chl-*a* in sub-area A was relatively higher in the later years than that of the earlier years for the same amount of river discharge in its range of 150–400 m<sup>3</sup> sec<sup>-1</sup>.

We therefore conclude that the detected increasing trend of satellite Chl-*a* in sub-area A is not related to an increase in river discharge.

### 3.3 Interannual change of nutrients in May and August

We also investigated the interannual change of TN and TP concentrations observed in May and August at the five Class-A rivers from 1998 to 2009 (Fig. 8(a) – (d)).

There was a decreasing trend in TN in the Oyabe River both in May (Spearman's rank correlation,  $r_s = -0.79$ ,  $p < 0.01$ ) and August ( $r_s = -0.77$ ,  $p < 0.01$ ) from 1998 to 2009. In contrast, TN concentration in the Jinzu River was higher than other rivers in August, and remained constant from 1998 to 2009.

There were decreasing trends in TP in the Oyabe River ( $r_s = -0.78$ ,  $p < 0.01$ ), Jinzu River ( $r_s = -0.74$ ,  $p < 0.01$ ) and Jouganji River ( $r_s = -0.70$ ,  $p < 0.01$ ) in August. No significant trend was detected for other TN and TP data in May and August.

## 4. Discussions

This study revealed seasonal and interannual variability of satellite Chl-*a* in three sub-areas (A, B and C) in Toyama Bay and evaluated the possible influence of river discharge and nutrients from 1998 to 2009. There were spring peak and fall peaks of satellite Chl-*a* in sub-area C every year, while satellite Chl-*a* in sub-area A peaked in summer. Significant positive correlations between satellite Chl-*a* and river discharge were found in sub-areas B and C from May to October, and also in sub-area A from August to October at river discharge amounts of less than 500 m<sup>3</sup> sec<sup>-1</sup>. An increasing trend of satellite Chl-*a* was detected in sub-area A in August to October from 1998 to 2009, but no

increasing trend was detected in river discharge and nutrients data.

It is known that there are spring and fall blooms of phytoplankton in the temperate zones (PARSONS *et al.*, 1984) and that they often begin with the development of thermal stratification of the water column (spring bloom) or decay of thermal stratification in the surface layer (fall bloom). On the other hand, SZE (1993) reported a single and long summer peak appears if eutrophication develops in oligotrophic lakes in the temperate zone, where spring and fall peaks of phytoplankton biomass is a typical seasonal pattern. It is also known that changes of these patterns in seasonal variation of phytoplankton biomass have been observed not only in fresh water but also in estuary barrages and enclosed bays (MURAKAMI, 1996; YAMADA and KAZIWARA, 2004).

A single and long summer peak pattern and interannual increasing trend of satellite Chl-*a* observed in sub-area A from 1998 to 2009 were considered as a sign of potential eutrophication. This result was consistent with TERAUCHI *et al.* (2014) that annual maximum in monthly mean Chl-*a* showed high and increasing trend in some spots of sub-area A. River discharge data from May to July and August to October did not show any trend. Nutrient concentration in May and August presented in this study did not show any increasing trend from 1998 to 2009. In fact, TN concentration in the Oyabe River showed a significant decreasing trend in May and August, as did TP concentrations in the Oyabe, Jinzu and Jouganji Rivers in August. On the other hand, in Jinzu River that account for 46% of the discharge from the five Class A River (JAPAN RIVER ASSOCIATION, 2004), TN concentration was significantly higher than other rivers and it remained constant from 1998 to 2009. TSUJIMOTO (2012) conducted monthly observation of nutrient and phytoplankton biomass at three water sampling stations near the Jinzu River mouth from April 2006 to February 2008 that corresponds to the later years of this study, and reported that both TN and TP concentration were always higher than the thresholds that limit phytoplankton growth at the

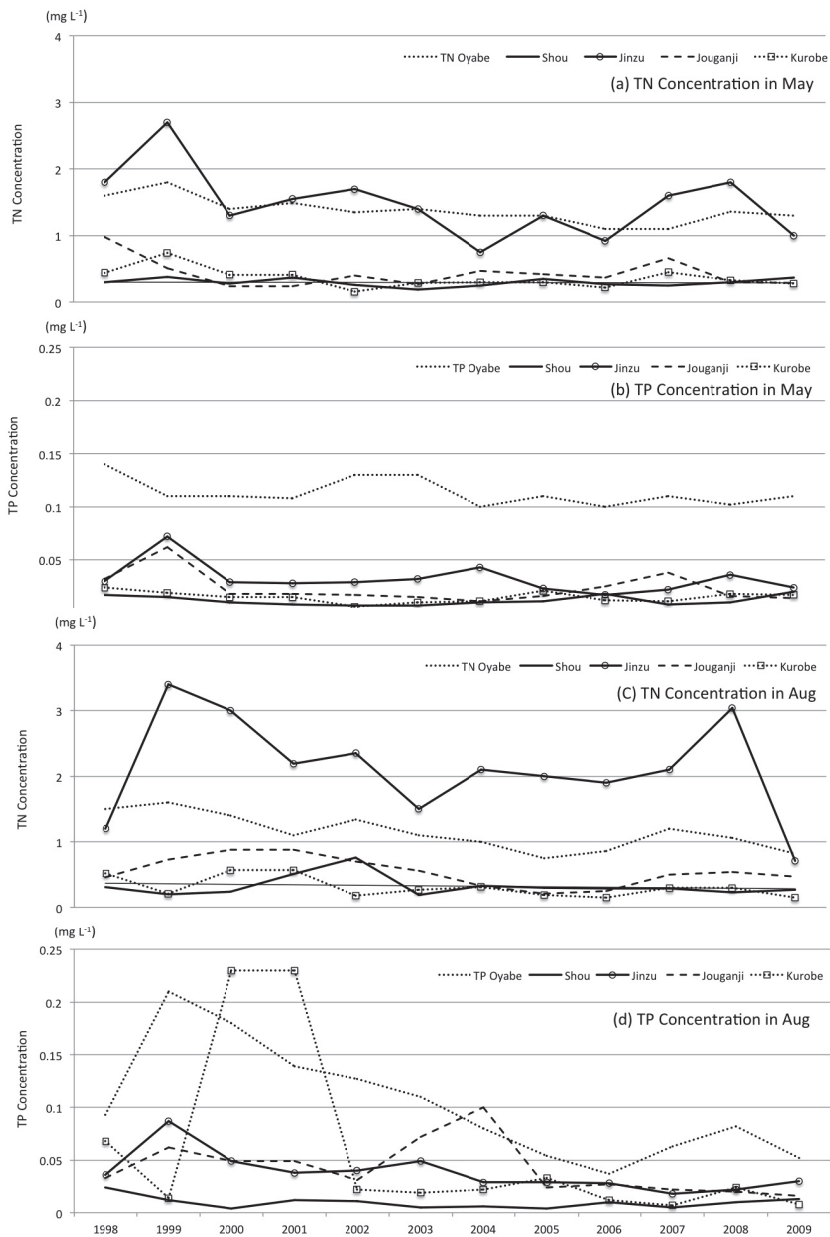


Fig. 8. Interannual change of TN and TP data observed in May and August at downstream points of the five Class-A rivers from 1998 to 2009. (a) TN concentration in May. (b) TP concentration in May. (c) TN concentration in August. (d) TP concentration in August.

water sampling station nearest the Jinzu River mouth (located in sub-area A of this study). Thus, the high concentration of TN in the Jinzu River was suspected as a compelling

cause of potential eutrophication in sub-area A. Although this hypothesis was not proved by the TN and TP data used in this study, it is possible that the May and August nutrient

data may have not been sufficient to manifest a link with satellite Chl-*a*.

Spring and fall peaks of satellite Chl-*a* observed in sub-area C indicated that sub-area C belongs to the typical temperate zone as reported by PARSONS *et al.* (1984), and phytoplankton growth is mainly controlled by nutrients provided from deeper layer by mixing. These peaks were also consistent with the spring and fall peaks of satellite Chl-*a* in the Sea of Japan observed by YAMADA *et al.* (2004). Nevertheless, it was suggested that river discharge does influence Chl-*a* variability in sub-areas B and C, because there was a significant positive correlation between satellite Chl-*a* and river discharge in these sub-areas from May to October. Satellite Chl-*a* in sub-area B increased towards summer after spring in some years, but the summer peak was shorter than sub-area A. NAGATA and NAKURA (1993) reported that there was a positive correlation between river discharge amount and the distribution of lower salinity water at the sea surface in Toyama Bay. As TSUJIMOTO (2012) reported that TN and TP concentration were higher than the thresholds that limit phytoplankton growth at the water sampling station in sub-area A, it was considered that excessive nutrients were occasionally delivered to sub-area B and C from May to October and contribute to increase in phytoplankton biomass. TSUJIMOTO (2012) also suggested that nutrients could possibly be transported to outer area before they were used through the process of phytoplankton photosynthesis in coastal area when radical increase in river discharge was recorded. TSUJIMOTO (2012) then indicated that those transported nutrients could contribute to increase phytoplankton in outer area, where river discharge flow slows down. This theory was consistent with our result that satellite Chl-*a* in sub-area A did not increase further once river discharge exceeded  $500 \text{ m}^{-3} \text{ sec}^{-1}$ .

TSUJIMOTO (2012) suggested that reduction of both nitrogen and phosphorus is necessary to conserve water quality in Toyama Bay, because the nutrient limitation was altered from nitrogen in 2006 to phosphorus in 2007 at the water sampling station away from the Jinzu River mouth (located in sub-area B in this

study). Our result also showed that land based sources of nutrients are possibly transported to sub-are B and C in Toyama Bay from May to October, it is therefore possible that a reduction of both nitrogen and phosphorus can contribute to controlling or limiting growth of phytoplankton not just in sub-area A, but also in sub-areas B and C. Since the seasonal variability of satellite Chl-*a* in sub-are A showed the single and long summer peak that indicates potential eutrophication almost every year, close attention must be paid in this sub-area to conserve water quality. Attention also needs to be paid to sub-area B, where satellite Chl-*a* increased occasionally from May to October in some years with probable excessive nutrients delivered from rivers, although the single and long summer peak pattern in satellite Chl-*a* is not yet observed.

## 5. Conclusion

Past studies in Toyama Bay indicated influence of river discharge on variability of phytoplankton biomass, but in a qualitative manner or with spatially and temporally limited ship observation data. This study used spatially and temporally intensive satellite Chl-*a* for long-term to measure the influence of river discharge on seasonal and interannual variability of phytoplankton biomass in Toyama Bay, and identified extent of land-based sources of nutrients from rivers. The influence of river discharge on satellite Chl-*a* was obvious in the sub-area A throughout the year, but it also occasionally extends to sub-areas B and C from May to October. Monitoring the peak pattern and level of seasonal variability in Chl-*a* was suggested for assessment and management of water quality, because a single and long summer peak pattern is correlated with symptoms of eutrophication.

It is therefore revealed from this study that monitoring of satellite Chl-*a* will be a promising environmental assessment tool for conservation of water quality in Toyama Bay and other coastal waters.

## Acknowledgement

We would like to thank NASA OBPG for providing ocean color satellite data and the

NOAA Satellite Oceanography Team for providing satellite derived sea surface temperature data. We also thank the Ministry of Land, Infrastructure, Transport and Tourism of Japan for providing river discharge data and Eric Stewart for final draft English editing. This study was supported by the Ministry of the Environment of Japan.

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## 追悼：野村 正 先生 —海は生命のゆりかご—

本学会名誉会員、東北大学名誉教授の野村正先生は2014年3月8日に87歳でご逝去されました。謹んでご報告申し上げます。

野村先生は蔵王の山々を望む宮城県村田町に1926年に生まれ、1951年に東北大学農学部水産学科を卒業後東北大学農学部助手（水産利用学講座）に採用され、1959年より1年半フランス政府給費留学生としてパリ大学海洋学研究所（モーリス・フォンテーヌ教授）およびモナコ海洋研究所に留学されました。その後東北大学農学部の講師、助教授を経て1979年に教授（水産増殖学講座）になりました。またその間、1973年から1年間、西ブルターニュ大学理学部で招聘助教授として学生の指導を行いました。さらに京都のルイ・パストゥール医学研究センターの設立にも関わり、評議員を務めました。

研究面ではフランス留学を機に水産動物のホルモンに関する研究を開始されました。特に二枚貝を対象にプロスタグランジンなど生殖に関係するホルモン類について先駆的な研究成果を挙げました。業績は数々ありますが、若かりし頃、例えばフランスにおいてカキが病気のため絶滅の危機に瀕した時、東北大学農学部の今井教授と共に宮城県産の丈夫なマガキをフランスに送り危機を救うことに尽力しました。この日本によるマガキの恩をフランスのカキ業者は代々語り継いでおり、その縁で先の東日本大震災の際はフランスの業者らによる支援の輪が大きく広がりました。さらに大学やフランス国立海洋開発



写真1 セカルディさんらを歓迎して（平成24年2月3日）

地元の魚介類を肴に宮城の地酒を飲み、久しぶりの再会を喜び合った。前列左からエクスマルセイユ大・ストーラさん、野村先生と固い握手をかわすセカルディさん、仙台日仏協会・アリアンス・フランセーズ院長・ロジェ・コカーさん、同秘書・高橋さん。後列左から東北大・ゴベールさん、農林漁業情報技術協会・関さん、野村先生、本学会・小池さん、石巻専修大・松谷さん、および筆者。



写真2 マリオジョルスさんを囲んで（平成23年12月28日）

秋田の郷土料理きりたんぼ鍋に舌鼓を打ち、途中なまはげの乱入もあり大いに盛り上がった。左から時計回りに松谷さん（前出）、野村先生、東北大・尾定さん、東邦大・大越さん、東北大・大越さん、小池さん（前出）、マリオジョルスさん、小池さんご夫人、東北大・佐々木さん。

研究所（IFREMER）と協力し、フランスガキの研究も行いました。現在ではフランスガキはオイスターバーを中心に国内でも人気を博しています。フランスで始まりヨーロッパに広がった海洋療法・タラソテラピーも1970年代まで日本では全く知られていませんでしたが、自著「海洋生物の生理活性物質」（南江堂、1978年）により日本で初めて紹介することとなり、その後日本海洋療法学会を組織し科学的エビデンスに裏付けられた民間療法の一つとして知名度の向上と普及に貢献しました。本学会の活動に関しては1962年から約30年間評議員を務められ、2007年には名誉会員になりました。また1984年には仙台を会場に日仏海洋学国際シンポジウムも開催しました。先生は「ムッシュ」の愛称で慕われ、その下には多くのフランス人研究者や留学生が訪れ海洋生物の研究や資料の収集を行いました。先生のような古い友人には日仏海洋学会会長のユベール・セカルディさんやパリ工科大学教授のカトリーヌ・マリオジョルスさんらがおります。お二人は東日本大震災の折も友人・知人を見舞うためにいち早く来日してくれました。その際も野村先生は返礼の夕食会を仙台で催しております（写真1と2）。お二人には先生との思い出を寄せて頂きました。

上述のような永年の日仏における数々の学術的貢献が高く評価され、2013年3月にはフランス政府より「パルム・アカデミック（教育功労章）オフィシエ」に叙されました（La mer 51, 133, 2013）。

このように偉大な師を失ったことは残念でありませんが、先生が大好きだったフレーズ「La mer est la verceau de la vie（海は生命のゆりかごである）」に込められた海に対する深い思いと先生の薫陶が日仏の学術交流に今後も引き継がれていくことを願いながら、心より哀悼の意を表したいと思います。

中野俊樹（日仏海洋学会幹事、東北大学大学院農学研究所）



## An ultimate proof of a sincere friendship

It is a great honor to evoke the memory of Professor Tadashi NOMURA and it is for me with a profound emotion that I am writing these lines.

First of all, he was an excellent and faithful friend of mine since a long time. Then, he helped us in several friendly cooperation between France and Japan and between the twin Societies franco-japonaises d'Océanographie. I cannot forget a very friendly dinner party spent in Sendai, two years ago, with several of his best colleagues and other scientific personalities belonging to the two countries.

He had a very noticeable career as a teacher and as a researcher in several fields of sciences and technologies, particularly in the field of marine science, such as aquaculture, biology of mollusks, and marine biochemistry. His research dealing with hormones in fishes led him to work with Professor Maurice Fontaine of the French National Museum of Natural History and several other scientists. His cooperative works were established beyond his personal domain of expertise.

He learned French language in Japan and he was Fellow of the French Government. He participated actively in most seminars, colloquiums, and symposiums of the two French-Japanese Societies of Oceanography and was even belongs to the Organizing Committees. His precious knowledge of the French language was very helpful during these scientific meetings. In Bretagne region, he stayed as Associate Professor at the University of Western Brittany.

He created new concepts in marine biochemistry of marine animals, and his book "Biologically Active Substance Produced by Marine Organisms" is remarkable. Professor NOMURA also interested in coastal development. He was also one of the first specialists to disseminate in Japan the techniques, the interest, and the use of the Thalassotherapy systems, he had discovered in France. He helped very often young researchers arriving in Japan, for their adaptation to their laboratory, and in their personal life.

The Government of France attributed the insignia of "Officer of the Academic Palms" to Professor NOMURA Emeritus Professor at Tohoku University in Sendai, in March 2013 for his fructuous career, justified fully this decoration.

The activities of Professor NOMURA helped very much scientific relations between France and Japan and a true and friendly dialogue between the two countries.

Hubert-Jean Ceccaldi

President of the Société franco-japonaise d'Océanographie

(仏日海洋学会会長 ユベール・セカルディ)

## Professor Nomura Tadashi: scientist, humanist and joyful, serving the Japan-France cooperation

I have been very lucky to stay in Japan two years for a post-doctorate period (1984–1986) which I devoted to research about oyster culture, also taking opportunity to learn from the Japanese aquaculture and fisheries sector. This stay has been determining in my career, because the lessons I drew have later considerably fed my professional thoughts and activities.

During my stay in Japan, I was based at Tokyo University of Fisheries in the laboratory of Professor Ogasawara, specialist in oyster culture, who introduced me to adequate persons in research and development sectors in Hiroshima Prefecture. But my knowledge of Japanese oyster culture would have been incomplete without understanding oyster culture in Miyagi and Iwate Prefectures, and that has been possible thanks to Professor Tadashi Nomura. I stayed 3 months in the laboratory of Pr. Nomura in Tohoku University in Sendai, from November 1984 to February 1985. Pr. Nomura, through his broad professional network, opened for me the doors of all the organizations interesting for my work, in the professional sector and in research. He shouldered me in my reflection, my information retrievals and my understanding of these sectors. And he welcomed me with an incommensurable kindness, integrated me in his friendly and joyful team, where I was invited to parties and dinners. Pr. Nomura was not only the professor, and it is fair to his memory to mention how his kind and merry character created an excellent atmosphere in his team.

In short, I am indebted for him one extremely happy and fertile period of my scientific training. Later on, each time we met, we shared very pleasant times and interesting exchanges about our common passion, aquaculture. I can mention Kyoto where he introduced me Gion, Paris where I was so happy to welcome him and Mrs. Nomura, and Sendai in 2004, where he organized for me a wonderful diner with all my colleagues and friends of 20 years before!

Pr. Nomura leaves to us not only a scientific work but a very friendly network of scientist from France and Japan, notably through his former students. He was a remarkable man, who served the Japanese-French cooperation through his scientific knowledge and very much through his deep friendship for France. Many French scientists in fisheries owe him a lot, because he did so much to create the conditions for a profitable training in Japan for young people or rich exchanges and study trips for scientists of both countries.

Catherine Mariojouis

Professor in AgroParisTech

(パリ工科大学教授 カトリーヌ・マリオジョルス)

## 報告

# 沖ノ鳥島での観測

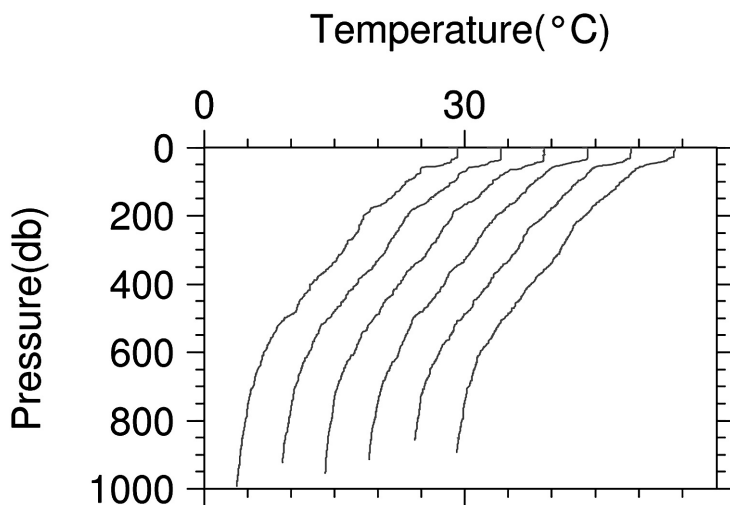
中野知香\*  
(Haruka NAKANO)

### はじめに

私は東京海洋大学で海洋物理、特に乱流について研究しています。乱流は水塊の変質過程や海洋大循環、物質の拡散などに関わる物理過程であり、その効果は非常に重要です。広範な海域での観測を重ねる必要があります。沖ノ鳥島は、北緯 20 度 25 分、東経 136 度 04 分に位置しており、日本領土ではありますが、このような離島で定期的に観測を行うことは海洋学的に見ても非常に興味深いことだと思いますし、沖ノ鳥島周辺海域の海洋微細構造はまだ観測されていません。今回、東京都立大島海洋国際高校で実施されている沖ノ鳥島周辺海域での観測航海に参加する機会を得ましたので報告いたします。

東京都立大島海洋国際高校では実習船大島丸を利用し、沖ノ鳥島周辺海域での観測実習を行っています。2007 年より継続して水温・塩分の鉛直且つ水平分布を観測しており、2012 年には日本海事広報協会主催のジュニアマリン賞高校生部門において STMW (Sub Tropical Mode Water) の経年変動に着目し解析した結果を発表し優秀賞を収めており、その活動は非常に活発といえます。

今回の観測は実習生 6 名が乗船し、2014 年 7 月 19 日に伊豆大島を出港し、沖ノ鳥島海域で 2 日間にわたり CTD 観測、ネット採集観測を行い、7 月 25 日に帰港いたしました。観測点は 27 点であり、その一例を下図に示します。



沖ノ鳥島周辺海域の水温. 5度ずつずらした

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沖ノ鳥島を望む

今回の観測では種々の制約があり、短期間で観測を切り上げざるを得ませんでした。非常に貴重なデータを得ることが出来ました。このように地道に観測データを積み上げることの必要性を実感いたしました。

しかしながら、実習船等により一旦策定された観測内容は、よほどのことが無い限り変更されることはありません。確かに、継続してデータを集めることも重要ですが、こういった観測航海をより実りのあるものとするためにも、今まで蓄積したデータを見直し、その解析結果を観測計画に反映させること、また、最新の観測項目を付け加えることも必要だと考えられます。高校の先生方が生物、化学、物理の枠を超えて総合的な観点から観測を立案することの難しさがあることから、大学や研究機関との連携を図ることで、より充実した観測を行っていくことが今後の課題であるといえます。またこの航海を通じて、そのような活動に積極的に関わってゆく姿勢がこれからの研究者に必要なのではないかと感じました。

来年度以降は、可能であれば、研究室で所有している測器を持ち込み、観測航海に参加したいと思います。

#### 謝 辞

沖ノ鳥島での観測という貴重な機会を下さった東京都立大島海洋国際高校校長千葉勝吾先生や船長をはじめとする大島丸の乗組員の皆さま、また、

乗船教官である平塚正彦先生、磯貝大介先生には大変お世話になり、深く感謝いたします。実習生との観測航海は大変楽しいものとなりました。生徒のみなさんありがとうございました。また、快く送り出してくださった東京海洋大学吉田次郎教授と根本雅生准教授に感謝いたします。また今回の乗船に関しては、公益財団法人日本科学協会による笹川科学研究助成を受けております。この場を借りて御礼申し上げます。

資料

第52巻第3号掲載欧文論文の和文要旨

中村 玄<sup>1,2)</sup>・門脇一郎<sup>1,2)</sup>・永塚翔佳<sup>1,1)</sup>・藤瀬良弘<sup>2)</sup>・木白俊哉<sup>3)</sup>・加藤秀弘<sup>1)</sup>：北太平洋産ミンククジラの胸鰭白斑形状～海域間変異と系群比較への応用の可能性～

本研究はミンククジラ *Balaenoptera acutorostrata* 胸鰭における白斑形状が系群識別標識としての有用性の評価を目的として、北太平洋産個体の胸鰭白斑の成長に伴う変化や雌雄差、変異を詳細に分析するとともに、北大西洋産個体との予備的比較を行った。北太平洋産個体については第二期北西太平洋鯨類捕獲調査 (JARPNII) において日本沿岸域および沖合域で捕獲された240個体 (雄：体長3.70-8.16 m,  $n=151$ , 雌：体長3.84-8.68 m,  $n=89$ ), 北大西洋産個体については既報の写真 ( $n=13$ ) を用いた。北太平洋産個体の胸鰭長に対する白斑長の相対値は成長依存的変化が認められなかったが、雄 (33.8%) は雌 (31.8%) に比べ相対値が大きく、雌雄差が認められた。胸鰭に対する白斑面積比は成長に伴い減少し、雄は雌に比べ大きい傾向が認められた。北太平洋産個体の白斑長 (33.4%), 白斑の面積比 (38.8%) はともに北大西洋産個体 (白斑長：40.7%, 面積比：55.5%) に比べて有意に小さいことが示された。胸鰭基部における白黒境界線の形状は成長依存的変化、性差がなく、北太平洋産個体の全個体で蛇行型である一方、北大西洋産個体では直線型であった。胸鰭白斑は系群指標として有望であるだけでなく、ミンククジラの種分化過程の解明への貢献も期待される。

(1 東京海洋大学 海洋科学部 海洋環境学科 海洋環境学部門 鯨類学研究室 〒108-8477 東京都港区港4-5-7, Tel : +81-03-5463-0561, Fax : +81-03-5463-0561, E mail : tardigrada.gensan@gmail.com, 2 (一財) 日本鯨類研究所 〒104-0055 東京都中央区豊海町4-5 豊海振興ビル5F, 3 独立行政法人 水産総合研究センター 国際水産資源研究所 横浜駐在 〒236-8648 神奈川県横浜市金沢区福浦2-12-4, # (株)メタウォーター 〒530-0018 大阪府大阪市北区小松原町2-4, ! (株)エクスモーション 〒108-0014 東京都港区芝5-33-7)

寺内元基<sup>1,2)</sup>・辻本 良<sup>1,3)</sup>・石坂丞二<sup>4)</sup>・中田英昭<sup>5)</sup>：富山湾における衛星データが捉えたクロロフィル *a* 濃度の季節および経年変動に対する河川流量の影響

富山湾沿岸では夏季における植物プランクトンの増加が、しばし水質悪化の原因とされてきた。そこで本研究では、植物プランクトン濃度の指標とされ、衛星観測によって推定が可能なクロロフィル *a* 濃度 (衛星クロロフィル *a* 濃度) と河川流量を比較し、河川を通じて陸域から供給される栄養塩が富山湾内のクロロフィル *a* 濃度に与える影響を評価した。まず、富山湾を衛星クロロフィル *a* 濃度のピークが出現するタイミングと富栄養化の可能性がある区域の分布によりサブエリアに分けた。湾沖合のサブエリアにおいて、衛星クロロフィル *a* 濃度と河川流量に5月から10月にかけて有意な正の相関が認められたことから、河川を通じて湾内に流入する栄養塩が、沖合の海域にも運ばれていることが明らかとなった。湾奥部では、衛星クロロフィル *a* 濃度が夏季にかけて増加し、経年的に増加傾向がみられ、河川流量、栄養塩濃度との比較から、神通川からの高い全窒素負荷が湾奥部の富栄養化に寄与している可能性が高いことが示唆された。本研究では、富栄養化に影響する要因のひとつである河川流量が、富山湾沿岸と5月から10月の沖合のクロロフィル *a* 濃度の変動に寄与していることが示された。これらのことから、衛星クロロフィル *a* 濃度のモニタリングは、富山湾や他の沿岸海域の水質保全において、有用な環境評価ツールであると考えられる。

(1 (公財) 環日本海環境協力センター, 2 長崎大学大学院 生産科学研究科, 3 富山県農林水産部水産漁港課, 4 名古屋大学地球水循環研究センター, 5 長崎大学大学院 水産・環境科学総合研究科, 1, 2 連絡先著者 : (公財) 環日本海環境協力センター 〒930-0856 富山県富山市牛島新町5-5 Tel: 076-445-1571, Fax: 076-445-1581, E-mail: terauchi@npec.or.jp)

## 学 会 記 事

1. 6月14日(土)日仏会館(東京都恵比寿)において2014年度総会を開催した。

2014年度(第55回)日仏海洋学会総会 議事録

日 時: 2014年6月14日(土)15時40分~16時25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出席者数の確認を行い,出席94名(出席25名,委任状による出席69名)により,本総会の成立(会員数133名の1/6の出席)が確認された。

議長: 小松会長

第1号議案 2013年度事業報告

(1) 庶務関係 (荒川庶務幹事)

2013年度の会員数は8名減少(増:特別会員4名,学生会員4名,減:名誉会員2名逝去,正会員13名,賛助会員1社)

(2) 活動状況 (荒川庶務幹事)

①評議員会1回(2013/6/22 日仏会館),幹事会2回(2013/4/29日仏会館,2013/11/28東京海洋大学),総会1回(2013/6/22),学術研究発表会1回(2013/6/22),第15回日仏海洋学シンポジウム(2013/10/17~22 フランス),日本学術会議における講演とポスター紹介(2013/11/29小松会長),日仏関連学会協議会(2013/6/17日仏会館-小松会長・荒川庶務幹事,2013/12/16日仏会館-小松会長)

②評議員選挙,会長選挙,学会賞選考委員半数改選

③学会賞1件,論文賞2件の授与

(3) 編集関係(吉田編集委員長)

学会誌「La mer」の編集状況と51巻1-4号を発刊

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 2013年度収支決算報告および監査報告

①神田会計幹事より資料1に従って,2013年度収支決算が報告された。

②野村監事より会計が適正であることが報告された。質疑ののち,第2号議案は承認された。

第3号議案 2014年度事業案(荒川庶務幹事)

①総会1回,学術研究発表会1回,評議員会1回,幹事会3回 開催(予定)

②2014年度論文賞の授与

③2015年度学会賞,論文賞の候補者の推薦

④学会賞委員半数改選

⑤学会誌「La mer」52巻1-4号 発刊(予定)

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 2014年度予算案(神田会計幹事)

資料2に従って,2014年度予算案が説明された。

審議ののち,第4号議案は承認された。

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)

2013年度は評議員選挙,会長選挙,学会賞選考委員半数改選を実施した。

役員・委員の就任が報告された。

第5号議案は承認された。

第6号議案 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を,2015年10月か11月に日仏会館で開催(予定)する方向で検討することが承認された。

報告事項

①会費振込を従来の郵便局(払込取扱票)だけでなく,銀行(みずほ,三菱東京UFJ,三井住友)での振込みを可能にした。払込手数料について,郵便局は今まで通り学会負担,銀行は個人負担になることを報告した。

②総会終了後,小池康之渉外幹事が,東北のカキ養殖業に対するフランスからの支援と復興状況に関して報告を行った。

「Oyster farming in Tohoku: post-tsunami restoration and technical adaptation of French culture systems(東北のカキ養殖:津波被災後の復興とフランスの技術導入)」

2. 6月14日(土)日仏会館(東京都恵比寿)において2014年度学術研究発表会を開催した。

日 時: 2014年6月14日(土)10時00分~15時30分

場 所: 日仏会館501会議室

プログラムは以下の通り。

10:00~10:45 座長 奥村 裕(東北水研)

①気仙沼湾の底泥に含まれる油分の蛍光特性

○戸口和貴<sup>1</sup>, 藤山凌多<sup>1</sup>, 池田吉用<sup>1</sup>, 荒川久幸<sup>1</sup>

(1: 海洋大院)

②東日本大震災後の気仙沼湾の海底堆積油量

○中村真由子<sup>1</sup>, 池田吉用<sup>1</sup>, 荒川久幸<sup>1</sup>

(1: 海洋大院)

③NaI(Tl)シンチレーションカウンタを用いたシロメバル *Sebastes cheni* 生体中の放射性セシウム濃度測定

○松本 陽<sup>1</sup>, 平川直人<sup>2</sup>, 荒川久幸<sup>1</sup>

(1: 海洋大院, 2: 福島水試)

10:45~11:30 座長 飯淵 敏夫(海生研)

④南北太平洋貧栄養海域における粒状リンの分布

○江濱 誠<sup>1</sup>, 橋濱史典<sup>1</sup>, 齊藤宏明<sup>2</sup>, 櫻庭涼輔<sup>3</sup>,

諏訪修平<sup>1</sup>, 神田穰太<sup>1</sup>, 佐藤光秀<sup>4</sup>  
(1: 海洋大院, 2: 東大大海研, 3: 海洋大,  
4: 東京大院)

⑤ナローマルチビームソナーを用いた藻場タイプ判別  
手法の開発に関する研究

○濱名正泰, 佐々修司, 小松輝久 (東大大海研)

⑥震災後の石巻沿岸を中心とした無給餌養殖漁場の環  
境について

○奥村 裕<sup>1</sup>, 増田義男<sup>2</sup>, 太田裕達<sup>2</sup>  
(1: 水研セ東北水研, 2: 宮城水技セ)

13:30~14:30 座長 内田 裕 (JAMSTEC)

⑦Quasi-horizontal observations of turbulence asso-  
ciated with phytoplankton spatial microstruc-  
tures in the upper ocean

○Herminio Poloni-Neto<sup>1</sup>, 田中 衛<sup>1</sup>, 山崎秀勝<sup>1</sup>  
(1: 海洋大)

⑧黒潮流軸付近における近慣性内部波の上下伝播の観  
測と数値実験

○長井健容<sup>1</sup>, 井上龍一郎<sup>2</sup>, A. Tandon<sup>3</sup>,  
E. Kunze<sup>4</sup>, A. Mahadevan<sup>5</sup>

(1: 海洋大, 2: JAMSTEC, 3: UMassD,  
4: UW, 5: WHOI)

⑨山陰海岸沖で観測された近慣性内部波の時空間変動  
○山崎恵市<sup>1</sup>, 北出裕二郎<sup>1</sup>, 井桁庸介<sup>2</sup>, 渡邊達郎<sup>2</sup>  
(1: 海洋大院, 2: 水研セ日水研)

⑩アドリア海における風と波の呼称の特徴—ダルマチ  
ア海岸における地域調査—

○矢内秋生 (武蔵野大)

14:30~15:30 座長 北出裕二郎 (海洋大院)

⑪北太平洋亜熱帯モード水中の水温微細構造から見た  
混合効率の研究

○黒野由依, 中野知香, 根本雅生,  
吉田次郎 (海洋大院)

⑫館山湾における乱流構造の研究

○古見拓郎, 中野知香, 吉田次郎,  
根本雅生 (海洋大院)

⑬館山湾におけるマアジの研究

○澁谷勝晶, 中野知香, 吉田次郎,  
根本雅生 (海洋大院)

⑭相模湾における外洋性サメ類の研究

○戸高耀介<sup>1</sup>, 中野知香<sup>1</sup>, 塩出大輔<sup>1</sup>, 吉田次郎<sup>1</sup>,  
根本雅生<sup>1</sup>, 塩崎 航<sup>2</sup>

(1: 海洋大院, 2: 国際水研)

15:40~16:25 総会

16:25~16:45 東北のカキ養殖業に対するフランスか  
らの支援と復興の状況報告 (小池康之会員)

「Oyster farming in Tohoku: post-tsunami restora-  
tion and technical adaptation of French culture sys-  
tems (東北のカキ養殖: 津波被災後の復興とフラン  
スの技術導入)」

16:45~16:55 2014年度日仏海洋学会論文賞授与式  
《論文賞受賞》田村 康氏 (海洋大) 「Occurrence pat-  
terns and ontogenetic intervals based on the devel-  
opment of swimming-and feeding-related  
characters in larval and juvenile Japanese sea bass  
(*Lateolabrax japonicus*) in Tokyo Bay」51巻1-  
2号, 13-29, 2013

《論文賞受賞》 國分優孝会員 (東大大海研) 「Biomass  
of marine macrophyte debris on the ocean floor  
southeast of Hokkaido Island adjusted by experi-  
mental catch efficiency estimates」50巻1-2号,  
11-22, 2012

17:00~19:00 懇親会 (BAR de ESPANA Ochoにて)

### 3. 新入会員

| 氏名                | 所属     | 紹介者  |
|-------------------|--------|------|
| 株式会社セア・プラス (賛助会員) |        | 荒川久幸 |
| 有木 瑞紀 (学生会員)      | 東京海洋大学 | 荒川久幸 |

### 4. 所属および住所変更

| 氏名    | 新しい所属先                                 |
|-------|--|
| 國分 優孝 | ダイキン工業株式会社 環境技術研究所                     |
| 高橋 暁  | (独) 産業技術総合研究所 地質情報研究部門<br>海洋環境地質研究グループ |
| 服部 寛  | 東海大学生物学部海洋生物科学科 (札幌キャンパス)              |

### 5. 寄贈図書および資料

農工研ニュース (農村工学研究所); No.91-92  
なつしま (JAMSTEC); 340-342  
Ocean Newsletter (海洋政策研究財団); No.333-338  
FRAN NEWS (水産総合研究センター); No.39  
Ocean Breeze (東京大学大気海洋研究所); 第16号  
東京大学大気海洋研究所 要覧・年報 2014  
独立行政法人 産業技術総合研究所 地質調査情報セン  
ター; 襟裳岬沖海底地質図 (CD-R)  
水産技術 (独立行政法人水産総合研究センター); 第7  
巻第1号

(資料 1)

## 平成 25 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 | 1,292,629 | 1,292,629 | 0         |                         |
| 正会員会費  | 984,000   | 1,152,000 | 168,000   | 8,000 円×144             |
| 特別会員   | 72,000    | 84,000    | 12,000    | 6,000 円×14              |
| 学生会員会費 | 4,000     | 36,000    | 32,000    | 4,000 円×9               |
| 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   | 125,081   | -24,919   |                         |
| 広告費    | 20,000    | 0         | -20,000   |                         |
| 別刷り代等  | 200,000   | 330,300   | 130,300   | 別刷り, 超過頁, カラー印刷費, 論文印刷費 |
| 掲載料    | 500,000   | 200,000   | -300,000  | 50,000 円×4 編            |
| 雑収入    | 100,000   | 30,755    | -69,245   | 学術著作権使用料他               |
| 寄付金    | 1         | 0         | -1        |                         |
| 収入合計   | 3,402,630 | 3,360,765 | -41,865   |                         |

| 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 | 1,350,000 | 1,167,190 | -182,810  | 51 (1.2) ~ 51 (3.4) |
| 送料・通信費 | 100,000   | 86,532    | -13,468   |                     |
| 事務費    | 700,000   | 592,721   | -107,279  | 事務用品, 人件費, 事務員交通費他  |
| 交通費    | 20,000    | 2,850     | -17,150   | 日仏会館 (品川駅~恵比寿駅)     |
| 会議費    | 5,000     | 2,310     | -2,690    |                     |
| 学会賞経費  | 30,000    | 25,746    | -4,254    | 賞状他                 |
| 雑費     | 25,000    | 19,210    | -5,790    | 振込手数料他              |
| 次年度繰越  | 1,172,630 | 1,464,206 | 291,576   |                     |
| 支出合計   | 3,402,630 | 3,360,765 | -41,865   |                     |



## (資料2)

## 平成26年度予算(案)

| 収入の部         |           |           |           |                                  |
|--------------|-----------|-----------|-----------|----------------------------------|
| 費目           | 26年度予算(A) | 25年度予算(B) | 増減(A)-(B) | 摘要                               |
| 前年度繰越金(銀行残高) | 1,464,206 | 1,292,629 | 171,577   |                                  |
| 正会員会費        | 880,000   | 984,000   | -104,000  | 8,000円×110名                      |
| 特別会員         | 96,000    | 72,000    | 24,000    | 6,000円×16名                       |
| 学生会員会費       | 24,000    | 4,000     | 20,000    | 4,000円×6名                        |
| 賛助会員会費       | 80,000    | 80,000    | 0         | 7社(8口分)                          |
| 学会誌売上金       | 150,000   | 150,000   | 0         |                                  |
| 広告費          | 20,000    | 20,000    | 0         |                                  |
| 掲載料          | 0         | 500,000   | -500,000  | 論文掲載料廃止によるもの                     |
| 論文印刷費・カラー印刷費 | 600,000   | 0         | 600,000   | (1論文あたり75,000円,年に8論文として試算)       |
| 別刷り印刷費       | 90,000    | 200,000   | -110,000  | 梱包送料含む(1論文あたり15,000円,年に6論文として試算) |
| 雑収入          | 100,000   | 100,000   | 0         | 学術著作権使用料他                        |
| 寄付金          | 0         | 1         | -1        |                                  |
| 収入合計         | 3,504,206 | 3,402,630 | 101,576   |                                  |

| 支出の部       |           |           |           |                  |
|------------|-----------|-----------|-----------|------------------|
| 費目         | 26年度予算(A) | 25年度予算(B) | 増減(A)-(B) | 摘要               |
| 学会誌印刷費     | 1,800,000 | 1,350,000 | 450,000   | 4冊×450,000円      |
| 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,事務員交通費他 |
| 交通費        | 20,000    | 20,000    | 0         |                  |
| 会議費        | 5,000     | 5,000     | 0         |                  |
| 学会賞経費      | 30,000    | 30,000    | 0         | 賞状他              |
| 雑費         | 25,000    | 25,000    | 0         | 振込み手数料他          |
| 次年度繰越(予備費) | 824,206   | 1,172,630 | -348,424  |                  |
| 支出合計       | 3,504,206 | 3,402,630 | 101,576   |                  |

## 賛 助 会 員

|                 |  |
|-----------------|--|
| 株式会社 イーエムエス     | 兵庫県神戸市中央区東川崎町 1-3-3<br>神戸ハーバーランドセンタービル 13F |
| いであ株式会社         | 東京都世田谷区駒沢 3-15-1                           |
| 有限会社 英和出版印刷社    | 東京都北区中里 2-14-8 シャンボール駒込 101                |
| 公益財団法人海洋生物環境研究所 | 東京都新宿区山吹町 347 藤和江戸川橋ビル 7階                  |
| ケー・エンジニアリング株式会社 | 東京都台東区浅草橋 5-14-10                          |
| 信幸建設株式会社        | 東京都千代田区神田司町 2-2-7<br>パークサイド 18階            |
| JFEアドバンテック株式会社  | 兵庫県神戸市西区井吹台東町 7-2-3                        |
| 株式会社 セア・プラス     | 神奈川県横浜市緑区十日市場町 832-8                       |

# 日仏海洋学会入会申込書

(正会員・学生会員)

|                      |        |      |    |         |
|----------------------|--------|------|----|---------|
|                      | 年度より入会 | 年    | 月  | 日申込     |
| 氏名                   |        |      |    |         |
| ローマ字                 |        | 年    | 月  | 日生      |
| 住所 〒                 |        |      |    |         |
| 勤務先 機関名              |        |      |    |         |
| 電話                   |        |      |    | E-mail: |
| 自宅住所 〒               |        |      |    |         |
| 電話                   |        |      |    | E-mail: |
| 紹介会員氏名               |        |      |    |         |
| 送付金額                 | 円      | 送金方法 |    |         |
| 会誌の送り先 (希望する方に○をつける) |        | 勤務先  | 自宅 |         |

(以下は学会事務局用)

|    |          |          |            |          |
|----|----------|----------|------------|----------|
| 受付 | 名簿<br>原簿 | 会費<br>原簿 | あて名<br>カード | 学会<br>記事 |
|----|----------|----------|------------|----------|

入会申込書送付先：〒150-0013 東京都渋谷区恵比寿 3-9-25

(財) 日仏会館内

日 仏 海 洋 学 会

郵便振替番号：00150-7-96503



# 日仏海洋学会入会申込書

(正会員・学生会員)

|                      |        |      |   |    |         |
|----------------------|--------|------|---|----|---------|
|                      | 年度より入会 | 年    | 月 | 日  | 申込      |
| 氏名                   |        |      |   |    |         |
| ローマ字                 |        | 年    | 月 | 日  | 生       |
| 住所 〒                 |        |      |   |    |         |
| 勤務先 機関名              |        |      |   |    |         |
| 電話                   |        |      |   |    | E-mail: |
| 自宅住所 〒               |        |      |   |    |         |
| 電話                   |        |      |   |    | E-mail: |
| 紹介会員氏名               |        |      |   |    |         |
| 送付金額                 | 円      | 送金方法 |   |    |         |
| 会誌の送り先 (希望する方に○をつける) |        | 勤務先  |   | 自宅 |         |

(以下は学会事務局用)

|    |    |    |     |    |
|----|----|----|-----|----|
| 受付 | 名簿 | 会費 | あて名 | 学会 |
|    | 原簿 | 原簿 | カード | 記事 |

入会申込書送付先：〒150-0013 東京都渋谷区恵比寿 3-9-25

(財) 日仏会館内

日 仏 海 洋 学 会

郵便振替番号：00150-7-96503