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Abundance, biomass and body size of the hydromedusa *Aglantha digitale* in the western and eastern subarctic Pacific during the summers of 2003–2006RUI SAITO^{1,*}, ATSUSHI YAMAGUCHI¹, SEI-ICHI SAITOH², KENSHI KUMA³ & ICHIRO IMAI¹¹Plankton Laboratory, Graduate School of Fisheries Sciences, Hokkaido University, 3–1–1 Minato-cho, Hakodate, Hokkaido 041–8611, Japan²Laboratory of Marine Bioresource and Environment Sensing, Graduate School of Fisheries Sciences, Hokkaido University, 3–1–1 Minato-cho, Hakodate, Hokkaido 041–8611, Japan³Marine Environmental Science Laboratory, Graduate School of Fisheries Sciences, Hokkaido University, 3–1–1 Minato-cho, Hakodate, Hokkaido 041–8611, Japan

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Abstract: The aim of this study is to evaluate regional and interannual changes in abundance, biomass and body size of the hydromedusa *Aglantha digitale* in the subarctic Pacific. *A. digitale* was sampled by 0–150 m vertical tows using a 100 μm mesh-size NORPAC net at stations from 41°30'N to 49°30'N along the 165°E line (western subarctic Pacific) and from 39°00'N to 53°30'N along the 165°W line (eastern subarctic Pacific) during the summers of 2003–2006. The mean numerical abundances during the course of the study in the west and east were 32.9 (range, 0–368) and 169.2 (0–768) ind. m^{-2} , respectively, and those of biomass were 26.3 (0–264) and 69.1 (0–418) mg DM m^{-2} , respectively. The abundance and biomass showed no significant north-south or year-to-year differences within each transect but they were significantly greater in the east in some years. The body size was characterized with the dominance of small-sized individuals in the east. The higher abundance and biomass, and smaller body size in the east were probably due to sampling during or just after their reproduction in the east.

Key words: abundance, bell height, hydromedusa, population structure, subarctic Pacific

The hydromedusa *Aglantha digitale* (O.F. Müller, 1766) has a circumpolar arctic distribution (Kramp 1959, 1965) and is known to be a common medusa in both the western and eastern subarctic Pacific (Arai & Fulton 1973, Takahashi & Ikeda 2006). This species plays an important role in marine ecosystems linking lower and higher trophic levels. The large-sized individuals prey on small copepods and chaetognaths, while the small-sized individuals feed on ciliates and diatoms (Smedstad 1972, Williams & Conway 1981, Pagès et al. 1996). This species is known to be preyed on by Atlantic mackerel and Chum salmon (Tsuruta 1963, Runge et al. 1987). In the subarctic Pacific, *A. digitale* numerical abundances are 9–67 ind. m^{-2} in the west [the Oyashio region, (Takahashi & Ikeda 2006)] and 10–250 ind. m^{-2} in the east [a coastal inlet of British Columbia and Station P (Arai & Fulton 1973)]. Regardless of the high abundance of *A. digitale* in the subarctic Pacific, there have not been enough studies on this species to understand its biology and ecology. In this study, we evaluated regional and interannual changes in abundance, biomass and body size of *A. digitale* in the subarctic Pacific.

Zooplankton sampling was conducted along the 165°E and 165°W lines on board the T/S “Oshoro-Maru” of the Faculty of Fisheries, Hokkaido University during cruises in the summers of 2003–2006 (Fig. 1a); henceforth the 165°E and 165°W transect lines are referred to simply as the “west” and “east”, respectively. The sampling period and number of sampling stations along each transect varied among years (Fig. 1b). In the west, samples were collected at 4–10 stations between 41°30'N and 49°30'N from 6 June to 8 July. In the east, samples were collected at 5–16 stations between 39°00'N and 53°30'N from 30 June to 2 August. Sampling was done by vertical tows from 150 m to the surface using a 45 cm diameter, 100 μm mesh-size NORPAC net (Motoda 1957), equipped with a flowmeter (Rigosha Co., Ltd., Japan). The net towing speed was 1 m sec^{-1} . The samples were immediately preserved in 5% formalin-seawater buffered with sodium tetraborate.

In the laboratory, the whole zooplankton sample was examined under a dissecting microscope, and all individuals of *Aglantha digitale* were sorted and counted. Bell height [BH: length from top to bottom of the bell (Takahashi & Ikeda 2006)] was measured using an eyepiece micrometer with a

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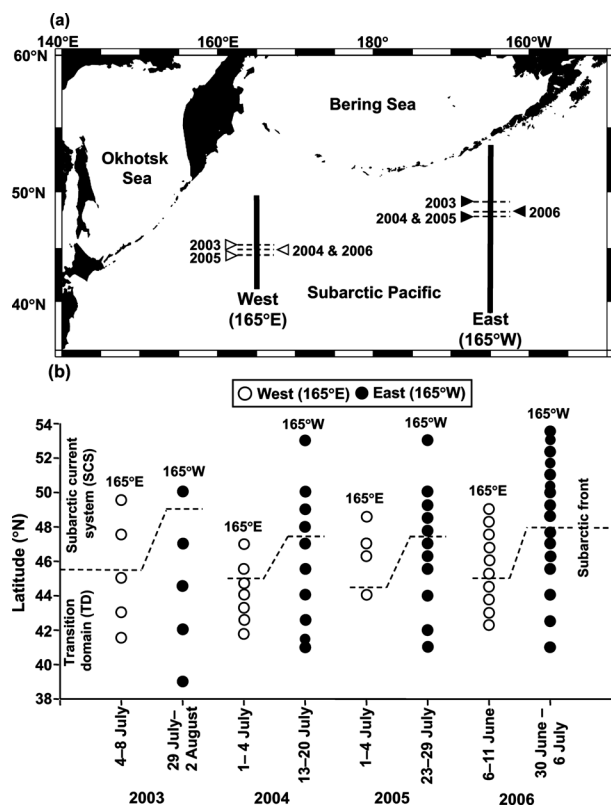


Fig 1. Sampling transects along the 165°E and 165°W lines in the subarctic Pacific (a) and details of the sampling location and time (b). Dashed lines show the approximate positions of the subarctic front. Open and solid circles in (b) indicate the stations along the 165°E and 165°W lines, respectively.

precision of 0.50 mm, and gonad length (GL) was measured with a precision of 0.05 mm. According to McLaren (1969), individuals of which GL was >10% of BH were regarded as mature, and individuals with GL ≤10% of BH were regarded as immature. Damaged individuals whose BH and GL could not be measured were also counted. The biomass of an individual of *A. digitale* was calculated using the following equation,

$$\log_{10} DM = 0.454 (\log_{10} BH)^2 + 1.883 \log_{10} BH - 2.402 \quad (r^2 = 0.98, p < 0.001),$$

where DM is dry mass (mg), and BH is bell height (mm) (cf. Takahashi & Ikeda 2006).

The spatial differences in *Aglantha digitale* abundance, biomass and bell height were tested by a Mann-Whitney *U*-test. The year-to-year differences in their abundance and biomass were tested by a Tukey-Kramer test. The spatial changes in the ratios of small-sized, large-sized cohorts, and mature individuals to total population were tested by a χ^2 test. Since the abundance of *A. digitale* at each station was not enough to compare BH among stations, the BH data were compiled for each transect. Cohort analyses of BH histogram data were made using Microsoft Excel Solver (Aizawa & Takiguchi 1999).

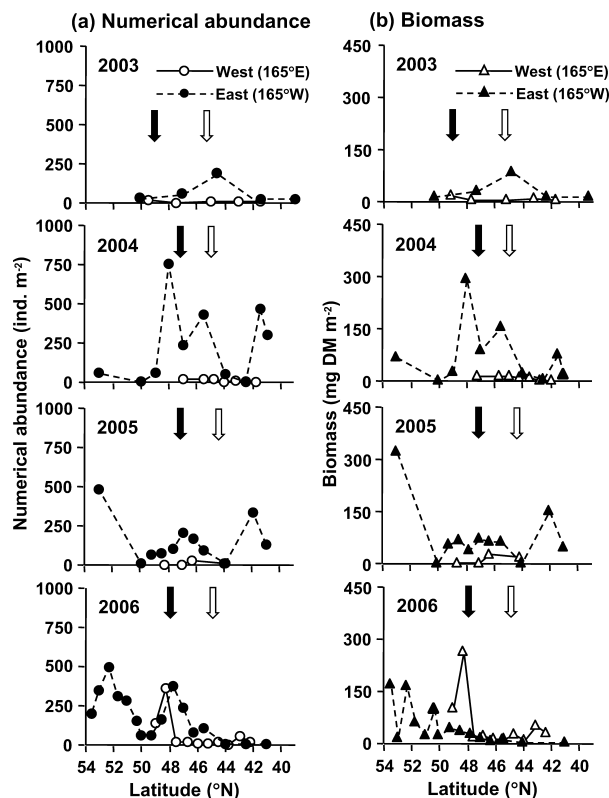


Fig. 2. Numerical abundance (a) and biomass (b) of the hydro-medusa *Aglantha digitale* along the 165°E and 165°W lines in the subarctic Pacific during the summers of 2003–2006. White and black arrows indicate the approximate positions of subarctic fronts along the 165°E and 165°W lines, respectively.

Temperature, salinity and chlorophyll-*a* data at each station during the sampling were published by Saito et al. (2011). The subarctic front [boundary of the subarctic current system (SCS) and the transition domain (TD), where the 4°C isothermal line is located below 100 m depth (Favorite et al. 1976, Anna et al. 1990)] in the east was located more northward than in the west (Fig. 1).

The grand mean numerical abundances for 2003–2006 in the west and east were 32.9 (range, 0–368) and 169.2 (0–768) ind. m⁻², respectively. In the west, the mean abundances from individual years were 7.5, 11.6, 11.1 and 69.4 ind. m⁻², respectively. There were no significant differences between these abundances ($p > 0.05$). In the east, they were 34.9, 248.0, 143.9 and 179.4 ind. m⁻², respectively, and there were also no significant differences between the years ($p > 0.05$).

The abundances along each transect line sometimes varied greatly station to station (Fig. 2a). However, in each year the mean abundances in the TD of the west (6.6, 8.6, 15.2, 24.1 ind. m⁻² in 2003–2006, respectively) and the east (43.6, 258.6, 139.8, 120.9 ind. m⁻² in 2003–2006, respectively) were not significantly different from the corresponding data from the SCS (8.8, 19.1, 9.8, 137.2 ind. m⁻² in 2003–2006, respectively, in the west and 232.0, 151.0, 238.0 ind. m⁻² in 2004–2006, respectively, in the east) ($p > 0.05$).

Significant differences in the abundance between the west and the east were observed for the TD in 2004, the SCS in 2005 and the SCS in 2006 ($p > 0.05$, Fig. 2a). In these three cases, the abundances in the east were 4–20 times greater than those in the west.

The mean biomasses throughout the study period in the west and east were 26.3 (range, 0–264) and 69.1 (0–418) mg DM m⁻², respectively. In the west, the mean biomasses from individual years from 2003–2006 were 4.3, 8.5, 10.6 and 56.0 mg DM m⁻², respectively. There were no significant differences between these biomasses ($p > 0.05$). In the east, they were 17.8, 82.1, 80.3 and 69.2 mg DM m⁻², respectively, and there were no significant differences between the years ($p > 0.05$).

The biomass along each transect line sometimes varied greatly from station to station (Fig. 2b). However, in each year the mean biomasses in the TD in the west (2.4, 6.2, 16.6, 23.3 mg DM m⁻² in 2003–2006, respectively) and the east (22.3, 101.2, 62.5, 39.2 mg DM m⁻² in 2003–2006, respectively) were not significantly different from the corresponding data from the SCS (7.0, 14.1, 8.6, 105.0 mg DM m⁻² in 2003–2006, respectively, in the west, 103.4, 111.5, 95.5 mg DM m⁻² in 2004–2006, respectively, in the east) ($p > 0.05$).

As observed in the numerical abundances, the biomasses showed significant differences between the west and east of the TD in 2004 and 2005 and of the SCS in 2006 ($p < 0.05$, Fig. 2b). In these cases, the mean biomasses in the east were 2–7 times greater than those in the west.

The BH size compositions in both the west and east showed bimodal distributions except in the east in 2004 and the west in 2006 (Fig. 3a, b). The cohort analysis indicated that the mean BH of the small-sized cohorts ranged between 4.0 and 8.5 mm. In the west, the ratios of small-sized cohorts to total population were 50% in 2003, 64% in 2004, and 25% in 2005. In the east, the ratios were 78% in 2003, 67% in 2005, and 76% in 2006, which were significantly higher than these values in the west ($p < 0.05$). The cohort analysis did not distinguish two different cohorts from the west in 2006 and the east in 2004. However, most individuals of these populations are regarded to belong to the small-sized cohort because of their small sizes; their mean BHs were 8.6 mm from the west in 2006 and 4.3 mm from the east in 2004. Hence these populations are treated as the small-sized cohort. The mean BH of the large-sized cohort ranged between 9.0 and 12.5 mm. The ratios of large-sized cohort to total population were significantly greater in the west than in the east ($p < 0.05$).

The mean BH of mature individuals ranged between 8.5 and 15.2 mm, and there was no significant difference between the west (9.1 mm in 2003, 11.7 mm in 2004, 11.8 mm in 2004, and 15.2 mm in 2006) and the east (8.5 mm in 2003, 11.2 mm in 2004, 10.5 mm in 2005 and 13.4 mm in 2006) ($p > 0.05$). The ratios of mature individuals to total population in the west were 25% in 2003, 36% in 2004, 60% in 2005, and 7% in 2006. Those in the east were 8% in 2003, 2% in 2004, 4% in 2005, and 10% in 2006. The ratios were significantly higher in the west than in the east ($p < 0.05$).

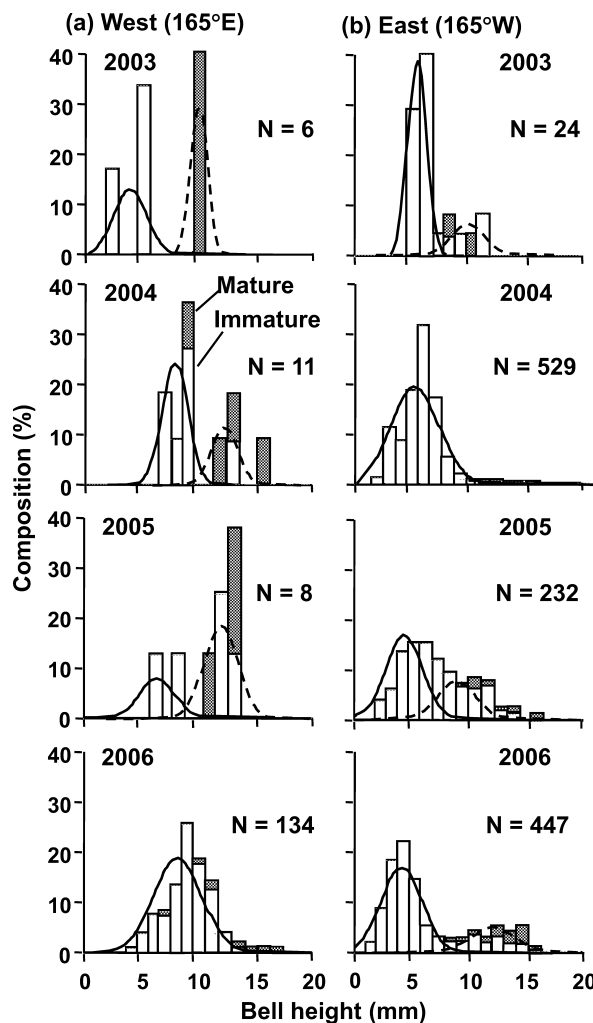


Fig. 3. Bell height composition of *Aglantha digitale* for the 165°E (a) and 165°W (b) lines in the subarctic Pacific during the summers of 2003–2006. Solid and open bars indicate mature and immature individuals, respectively. Normal distributions of analyzed cohorts are also shown; when two cohorts were distinguished, the large-sized one is shown by a dashed line.

The mean abundances of the small-sized cohort in the west in 2003–2006 were 3.9, 5.1, 2.9 and 70.9 ind. m⁻², respectively. Those in the east were 27.6, 269.4, 96.3 and 150.9 ind. m⁻², respectively. The abundances of the small-sized cohort in 2004, 2005 and 2006 in the east were significantly greater than those of the corresponding years in the west ($p < 0.05$). In contrast to the small-sized cohort, the mean numerical abundances of the large-sized cohort in the west (4.2 ind. m⁻² in 2003 and 8.2 ind. m⁻² in 2005) were not significantly different from those in the east in the same years (5.8 and 28.6 ind. m⁻², respectively) ($p > 0.05$).

The present study showed that in some years the mean abundances of *Aglantha digitale* in TD and SCS of the east were greater than those in the west, and small-sized individuals more dominated in the east than in the west. According to Takahashi & Ikeda (2006), the spawning season of *A. digitale*

is from July to September in the Oyashio region of the western subarctic Pacific, which is consistent with that in the eastern subarctic Pacific. They also revealed that the abundance increased rapidly from a low numerical abundance in early July to the annual peak in mid-August. Judging from such seasonal changes in abundance, the time lag of our sampling by more than a half month between the west (6 June–8 July) and the east (30 June–2 August) is considered as a probable reason for the east-west differences in the abundance and biomass. In the west, where sampling was mostly in June, the ratio of mature individuals was high and that of the small-sized cohort was low except in 2006, indicating that most of the samples were collected prior to their peak period of reproduction. Whereas in the east, where sampling was done mostly in July, we probably sampled *A. digitale* during or just after their reproduction, resulting in a higher abundance of small-sized recruited juveniles. These present results also suggest that the peak reproduction of *A. digitale* in oceanic regions of the subarctic Pacific occurs in July as observed in neritic waters of the northeastern Pacific (Arai & Fulton 1973).

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References

Aizawa Y, Takiguchi N (1999) Consideration of the methods for estimat-

- ing the age-composition from the length frequency data with MS-Excel. Bull Jpn Soc Fish Oceanogr 63: 205–214. (in Japanese with English abstract)
- Anma G, Masuda K, Kobayashi G, Yamaguchi M, Meguro T, Sasaki S, Ohtani K (1990) Oceanographic structures and changes around the transition domain along 180° longitude, during June 1979–1988. Bull Fac Fish Hokkaido Univ 41: 73–88.
- Arai MN, Fulton J (1973) Diel migration and breeding cycle of *Aglantha digitale* from two locations in the northeastern Pacific. J Fish Res Bd Can 30: 551–553.
- Favorite E, Dodimead AJ, Nasu K (1976) Oceanography of the subarctic Pacific region, 1960–71. Bull Int North Pac Fish Comm 33: 1–187.
- Kramp PL (1959) The hydromedusae of the Atlantic Ocean and adjacent waters. Dana Rep 46: 1–283.
- Kramp PL (1965) The hydromedusae of the Pacific and Indian Oceans. Section I Dana Rep 63: 1–162.
- McLaren IA (1969) Population and production ecology of zooplankton in Ogac Lake, a landlocked fjord on Baffin Island. J Fish Res Bd Can 26: 1485–1559.
- Motoda S (1957) North Pacific standard plankton net. Inf Bull Planktol Jpn 4: 13–15.
- Pagès F, González HE, González SR (1996) Diet of the gelatinous zooplankton in Hardangerfjord (Norway) and potential predatory impact by *Aglantha digitale* (Trachymedusae). Mar Ecol Prog Ser 139: 69–77.
- Runge JA, Pepin P, Silvert W (1987) Feeding behavior of the Atlantic mackerel *Scomber scombrus* on the hydromedusa *Aglantha digitale*. Mar Biol 94: 329–333.
- Saito R, Yamaguchi A, Saitoh S-i, Kuma K, Imai I (2011) East-west comparison of the zooplankton community in the subarctic Pacific during summers of 2003–2006. J Plankton Res 33: 145–160.
- Smedstad OM (1972) On the biology of *Aglantha digitale rosea* (Forbes) (Coelenterata: Trachymedusae) in the inner Oslofjord. Norw J Zool 20: 111–135.
- Takahashi D, Ikeda T (2006) Abundance, vertical distribution and life cycle patterns of the hydromedusa *Aglantha digitale* in the Oyashio region, western subarctic Pacific. Plankton Benthos Res 1: 91–96.
- Tsuruta A (1963) Distribution of plankton and its characteristics in the oceanic fishing grounds with special reference to their relation to fishery. J Shimonoseki Univ Fish 12: 13–214.
- Williams R, Conway DVP (1981) Vertical distribution and seasonal abundance of *Aglantha digitale* (O. F. Müller) (Coelenterata: Trachymedusae) and other planktonic coelenterates in the northeast Atlantic Ocean. J Plankton Res 3: 633–643.