SHORT COMMUNICATION

In situ egg production rate of the planktonic copepod *Acartia steueri* in Ilkwang Bay, southeastern coast of Korea

YEONGHA JUNG[1], HYUNG-KU KANG[2]* AND YONG JOO KANG[1]

[1]DEPARTMENT OF MARINE BIOLOGY, PUKYONG NATIONAL UNIVERSITY, BUSAN 608-737, KOREA AND [2]MARINE LIVING RESOURCES RESEARCH DIVISION, KOREA OCEAN RESEARCH & DEVELOPMENT INSTITUTE, ANSAN PO BOX 29, SEOUL 425-600, KOREA

*CORRESPONDING AUTHOR: kanghk@kordi.re.kr

Received March 31, 2004; accepted in principle June 11, 2004; accepted for publication July 1, 2004; published online July 27, 2004

Egg production rate (EPR) of the copepod Acartia steueri was investigated by in situ incubation in Ilkwang Bay, Korea. EPR ranged from 3.8 to 10.1 eggs female^{-1} *d*$^{-1}$*, and weight-specific growth rate decreased with increasing body weight of the adult female.*

Measurement of secondary production has been a primary goal of zooplankton research in relation to the Global Ocean Ecosystem Dynamics (GLOBEC) program and GLOBEC-like research (IGBP, 1999). Many methods for estimating secondary production have been proposed (Omori and Ikeda, 1984; Rigler and Downing, 1984), with the growth-rate method frequently used in copepod production studies (Peterson *et al.*, 1991, 2002; Huang *et al.*, 1993; Hutchings *et al.*, 1995; Liang and Uye, 1996). In general, the growth-rate method has two approaches: somatic production and egg production. Measurement of the somatic production of copepods, however, is considered a daunting task and not practical (Poulet *et al.*, 1995). Therefore, measurement of the egg production of adult female copepod was proposed as an alternative method for estimating pelagic secondary production and recruitment (Poulet *et al.*, 1995). Egg production rate (EPR) is a measure of population birth/recruitment rate and is also considered as the net production rate of adult female copepods.

In Korean waters, very few investigations on EPR of marine pelagic copepods have been conducted so far (Park and Lee, 1995; Park, 1997; Kang and Kang, 1998). We previously reported the EPR of the small marine copepod *Acartia steueri* in Ilkwang Bay, using an equation obtained in a laboratory experiment relating egg production to temperature and chlorophyll *a* concentration (Kang and Kang, 1998). However, the EPRs estimated in our previous study using this equation were low, suggesting that EPR of *A. steueri* might be underestimated due to the possibility of egg cannibalism by the adult females in the laboratory. Thus, we initiated the present study, in which we measured the EPR of *A. steueri* directly.

The purpose of this study was to measure the EPR of *A. steueri* through an *in situ* incubation experiment in Ilkwang Bay, to compare the results of the EPR to those of Kang and Kang (Kang and Kang, 1998) and to confirm the potential EPR of *A. steueri* in Ilkwang Bay.

A series of sampling was carried out in Ilkwang Bay (Fig. 1) on the southeastern coast of Korea from October 1997 to September 1998. Water temperature, salinity and chlorophyll *a* concentration were monitored at four stations (stations 1, 2, 3 and 4) to detail the seasonal variation of these variables in the bay. Water temperature and salinity were measured using an S-C-T meter (YSI model 33), and chlorophyll *a* concentration was determined by spectrophotometric method (Parson *et al.*, 1984) in surface water and bottom water at four stations (Fig. 1).

Zooplankton samples were collected at three stations (stations 1, 2 and 3) using a plankton net (45 cm mouth diameter and 330 μm mesh) by oblique hauls from the bottom to

doi:10.1093/plankt/fbh126, available online at www.plankt.oupjournals.org

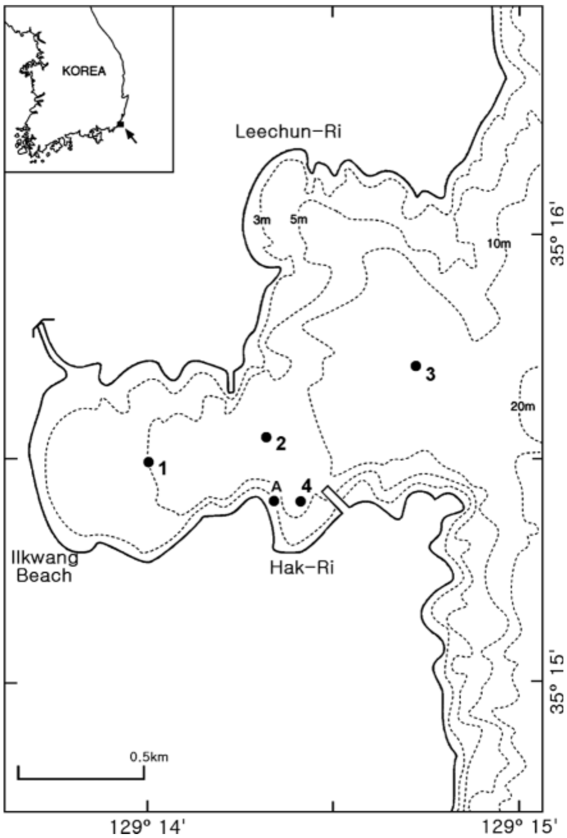

Fig. 1. Study area showing location of four sampling stations and a station (A) for copepod incubation in Ilkwang Bay.

the surface. The copepod *A. steueri* was identified and enumerated, and mean abundance of the adult female in the bay was presented as individuals per cubic meter.

To estimate the *in situ* EPR, adult females of *A. steueri* were collected using a 45 cm diameter net (330 μm mesh) with 1 L volume of cod end by vertical hauls from bottom to surface in the bay. The adult female copepods with the healthy-appearing eggs and many eggs developing in the oviduct were sorted under a stereomicroscope using a large-mouthed pipette and transferred into incubation bottles filled with filtered (50 μm) surface water. The incubation bottle was designed to minimize cannibalism of spawned eggs by adult female copepods. The incubation bottle (polyethylene) is composed of two chambers: spawning chamber (1.5 L volume) and egg-collecting chamber (400 mL volume). The spawning chamber in which the adult female copepods spawn has four small side windows with a 100 μm mesh screen to allow food particles to pass into the chamber during the incubation, and the bottom of the chamber was replaced by 300 μm mesh screen to exclude egg cannibalism. One to 16 adult females of *A. steueri* per bottle were incubated, and two to seven replicate bottles were suspended at ~1 m depth in a culturing station (Fig. 1) for 24–48 h. After the incubation of the adult females, the contents of the egg-collecting chamber were preserved in 5% formaldehyde, and the eggs and nauplii were counted under the stereomicroscope.

Weight-specific growth rate (i.e. weight-specific EPR) of the adult female copepod was calculated from Peterson *et al.* (Peterson *et al.*, 2002), using weights of eggs and adult female copepods and incubation time. The weight of egg of *A. steueri* was calculated from Uye (Uye, 1981) (0.045 μgC), and the weight of adult female copepod was calculated from Kang and Kang (Kang and Kang, 1997) using the length and weight relationship of *A. steueri*.

Mean water temperature and salinity ranged from 11.5 to 25.6°C (mean, 16.5°C) and from 29.6 to 34.3 (mean, 32.9) respectively. In early August, the water temperature suddenly decreased in relation to the effect of coldwater mass from the deeper water offshore. Salinity also decreased during the summer because of a heavy rainfall in 1998 (Fig. 2).

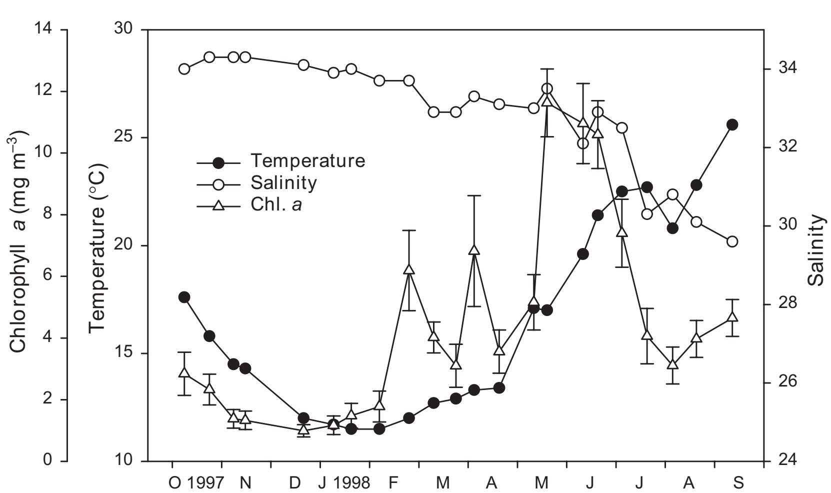

Fig. 2. Seasonal variations in water temperature, salinity and chlorophyll *a* concentration in Ilkwang Bay from October 1997 to September 1998.

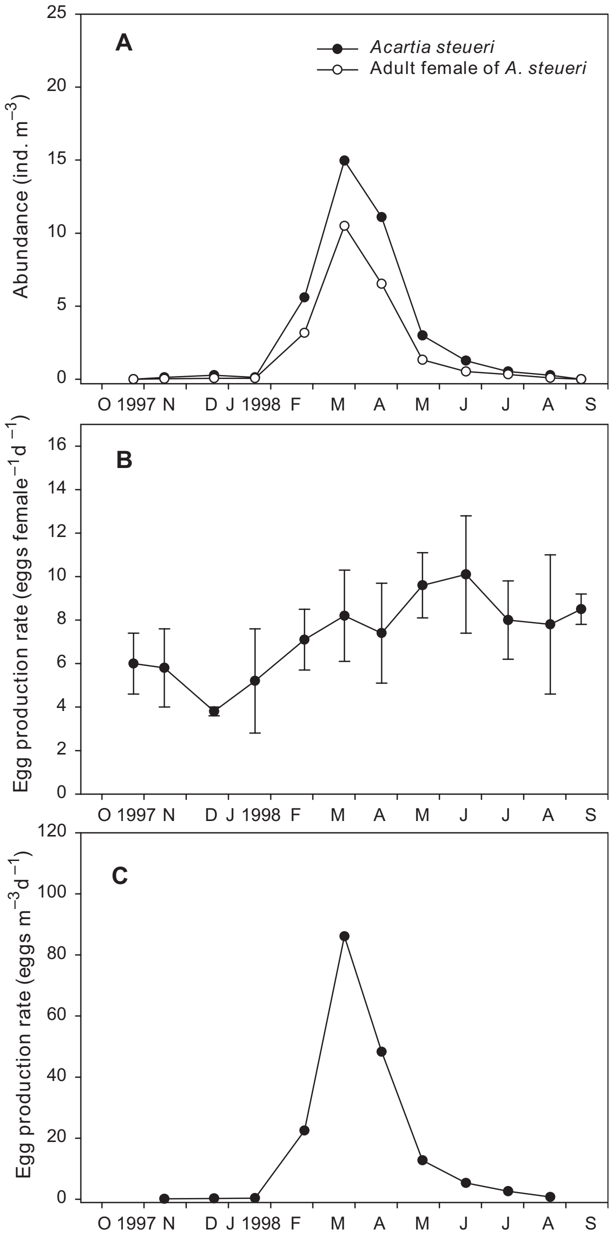

Fig. 3. Seasonal variations in mean abundance of *Acartia steueri* and adult female copepod at three stations (**A**), egg production rate measured by incubation (vertical bars indicate standard deviation, **B**) and population egg production rate (**C**). Adult female of *A. steueri* was not collected by copepod sampling in October 1997 and September 1998.

Mean chlorophyll *a* concentration ranged from 0.99 to 11.63 mg m^{-3} (mean, 4.48 mg m^{-3}), with the highest peak in late May–mid June and small peaks in late February and early April (Fig. 2).

Acartia steueri occurred in the plankton throughout the study period, except October 1997 and September 1998, with one peak in late March (Fig. 3). Mean abundance was rather low in the year and ranged from 0.1 to 15.0 ind. m^{-3} (mean, 3.7 ind. m^{-3}). Percent composition of adult female copepod of *A. steueri* was 23.1–70.1.

EPR (eggs female^{-1} d^{-1}) of *A. steueri* estimated by the incubation experiment was lowest in December; after that, the EPR increased gradually until late June and then slightly decreased (Fig. 3). The EPR ranged from 3.8 to 10.1 eggs female^{-1} d^{-1} (mean, 7.3 eggs female^{-1} d^{-1}; Table I). The population EPR (PEPR, eggs m^{-3} d^{-1}) showed a unimodal seasonal pattern, with one peak in late March similar to the abundance of *A. steueri* (Fig. 3), and PEPR was 0.2–86.1 eggs m^{-3} d^{-1} (mean, 17.9 eggs m^{-3} d^{-1}).

The EPR and the mean water temperature (excluding temperatures above ~22°C) were significantly correlated (r^2 = 0.5160, P < 0.05), but the water temperature accounted for only ~52% of the EPR (Fig. 4). However, there was a highly significant correlation between the EPR and the mean chlorophyll *a* concentration (r^2 = 0.8541, P < 0.001), with EPR increasing with increasing chlorophyll *a* concentration (Fig. 4).

Weight-specific growth rate of *A. steueri* (Table II) ranged from 0.022 to 0.071 d^{-1} (mean, 0.047 d^{-1}). The weight-specific growth rate and the female body weight were negatively correlated (r^2 = 0.3687, P < 0.05), the weight-specific growth rate decreasing with increasing female body weight (Fig. 4).

Absence of animals during October 1997 and September, 1998 could be the result of sampling variability related to patchy distribution of the copepods. Kang (Kang, 1997) reported that the abundance of *A. steueri* including nauplii, copepodids and adults, using a net with 64 μm mesh, had the highest peak in July and the other peaks in mid-November, late February and May, showing a high variation in abundance. The seasonal pattern of the mean abundance of *A. steueri* from three sampling stations in the present study was unimodal, with one peak in late March (Fig. 3). The difference in the seasonal variation of abundance of *A. steueri* between both studies in Ilkwang Bay might be due to the difference in plankton net used (e.g. omitting nauplii and copepodids in the present study) and the year-to-year variation in plankton abundance in relation to the heavy rainfall in the summer and/or the potential for sampling variability. In particular, the heavy rainfall in 1998 may have negatively affected the recruitment of nauplii into adult population after maximum abundance or maximum EPR of *A. steueri* in March–April (Fig. 3). In addition, the abundance and distribution of *A. steueri* vary according to the intrusion of offshore water (Yoo *et al.*, 1991). Given the shallow water depth of Ilkwang Bay, the abundance of *A. steueri* will be strongly affected by tide, and most nauplii hatched in the bay might be transferred offshore such that there was no distinct peak of developing stages after the maximum abundance of eggs in the bay.

Table I: Summary of in situ experiment of egg production (EPR) of Acartia steueri

Date	Temperature (°C)	Chl *a* (mg m^{-3})	Number of incubations	Total number of females incubated	Mean EPR ± SD (eggs female^{-1} d^{-1})
25 October 1997	15.8	2.33	2	2	6.0 ± 1.4
16 November	14.3	1.33	2	3	5.8 ± 1.8
22 December	12.0	0.99	2	5	3.9 ± 0.2
21 January 1998	11.5	1.48	3	8	5.2 ± 2.4
20 February	12.0	6.19	6	24	7.1 ± 1.4
25 March	12.9	3.10	7	30	8.2 ± 2.1
21 April	13.4	3.56	7	34	7.4 ± 2.3
20 May	17.0	11.63	5	18	9.6 ± 1.5
21 June	21.4	10.60	4	13	10.1 ± 2.7
21 July	22.7	4.06	3	5	8.0 ± 1.8
21 August	22.8	3.97	2	4	7.8 ± 3.2
12 September	25.6	4.65	2	3	8.5 ± 0.7

Mean EPR of *A. steueri* in terms of eggs per female per day in the present study was similar to that of Kang and Kang (Kang and Kang, 1998), suggesting no significant difference between the two methods, the direct and indirect methods, respectively (Table III). Therefore, the EPR of *A. steueri* in Ilkwang Bay might be simply measured using the equation of Kang and Kang (Kang and Kang, 1998), without laborious field studies. In brief, the relationship is given as follows: the specific EPR of adult female (g_f, d^{-1}) is estimated by substituting ambient water temperature (T, °C) and chlorophyll *a* concentration (S, mg m^{-3}) into the equation, $g_f = 0.00206(T - 0.5)^{1.33}S/(0.912 + S)$. Then, EPR (μgC m^{-3} d^{-1}) is calculated by the specific EPR multiplied by the biomass of adult female (μgC m^{-3}). Nevertheless, the mean EPR of *A. steueri* in this study (7.3 eggs female^{-1} d^{-1}) was lower than that of *A. steueri* in Uye (Uye, 1981), *Acartia hudsonica* in Sekiguchi *et al.* (Sekiguchi *et al.*, 1980), *Acartia omorii* in Liang and Uye (Liang and Uye, 1996) and *Acartia tonsa* in Ambler (Ambler, 1986) (Table III). The ratio of observed EPR to maximum EPRs (MEPR) is often used as a measure of the degree of growth limitation in copepods (Peterson *et al.*, 2002). If we roughly calculate the MEPR of *A. steueri* from Uye (Uye, 1981) as ~27 eggs female^{-1} d^{-1}, the EPR of *A. steueri* in the present study is 27% of MEPR, indicating a significant degree of growth limitation by food, temperature and other unknown factors.

We found a highly significant correlation between the EPR and the mean chlorophyll *a* concentration for *A. steueri*, and ~85% of the EPR was closely related to the variation of chlorophyll *a* concentration (Fig. 4). The variation of the mean water temperature was relatively less important in controlling the EPR of *A. steueri* than the variation of chlorophyll *a* concentration (Fig. 4), implying that water temperature alone may not be a reasonable factor explaining the variation of EPR in Ilkwang Bay, although Huntley and Lopez (Huntley and Lopez, 1992) demonstrated the importance of water temperature in copepod production. The chlorophyll *a* concentration in Ilkwang Bay (Fig. 2) was generally high, with a mean value of 4.48 mg m^{-3}, roughly equivalent to 36–264 mgC m^{-3} [assuming carbon-to-chlorophyll *a* ratio of 8–59; (Arin *et al.*, 2002)]. This should be sufficient carbon to produce maximum eggs in an *Acartia* species. However, the EPR of *A. steueri* in the present study was far less than the roughly estimated MEPR of *A. steueri* from Uye (Uye, 1981). This result may imply that food quality (Gómez-Gutiérrez and Peterson, 1999) and food size (Uye and Murase, 1997) of phytoplankton available to the copepod are also related to the EPR of the copepod.

Weight-specific EPR is known to be a growth indicator of adult female copepod (i.e. weight-specific growth rate; Berggreen *et al.*, 1988; Peterson *et al.*, 1991; Hirst and Bunker, 2003). We compared the weight-specific growth rate of some calanoid copepods (Table IV). The weight-specific growth rate of *A. steueri* in the present study (0.047 d^{-1}) was relatively lower than that of *A. steueri* in Kang and Kang (Kang and Kang, 1998), *Paracalanus* sp. in Uye and Shibuno (Uye and Shibuno, 1992) and *Calanus pacificus* in Peterson *et al.* (Peterson *et al.*, 2002) and similar to that of *Calanus marshallae* in Peterson *et al.* (Peterson *et al.*, 2002) and *Paracalanus parvus* in Gómez-Gutiérrez and Peterson (Gómez-Gutiérrez and Peterson, 1999). It has been known that at a given fixed chlorophyll *a* concentration, the growth rate (or EPR) of smaller copepods should always be greater than that of larger copepods in the laboratory (Vidal, 1980). However, the weight-specific growth rate

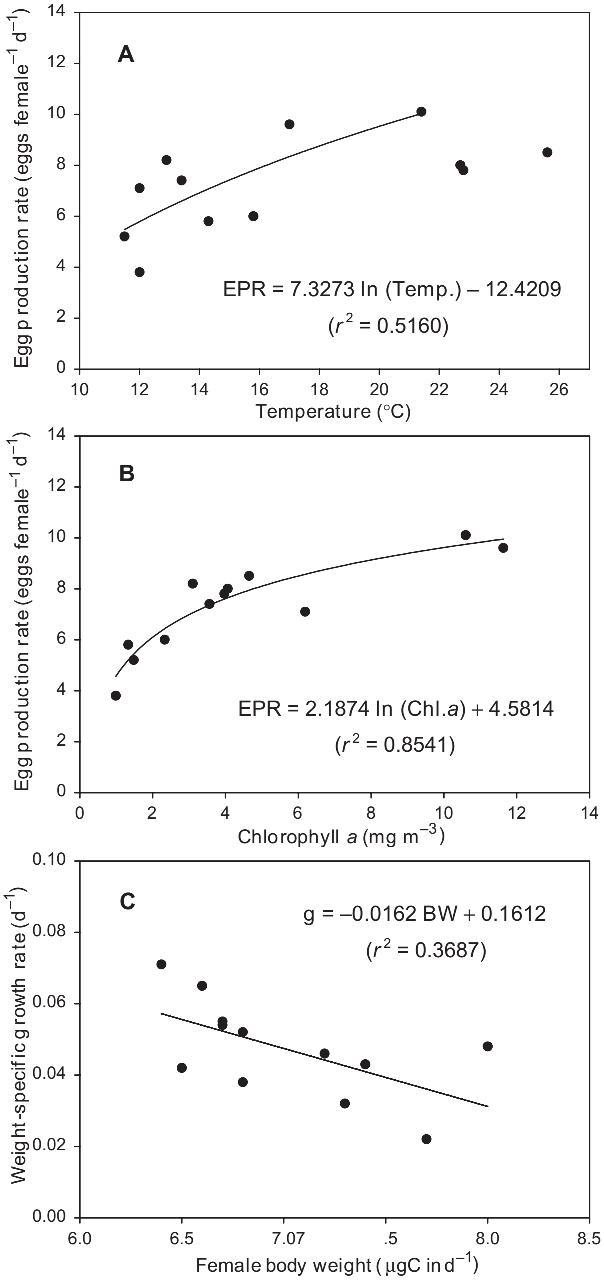

Fig. 4. *Acartia steueri*. Egg production rate (EPR) as a function of mean water temperature (**A**) and mean chlorophyll *a* concentration (**B**). Weight-specific growth rate (*g*) as a function of female body weight (**C**). Temp., temperature; Chl *a*, chlorophyll *a* concentration; BW, female body weight.

Table II: Body weight of adult female, egg production rate and weight-specific growth rate of Acartia steueri

Date	Body weight of female (μgC ind^{-1})	Egg production rate (μgC female^{-1} d^{-1})	Weight-specific growth rate (d^{-1})
25 October 1997	6.5	0.270	0.042
16 November	6.8	0.261	0.038
22 December	7.7	0.171	0.022
21 January 1998	7.3	0.234	0.032
20 February	7.4	0.320	0.043
25 March	6.7	0.369	0.055
21 April	7.2	0.333	0.046
20 May	6.6	0.432	0.065
21 June	6.4	0.455	0.071
21 July	6.7	0.360	0.054
21 August	6.8	0.351	0.052
12 September	8.0	0.383	0.048

The egg production rate in terms of carbon content was calculated using the carbon weight (0.045 μgC) of the eggs of *A. steueri* (Uye, 1981).

Table III: Comparison of egg production rate (EPR) among the genus Acartia

Species	Temperature (°C)	EPR (eggs female^{-1} d^{-1})	Author(s)
Acartia hudsonica	15	20	Sekiguchi *et al.* (1980)
Acartia longiremis	7–16	7.6	Peterson *et al.* (1991)
A. longiremis	7–14	0.4–17.1	Nielsen and Andersen (2002)
Acartia omorii	8.9–24.3	26–60	Liang and Uye (1996)
Acartia steueri	15	17–37	Uye (1981)
A. steueri	11.0–25.4	5.4–12.5 (8.0)	Kang and Kang (1998)
Acartia tonsa	15	22	Ambler (1986)
A. steueri	11.5–25.6	3.9–10.1 (7.3)	This study

The values in parentheses indicate the mean EPR.

of copepods was variable between and within species (Table IV). The weight-specific growth rate decreased with increasing female body weight in the present study (Fig. 4). Hirst and Bunker (Hirst and Bunker, 2003) demonstrated that the relationship between female weight-specific growth rate and the female body weight was negative in broadcast spawners, but the relationship might be negative or positive in sac-spawning adults depending on food availability, indicating that the relationship might vary in association with the degree of food limitation in the field. Therefore, the poor relationship seen in Table IV might be related to food quality (Gómez-Gutiérrez and Peterson, 1999; Jones *et al.*, 2002) and food limitation (Hirst and Bunker, 2003) in the field.

Table IV: Comparison of weight-specific growth rate (d^{-1}) among calanoid copepods

Species	Temperature (°C)	Weight-specific growth rate	Authors
Calanus marshallae	10–13	0.03–0.06	Peterson *et al.* (2002)
Calanus pacificus	10–13	0.19–0.20	Peterson *et al.* (2002)
Paracalanus sp.	17.5	0.26	Uye and Shibuno (1992)
Paracalanus parvus	10–13	0.04–0.10	Gómez-Gutiérrez and Peterson (1999)
Centropages abdominalis	10–13	0.03–0.19	Gómez-Gutiérrez and Peterson (1999)
Acartia longiremis	10–13	0.01–0.20	Gómez-Gutiérrez and Peterson (1999)
A. longiremis	7–16	0.03–0.13	Peterson *et al.* (1991)
Acartia steueri	11.0–25.4	0.064	Kang and Kang (1998)
A. steueri	11.5–25.6	0.047	This study

In conclusion, our results confirm that the EPR of *A. steueri* in terms of eggs per female per day was similar to the value obtained by Kang and Kang (Kang and Kang, 1998), indicating that the equation obtained from the laboratory experiment with factors including water temperature and chlorophyll *a* concentration might be applicable for the estimation of egg pro-duction of *A. steueri* in Ilkwang Bay. Gómez-Gutiérrez and Peterson (Gómez-Gutiérrez and Peterson, 1999) pointed out that egg production could be a sensitive indicator of how copepod populations respond to changes in temperature, water-column stability and food availability. Further studies on EPR of dominant copepods in Korean waters will be necessary to understand the biological function of the copepods in the marine ecosystem.

ACKNOWLEDGEMENTS

We thank W. T. Peterson for valuable comments on the manuscript.

REFERENCES

Ambler, J. W. (1986) Effect of food quantity and quality on egg production of *Acartia tonsa* Dana from East Lagoon, Galveston, Texas. *Est. Coast. Shelf Sci.*, **23**, 183–196.

Arin, L., Moran, X. A. G. and Estrada, M. (2002) Phytoplankton size distribution and growth rates in the Alboran Sea (SW Mediterranean): Short term variability related to mesoscale hydrodynamics. *J. Plankton Res.*, **24**, 1019–1033.

Berggreen, U., Hansen, B. and Kiørboe, T. (1988) Food size spectra, ingestion and growth of the copepod *Acartia tonsa* during development: Implications for determination of copepod production. *Mar. Biol.*, **99**, 341–352.

Gómez-Gutiérrez, J. and Peterson, W. T. (1999) Egg production rates of eight calanoid copepod species during summer 1997 off Newport, Oregon, USA. *J. Plankton Res.*, **21**, 637–657.

Hirst, A. G. and Bunker, A. J. (2003) Growth of marine planktonic copepods: Global rates and patterns in relation to chlorophyll *a*, temperature, and body weight. *Limnol. Oceanogr.*, **48**, 1988–2010.

Huang, C., Uye, S. and Onbé, T. (1993) Geographic distribution, seasonal life cycle, biomass and production of a planktonic copepod *Calanus sinicus* in the Inland Sea of Japan and its neighboring Pacific Ocean. *J. Plankton Res.*, **15**, 1229–1246.

Huntley, M. and Lopez, M. D. G. (1992) Temperature-dependent production of marine copepods: a global synthesis. *Am. Nat.*, **140**, 201–242.

Hutchings, L., Verheye, M., Mitchell-Innes, B. A. *et al.* (1995) Copepod production in the southern Benguela system. *ICES J. Mar. Sci.*, **52**, 439–455.

IGBP (1999) Global Ocean Ecosystem Dynamics (GLOBEC) Implementation Plan. *IGBP Rep. 47*. The International Geosphere-Biosphere Programme, Stockholm, Sweden, 207 pp.

Jones, R. H., Flynn, K. J. and Anderson, T. R. (2002) Effect of food quality on carbon and nitrogen growth efficiency in the copepod *Acartia tonsa*. *Mar. Ecol. Prog. Ser.*, **235**, 147–156.

Kang, H.-K. (1997) Primary production and production of copepod *Acartia steueri* in Ilkwang Bay, southeast coast of Korea. PhD Thesis. Pukyong National University, Busan, 226 pp.

Kang, H.-K. and Kang, Y. J. (1997) Length and weight relationship of *Acartia steueri* (Copepoda: Calanoida) in Ilkwang Bay, Korea. *J. Korean Fish. Soc.*, **30**, 906–908.

Kang, H.-K. and Kang, Y. J. (1998) Egg production of the copepod *Acartia steueri* in Ilkwang Bay, southeastern coast of Korea. *J. Korean Fish. Soc.*, **31**, 288–295.

Liang, D. and Uye, S. (1996) Population dynamics and production of the planktonic copepods in a eutrophic inlet of the Inland Sea of Japan. II. *Acartia omorii*. *Mar. Biol.*, **125**, 109–117.

Nielsen, T. G. and Andersen, C. M. (2002) Plankton community structure and production along a freshwater-influenced Norwegian fjord system. *Mar. Biol.*, **141**, 707–724.

Omori, M. and Ikeda, T. (1984) *Methods in Marine Zooplankton Ecology*. Wiley, New York, 332 pp.

Park, C. (1997) Seasonal distribution, egg production and feeding by the marine copepod *Calanus sinicus* in Asan Bay, Korea. *J. Korean Soc. Oceanogr.*, **32**, 85–92.

Park, C. and Lee, P. G. (1995) Egg production by marine copepod *Calanus sinicus* in Asan Bay, Korea. *J. Korean Fish. Soc.*, **28**, 105–113.

Parson, T. R., Maita, Y. and Lalli, C. M. (1984) *A Manual of Chemical and Biological Methods for Seawater Analysis*. Pergamon Press, New York, NY, 173 pp.

Peterson, W. T., Gómez-Gutiérrez, J. and Morgan, C. A. (2002) Cross-shelf variation in calanoid copepod production during summer 1996 off the Oregon coast, USA. *Mar. Biol.*, **141**, 353–365.

Peterson, W. T., Tiselius, P. and Kiørboe, T. (1991) Copepod egg production, molting and growth rates, and secondary production, in the Skagerrak in August 1988. *J. Plankton Res.*, **13**, 131–154.

Poulet, S. A., Ianora, A., Laabir, M. *et al.* (1995) Towards the measurement of secondary production and recruitment in copepods. *ICES J. Mar. Sci.*, **52**, 359–368.

Rigler, F. H. and Downing, J. A. (1984) The calculation of secondary productivity. In Downing, J. A. and Rigler, F. H. (eds), *A Manual on Methods for the Assessment of Secondary Productivity in Fresh Waters*. Blackwell Scientific, Oxford, pp. 19–58.

Sekiguchi, H., McLaren, I. A. and Corkett, C. J. (1980) Relationship between growth rate and egg production in the copepod *Acartia clausi hudsonica*. *Mar. Biol.*, **58**, 133–138.

Uye, S. (1981) Fecundity studies of neritic calanoid copepods *Acartia clausi* Giesbrecht and *A. steueri* Smirnov: a simple empirical model of daily egg production. *J. Exp. Mar. Biol. Ecol.*, **50**, 255–271.

Uye, S. and Murase, A. (1997) Relationship of egg production rates of the planktonic copepod *Calanus sinicus* to phytoplankton availability in the Inland Sea of Japan. *Plankton Biol. Ecol.*, **44**, 3–11.

Uye, S. and Shibuno, N. (1992) Reproductive biology of the planktonic copepod *Paracalanus* sp. in the Inland Sea of Japan. *J. Plankton Res.*, **14**, 343–358.

Vidal, J. (1980) Physioecology of zooplankton. 1. Effects of phytoplankton concentration, temperature and body size on the growth of *Calanus pacificus* and *Pseudocalanus* sp. *Mar. Biol.*, **56**, 111–134.

Yoo, K. I., Hue, H. K. and Lee, W. C. (1991) Taxonomical revision on the genus *Acartia* (Copepoda: Calanoida) in the Korean waters. *Bull. Korean Fish. Soc.*, **24**, 255–265.