Zoosymposia 7: 225–230 (2012)
www.mapress.com/zoosymposia/
Copyright © 2012 · Magnolia Press

ISSN 1178-9905 (print edition)
ZOOSYMPOSIA
ISSN 1178-9913 (online edition)

Growth and gonad development of the sea urchin *Hemicentrotus pulcherrimus* in an *Eisenia* kelp bed in the Oshika Peninsula, northern Japan*

YUKIO AGATSUMA[1,2], NANAKO TODA[1], MAKOTO OGASAWARA[1], JUNJI KINOSHITA[1], MASAYUKI WATANABE[1], TOSHIYUKI MATSUI[1] & ERI INOMATA[1]

[1] *Graduate School of Agricultural Science, Tohoku University, Sendai, Japan*
[2] *Corresponding author, E-mail: agatsuma@bios.tohoku.ac.jp*

**In*: Kroh, A. & Reich, M. (Eds.) Echinoderm Research 2010: Proceedings of the Seventh European Conference on Echinoderms, Göttingen, Germany, 2–9 October 2010. *Zoosymposia*, 7, xii + 316 pp.

Abstract

To elucidate growth and gonad development of *Hemicentrotus pulcherrimus* in the bed of *Eisenia bicyclis*, we examined gonad indices, gonad histology, gut content indices and ages of the sea urchins collected approximately monthly from March 2008 to September 2009 in Kitsunezaki in the Oshika Peninsula, northern Japan. We also monitored the densities of the kelp in six 1 m^2 quadrates. The kelp at 1- to 3-years of age decreased in density from January to July due to strong wave action. The urchin test diameters at 1-, 2- and 3-years of age were 12.7 mm, 23.7 mm and 30.5 mm, respectively and these growth rates were equal to that measured in *Sargassum* beds in previous studies. The gonad recovering stage was classified into the two sub-class stages; the recovering I stage with relict spermatozoa or ova surrounded by renewed nutritive phagocytes, and the recovering II stage with nutritive phagocytes filling the lumen. The recovering I stages was prolonged from February to April when the gonad indices were around 10 % of total body weight, then rose sharply through the recovering II stage during May to August and the growing stage until October. The gonad indices rose sharply from November and reached a maximum of 18.8 in December when the gonad shifted from the premature to mature stages, then fell in January at the partly spawned and spent stages. Gut content indices were high at the recovering I stage, suggesting high availability of the drift thalli and lateral blades dislodged from the kelps and accumulation of nutrients in nutritive phagocytes.

Key words: Growth, gonad development, sea urchins, *Hemicentrotus pulcherrimus*

Introduction

Temporal and spatial variations of the growth and gonad production of sea urchins are closely associated with difference in the algal vegetations. It is well known that grazing front or change in feeding behavior from drift to attached algae as food source of strongylocentrotid sea urchins result in kelp deforestation (Breen & Mann 1976; Harrold & Reed 1985). In southwestern Australia, *Heliocidaris erythrogramma* consumes mainly detached fragments of large brown macroalgae, such as *Ecklonia radiata* (Vanderklift & Kendrick 2005; Vanderklift & Wernberg 2008). But, there are a few studies on the seasonal gonad production in relation to the seasonal algal biomass or the drift abundance (Endo *et al.* 2007; Basch & Tegner 2007).

The growth and gonad production of the edible sea urchin *Hemicentrotus pulcherrimus*, which is

Accepted by A. Kroh: 27 July 2011; published 12 Dec. 2012

most widely distributed in Japan, also differ among different algal beds (Agatsuma *et al.* 2005; Endo *et al.* 2007). Grazing of attached kelp by this sea urchin has not been observed. The present study aims to clarify age and growth, and seasonal gonad development of *H. pulcherrimus* in a bed of the kelp *Eisenia bicyclis* in relation to seasonal changes in the drift abundance. We classified the recovering stage into two sub-stages; the recovering I stage with relict spermatozoa or ova surrounded by renewed nutritive phagocytes, and the recovering II stage with small numbers of primary spermatocytes or previtellogenic oocytes along the acinal wall and with nutritive phagocytes filling the lumen.

Study Area

This study was undertaken in shallow waters in Kitsunezaki (38° 21′ N, 141° 25′ E) in the Oshika Peninsula, Miyagi Prefecture, northern Honshu, Japan, where the beds of the kelp *Eisenia bicyclis* grow on boulder sea beds up to a depth of 2 m along the shore in the range of about 200 m.

Materials and Methods

We collected about 20 to 50 adult *H. pulcherrimus* in a bed of *E. bicyclis* at the depths of 1.0–1.5 m in Kitsunezaki approximately monthly from March 2008 to September 2009. At this study site, no other species of sea urchin are present. We measured test diameter and body wet weight of all sea urchins collected using a vernier caliper (0.1 mm accuracy) and an electric balance (0.01 g accuracy), respectively. We also measured gonad wet weight and gut content wet weight of the large 20 specimens, and calculated the gonad index and gut content index as the percentages relative to body weight. The ages of all sea urchins were determined by the number of black bands formed in the genital plates (Agatsuma & Nakata 2004). A regression formula between the maximum width of the fifth genital plate and the test diameter was calculated by the least squares method and the relationship between age and test diameter was obtained.

According to standard histological techniques, we made the serial cross sections of the gonads of large 10 specimens, and classified into the six gonad developmental stages from developmental process of germinal cells and nutritive phagocytes (Byrne 1990).

In the kelp bed, we placed two 1 m^2 quadrates along the nails knocked into the seabed at each of three places, and counted the thallus numbers in each of the six 1 m^2 quadrates, bimonthly from September 2008 to July 2009. In September 2008 and July 2009, we measured the branch length of the kelps between the center part where stipe is bifurcated and the eroded terminal blade at the lower margin of lateral blades as age marker in each quadrate using a vernier caliper and estimated ages according to Taniguchi & Kato (1984), who studied at Tomarihama (38° 21′ N, 141° 31′ E) in the Oshika Peninsula adjacent to this study site.

During this survey, we obtained the data of monthly wind direction from north-northwest, northwest, west-northwest and west, which cause wave action at this study site and the daily maximum velocities observed at intervals of 10 minutes by the Ishinomaki Meteorological Observatory, Meteorological Agency. In parallel with sea urchin collection, we measured the surface water temperature at the study site using a bar thermometer.

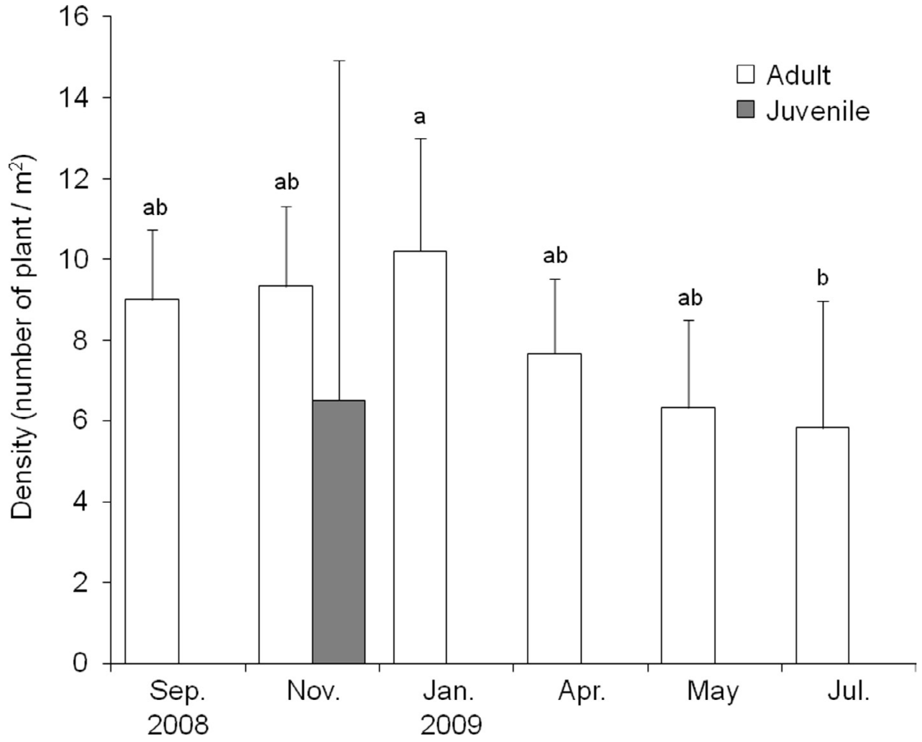

FIGURE 1. Changes in densities of adult and juvenile *Eisenia bicyclis* in the six 1 m^2 quadrates. Vertical bars indicate standard errors. Different letters indicate significant differences in the adult densities among months ($P < 0.05$).

Results and Discussion

Sea surface water temperature at the study site reached to a maximum of 23.0°C in July in 2008, and a minimum of 6.4°C in January and a maximum of 22.5°C in July in 2009. In March 2008 and during November to March 2009, the monthly frequencies of the winds from north-northwest, northwest, west-northwest and west were high and the daily maximum velocities were also higher than the other months. In particular, the wind velocities from west-northwest were high, exceeding 15 m/sec. This directional wind with high velocities was occasionally found during April to June in 2009.

The average densities of adult kelp in the six 1 m^2 quadrates ranged 9 to 10 individuals/m^2 from September 2008 to January 2009, decreased until April when the wave action was high, and significantly decreased to 5.8 individuals/m^2 in July (Fig. 1). Meanwhile, 6.5 juveniles/m^2 appeared in November, and then disappeared. The branch lengths of the kelps were less than 20 cm, ranging 1- to 5-years of age. During the 10 months from September 2008 to July 2009, the kelps with the branch length of less than 12 cm corresponding to 1- to 3-years of age disappeared markedly.

The urchin test diameters at 1-, 2- and 3-years of age were 12.7 mm, 23.7 mm and 30.5 mm, respectively. This test growth is faster than that in the algal turfs (Agatsuma *et al.* 2005) and almost equal to that in *Sargassum* bed (Agatsuma & Nakata 2004; Agatsuma *et al.* 2005).

From histological observation of the gonads, we classified the recovering stage into the two sub-stages; the recovering I stage with relict spermatozoa or ova surrounded by renewed nutritive phagocytes, and the recovering II stage with small numbers of primary spermatocytes or previtellogenic oocytes along the acinal wall and with nutritive phagocytes filling the lumen (Fig. 2). Subsequent gonad development stages were the growing stage, with increasing numbers of spermatocytes or early vitellogenic oocytes along the acinal wall and with nutritive phagocytes filling the lumen, the

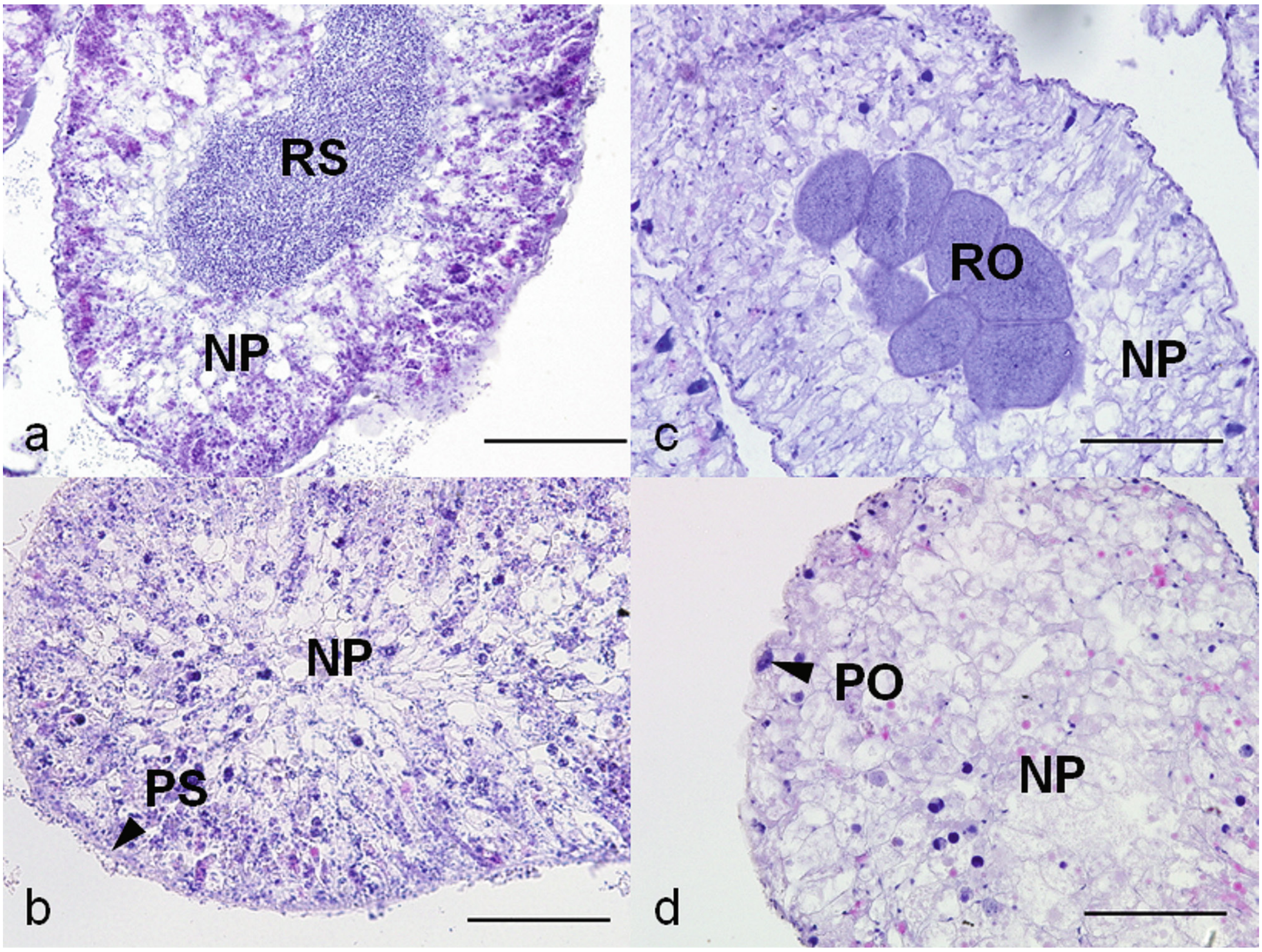

FIGURE 2. Histology of ovaries (right) and testes (left) at the recovering I stage (a, c) and the recovering II stage (b, d). NP, nutritive phagocytes; PS, primary spermatocytes; PO, previtellogenic oocytes; RS, relict spermatozoa; RO, relict ova. Scale bars represent 100 µm.

premature stage, with spermatozoa or ova at the center of the lumen and with spermatocytes and vitellogenic oocytes, the mature stage, with spermatozoa or ova filling the lumen and with spermatocytes and small numbers of vitellogenic oocytes along the acinal wall, the partly spawned stage, with ova loosely packed and separated by spaces and with spermatozoa less concentrated and with spaces in the lumen, and the spent stage, with some relict spermatozoa or ova and empty spaces in the lumen. Monthly changes in gonad indices and gut content indices are shown in Figure 3. The gonad indices were around 10 from March to April 2008 when the gonads shifted from the partly spawned to the recovering I stages. Then, the recovering II stage was occupied from May to August, and the growing stage was predominant from September to October. During April to October, the gonad indices rose significantly, and reached a peak of 18.8 in November when the gonad shifted to the pre-mature stage. Part of gonads shifted to the mature stage in December and the gonad indices fell to January, then remained around 10 until April at the recovering I stage. The gonad shifted to the recovering II stage from May and the indices rose the same as the previous year.

The gut content indices change was the reverse of that of the from the gonad indices, rose from the premature or mature stage to the recovering I stages significantly, indicating the most abundant

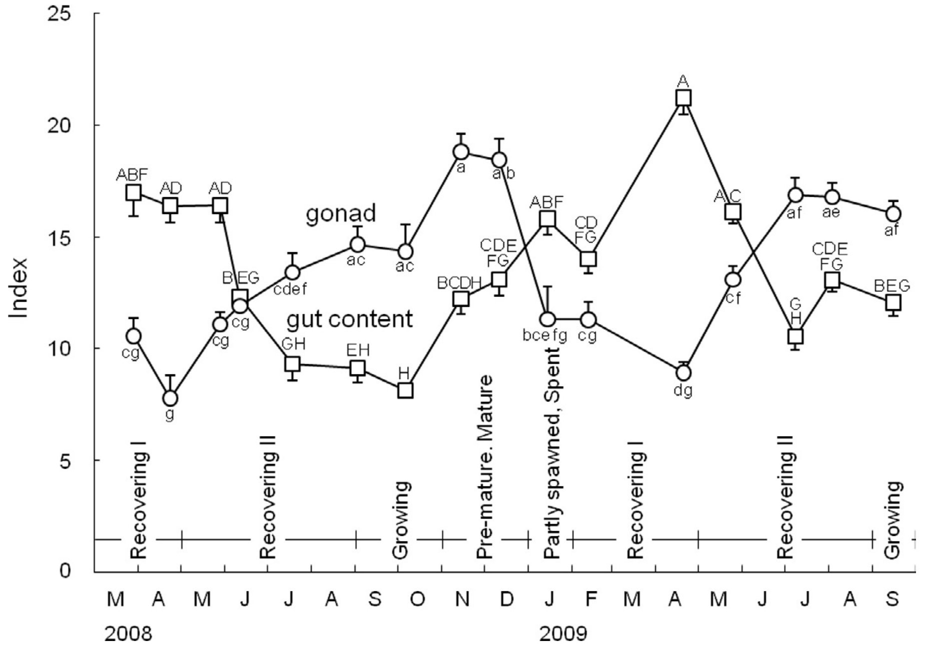

FIGURE 3. Monthly changes in the gonad index (open circles) and the gut content index (open squares). Vertical bars indicate standard errors. Different letters indicate significant differences in each index among months ($P < 0.05$).

food intake in the course of the year, and fell to the recovering II stage significantly. The gut content indices were high at the partly spawned, the spent, recovering I stages and the early periods of the recovering II stage, showing high grazing activity at lower water temperature when active movement to algal turf for foraging (Agatsuma *et al.* 2006). The recovering I stage shows no phagocytosis of relict gametes. The stage was prolonged due to abundant food intake and accumulation of nutrients in nutritive phagocytes in the gonad, resulting in test growth and subsequent increase in gonad indices at the recovering II stage. Prolonged recovering I stage is a species-specific characteristic found in *H. pulcherrimus* (Ogasawara *et al.* 2011) with spawning season in winter.

During summer to autumn when gonads increase in size, the drift thalli of the kelp decreased, however, the dislodgement of lateral blades increases (Taniguchi *et al.* 1991, 1993a). The maximum gonad index of *H. pulcherrimus* fed *E. bicyclis* in excess attains 30 (Endo 2008). But, the maximum index of 18.8 in November in the present study is less than that of 25.0 in the *Sargassum* bed in Oshoro Bay, Hokkaido (Agatsuma & Nakata 2004), showing low availability of the kelp as food. During winter to spring, the increase in the drift thalli of the kelp due to high wave action the same as found in *Macrocystis pyrifera* forest (Seymour *et al.* 1989), in addition, the dislodgement of lateral blades (Taniguchi *et al.* 1991, 1993a, b) show high availability of the kelps as food for the sea urchins.

Conclusions

Hemicentrotus pulcherrimus in *E. bicyclis* forest consumes the drift as food source, which contribute the somatic growth, especially at recovering I stage in spring, but does not gonad production during summer to autumn.

Acknowledgements

We sincerely thank H. Hiratsuka of Miyagi Fisheries Co-operative Association, Ishinomaki Branch for his cooperation with this field study.

References

Agatsuma, Y. & Nakata, A. (2004) Age determination, reproduction and growth of the sea urchin *Hemicentrotus pulcherrimus* in Oshoro Bay, Hokkaido, Japan. *Journal of the Marine Biological Association of the United Kingdom*, 84(2), 401–405.

Agatsuma, Y., Nakabayashi, N., Miura, N. & Taniguchi, K. (2005) Growth and gonad production of the sea urchin *Hemicentrotus pulcherrimus* in the fucoid bed and algal turf in northern Japan. *Marine Ecology*, 26(2), 100–109.

Agatsuma, Y., Yamada, H. & Taniguchi, K. (2006) Distribution of the sea urchin *Hemicentrotus pulcherrimus* along a shallow bathymetric gradient in Onagawa Bay in northern Honshu, Japan. *Journal of Shellfish Research*, 25(3), 1027–1036.

Basch, L.V. & Tegner, M.J. (2007) Reproductive responses of purple sea urchin (*Strongylocentrotus purpuratus*) populations to environmental conditions across a coastal depth gradient. *Bulletin of Marine Science*, 81(2), 255–282.

Breen, P.A. & Mann, K.H. (1975) Destructive grazing of kelp by sea urchins in eastern Canada. *Journal of the Fisheries Research Board of Canada*, 33(6), 1278–1283.

Byrne, M. (1990) Annual reproductive cycles of the commercial sea urchin *Paracentrotus lividus* from an exposed intertidal and a sheltered subtidal habitat on the west coast of Ireland. *Marine Biology*, 104(2), 275–289.

Endo, H. (2008) *Ecological studies on growth and gonad development of the sea urchin Hemicentrotus pulcherrimus in fucoid beds*. Ph.D. thesis, Tohoku University. http://hdl.handle.net/10097/34652.

Endo, H., Nakabayashi, N., Agatsuma, Y. & Taniguchi, K. (2007) Food of the sea urchins *Strongylocentrotus nudus* and *Hemicentrotus pulcherrimus* associated with vertical distributions in fucoid beds and crustose coralline flats in northern Honshu, Japan. *Marine Ecology Progress Series*, 352, 125–135.

Harrold, C. & Reed, D.C. (1985) Food availability, sea urchin grazing, and kelp forest community structure. *Ecology*, 66(4), 1160–1169.

Jensen, M. (1969) Age determination of echinoids. *Sarsia*, 37, 41–44.

Kawamura, K. (1973) Fishery biological studies on a sea urchin *Strongylocentrotus intermedius* (A. Agassiz). *Scientific Reports of Hokkaido Fisheries Experimental Station*, 16, 1–54 [in Japanese with English abstract].

Ogasawara, M., Matsui, T. & Agatsuma, Y. (2011) Growth and rapid gonad recovery of the sea urchin *Hemicentrotus pulcherrimus* after spawning in an *Undaria pinnatifida* and *Saccharina japonica* kelp bed. *Journal of Shellfish Research*, 30(1), 159–166.

Seymour, R.J., Tegner, M.J., Dayton, P.K. & Parnell, P.E. (1989) Storm wave induced mortality of giant kelp, *Macrocyctis pyrifera*, in southern California. *Estuarine, Coastal and Shelf Science*, 28, 277–292.

Taniguchi, K., Isogami, K. & Kojima, H. (1991) Observations on the growth and maturation of 2–4 year old plants of *Eisenia bicyclis* (Laminariaceae, Phaeophyta). *The Japanese Journal of Phycology*, 39(1), 43–47 [in Japanese with English abstract].

Taniguchi, K., Kojima, H. & Isogami, K. (1993a) The growth and maturation of 5 and 6 year-old plants of *Eisenia bicyclis* (Laminariaceae; Phaeophyta). *Nippon Suisan Gakkaishi [= The Japanese Society of Fisheries Science]*, 59(8), 1349–1353 [in Japanese with English abstract].

Taniguchi, K., Kojima, H. & Yamada, H. (1993b) Observation on growth and maturation of one-year-old plants of *Eisenia bicyclis* (Laminariaceae; Phaeophyta). *Nippon Suisan Gakkaishi [= The Japanese Society of Fisheries Science]*, 59(3), 441–444 [in Japanese with English abstract].

Taniguchi, K. & Kato, F. (1984) On age and growth of *Eisenia bicyclis* (Kjellman) Setchell (Phaeophyceae, Laminariales). The *Bulletin of Tohoku Regional Fisheries Research Laboratory*, 46, 15–19.

Vanderklift, M.A. & Kendrick, G.A. (2005) Contrasting influence of sea urchins on attached and drift macroalgae. *Marine Ecology Progress Series*, 299, 101–110.

Vanderklift, M.A. & Wernberg, T. (2008) Detached kelps from distant sources are a food subsidy for sea urchins. *Oecologia*, 157(2), 327–335.