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Population ecology of *Palaemon gravieri* (Yu, 1930) (Decapoda, Caridea, Palaemonidae) in Osaka Bay, Japan*1

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Growth, fecundity, and stomach contents of the caridean shrimp, *Palaemon gravieri*, in Osaka Bay were studied. The growth curves are $Lt=10.46\ (1-\exp(-3.865(0.08333t-0.009012+0.1560\sin(0.5236t-5.865))))$ for males and $Lt=24.47(1-\exp(-0.6764(0.08333t+0.4103+0.1523\sin(0.5236t-6.347))))$ for females, where Lt is the carapace length (mm) at age t (months) after June when larval settlement was estimated to occur. The life span is about one year for both sexes. The breeding season (occurrence of ovigerous females) extends from March to October. Ovigerous females that occur late in the season, from August to October, are offspring from the large-sized females which incubate eggs at the beginning of the breeding season. The number of eggs incubated (Y) is related to female carapace length (X, mm): $Y=0.07487X^{4.136}$ ($n=43$, $r=0.919$, $P<0.001$). Stomach contents show that this species is a scavenger.

1. Introduction

Eleven species of *Palaemon* are distributed in Japan[1,2,3], but reports on population dynamics are available for only four species, e.g. *P. macrodactylus* by Omori and Chida[4,5], *P. ortmanni* by Maihara and Suzuki[6], *P. paucidens* by Kamita[7] and Nishino[8], and *P. serrifer* by Yasuda[9]. *P. macrodactylus*, *P. ortmanni*, and *P. serrifer* are marine species and *P. paucidens* is a freshwater species[2,3].

P. gravieri is distributed in China, Taiwan, Korea and Japan[3]. The present authors had a chance to obtain specimens of *P. gravieri* collected successively in Osaka Bay employing bottom trawl for penaeid prawns and other edible animals during surveys by the research vessel Konpira-maru, Hyogo Prefectural Fisheries Experimental Station. Although the number of *P. gravieri* taken was insufficient for a detailed study of the population dynamics, information on the growth, fecundity, and diet of this species could be deduced from the data set.

2. Materials and Methods

Animals were captured with a bottom trawl (mesh size of cod end, ca. 1×1 cm) in Osaka Bay, Japan (135°0'−135°10'E, 34°20'−34°35'N, water depth 30−60 m), at night once almost every month from September 1985 to February 1987. *P. gravieri* used here were selected from a subsample of the total catch which was preserved in 10% formalin. Thus, the monthly number of specimens do not reflect the density within the population.

Separation of sex was examined from the morphology of the endopod of the second pleopod following Kubo[10]. For measuring *P. gravieri*, CL (=carapace length) was adopted. This is the distance from the

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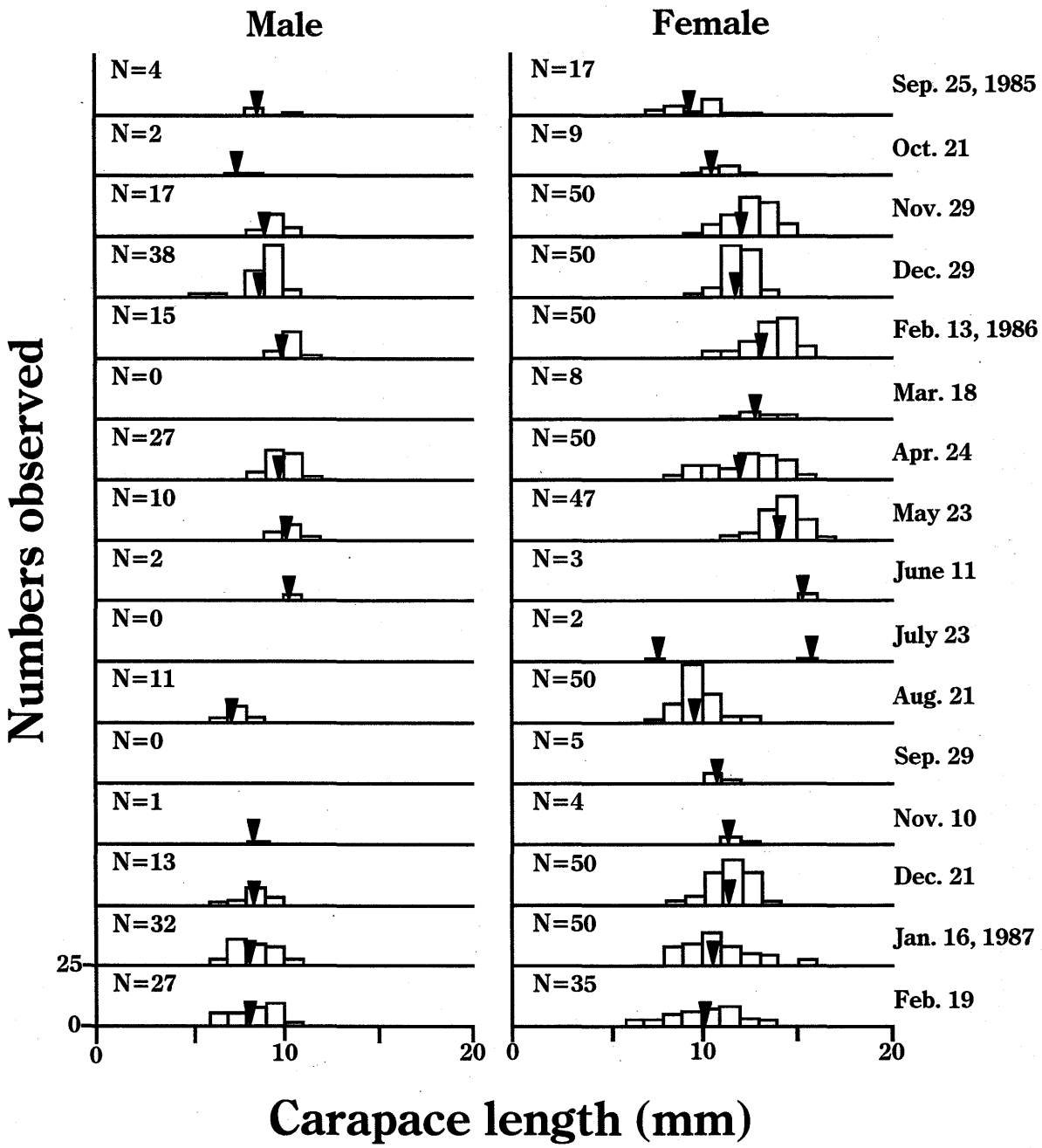

Fig. 1. Size distribution of *Palaemon gravieri* collected in Osaka Bay. Triangles indicate the means of samples.

posterior margin of the orbit to the posterodorsal margin of the carapace. BL (=body length) is the length from the posterior margin of the orbit to the posterior margin of the telson. This also was measured on specimens from a stratified sample of CL to study a relationship with CL.

Bertalanffy growth curves with a periodic function[11] were applied to the mean CLs of the male and the female cohorts by the Marquardt method[12].

Fifty eggs were removed from each ovigerous female, and their lengths and widths were measured under microscope to the nearest 0.01 mm. The number of eggs carried by an ovigerous female was counted for 43 individuals.

Stomach contents of specimens were observed under a binocular microscope.

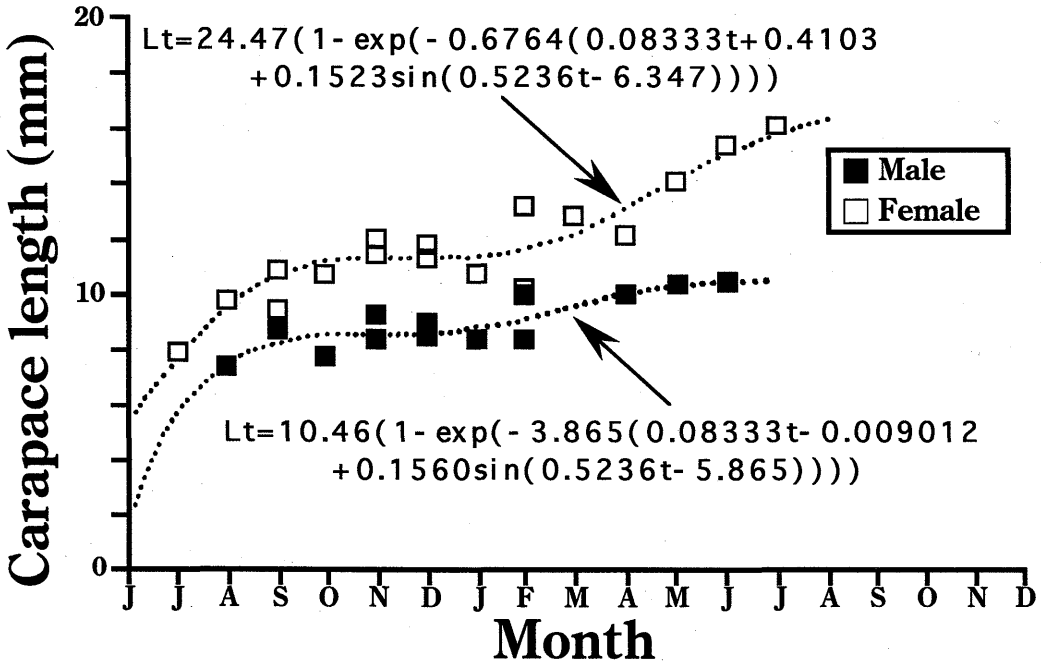

Fig. 2. Growth curves of *Palaemon gravieri*. The means of the 13 male cohorts and the 17 female cohorts (triangles in Fig. 1) were used for the growth analysis.

3. Results

3.1 Size measurements

Linear relationships for males:

$$Y = 3.233X + 3.080 \quad (n=127,\ r=0.962,\ P<0.001) \quad (1)$$

and for females:

$$Y = 3.352X + 1.606 \quad (n=145,\ r=0.984,\ P<0.001) \quad (2)$$

where, X is CL (mm) and Y is BL (mm). The slope coefficients and the intercepts of these two regression equations were identical to each other (ANCOVA, $P>0.05$). Hence, a common regression was recalculated as

$$Y = 3.277X + 2.588 \quad (n=272,\ r=0.986,\ P<0.001) \quad (3)$$

3.2 Growth

In this study, 199 males and 480 females of *P. gravieri* were examined. Ranges of CLs were 5.3−11.5 mm for males and 6.3−16.0 mm for females. Monthly CL distributions of specimens are shown in Fig. 1. The earliest recruitment of juveniles was observed in July. Furthermore, many ovigerous females were captured in April and May as described below. Thus, we applied Bertalanffy growth curves with a periodic function to the mean CLs (triangles in Fig. 1) of the male and the female cohorts based upon the modal settlement of larvae that was estimated to occur in June (Fig. 2):

Male

$$Lt = 10.46(1-\exp(-3.865(0.08333t-0.009012 +0.1560\sin(0.5236t-5.865)))) \quad (4)$$

Female

$$Lt = 24.47(1-\exp(-0.6764(0.08333t+0.4103 +0.1523\sin(0.5236t-6.347)))) \quad (5)$$

where, Lt is CL (mm) at age t (months) after settlement and exp is the exponential function. The residual sum of squares as a measure of the goodness of fit was 3.16 and 9.13 for growth equations (4) and (5), respectively.

Males of *P. gravieri* grew rapidly and reached over 8 mm CL in three months after hatching in Osaka Bay. Although the cohort grew little from September to the following January, growth recommenced in February and males reached to 10.3 mm in June one year after settlement and then they died. In females, the growth rate was faster than that of the male. They reached to 11 mm

Table 1. Monthly occurrence of ovigerous *Palaemon gravieri* collected in Osaka Bay

Date	No. of females			B/A	Mean CL (mm) of female cohort	Mean (range) CL (mm) of ovigerous females
	Observed	≧8.1mm CL*1 (A)	Ovigerous (B)			
Sep. 25, 1985	17	12	0	0	9.3	
Oct. 21	9	9	1	0.11	10.6	11.0
Nov. 29	50	50	0	0	12.0	
Dec. 29	50	50	0	0	11.8	
Feb. 13, 1986	50	50	0	0	13.2	
Mar. 18	8	8	1	0.12	12.8	14.1
Apr. 24	50	50	43	0.86	12.1	12.3 (8.6 - 15.2)
May 23	47	47	26	0.55	14.1	13.9 (11.5 - 16.0)
June 11	3	3	3	1.00	15.2	15.2 (15.0 - 15.5)
July 23	2	1	1	1.00	15.9*2	15.9
Aug. 21	50	50	39	0.78	9.6	9.7 (8.1 - 12.9)
Sep. 29	5	5	3	0.60	10.7	10.8 (10.5 - 11.0)
Nov. 10	4	4	0	0	11.4	
Dec. 21	50	50	0	0	11.3	
Jan. 16, 1987	50	50	0	0	10.6	
Feb. 19	35	29	0	0	10.0	

*1 The size of the smallest ovigerous female
*2 Largest-sized cohort

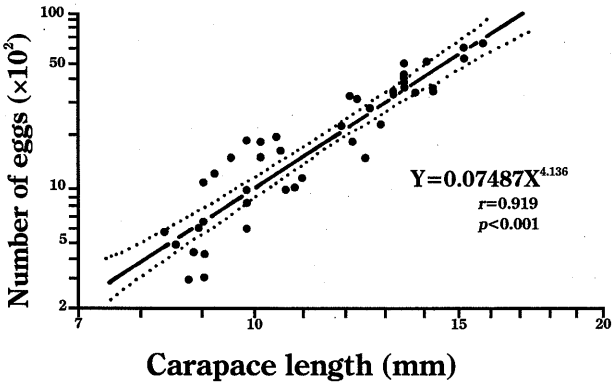

Fig. 3. Relationship between the carapace length and the number of eggs incubated by *Palaemon gravieri* in Osaka Bay. Dotted curves indicate the 95 % confidence limits of expectation.

CL in four months after settlement and remained at a low growth rate until the following January, however growth recommenced in February and reached over 15 mm in July over one year after settlement and they died after spawning (Fig. 2).

3.3 Fecundity

Eggs of *P. gravieri* are oval in shape. The mean (range) dimensions of 50 eggs were 0.49 (0.40−0.52) × 0.40 (0.38−0.45) mm for uneyed eggs and 0.69 (0.62−0.75) × 0.55 (0.45 −0.65) mm for eyed ones.

The number of eggs attached to pleopods of 43 ovigerous *P. gravieri* was counted. The range of CLs of ovigerous females was 8.3−15.8 mm and that of the number of eggs was 305−6456. A regression formula was applied to the relationship between the CL (X, mm) of females and the number of eggs incubated (Y) by the least squares method (Fig. 3):

$Y=0.07487X^{4.136}$ ($n=43$, $r=0.919$, $P<0.001$) (6)

The lower size limit for ovigerous *P. gravieri* was 8.1mm CL though we did not count its number of eggs due to the large amount of egg loss that appeared to have occurred.

The ovigerous females appeared between March and October in this bay (Table 1). Their frequency of occurrence was high from April to September. A female of *P. gravieri* experienced twice the spawning during its life (Fig. 2 and Table 1). CLs of ovigerous female that appeared from March to July were larger than those from August to October (Table 1). Ovigerous females that appeared at the beginning of the season, March and July, were spawned in the previous year and those from August to October originated from the generation born at the beginning of the season.

3.4 Stomach contents

Most of stomach contents of *P. gravieri* were very small fragments of organisms.

Prey materials we could identify were the setae of polychaetes, exoskeletons of small crustaceans, scales of cycloid fish, and horny rings of cuttlefish. *P. gravieri* has no raptorial weapon to prey on living animals, thus, we conclude that this shrimp is a scavenger.

4. Discussion

The life span after settlement of *P. gravieri* is about one year in Osaka Bay (Figs. 1 and 2). The life spans of *P. macrodactylus* from Matsushima Bay (Miyagi Prefecture), *P. ortmanni* from Suruga Bay (Shizuoka Prefecture), and *P. paucidens* from various places of Japan, have been found to be over two years[4, 6, 7]. Yasuda[9] estimated *P. serrifer* from Kasaoka Bay (Okayama Prefecture) survived for 4 - 12 months.

P. gravieri and the former three species reach more than BL 50 mm, but that of *P. serrifer* is 30−40 mm[1, 2]. As a result, the growth rate of *P. gravieri* is more rapid than that of others. However, the present species has a smaller size range of uneyed eggs (0.49×0.40 mm) than those of the other four species, *i.e.*, 1.27×1.02 mm, 0.73×0.56 mm, 0.69×0.55 mm, and 0.61×0.50 mm for *P. paucidens*, *P. macrodactylus*, *P. serrifer*, and *P. ortmanni*, respectively[6, 8, 13]. Therefore, it is concluded that *P. gravieri* has more strongly selected a *r*-strategy rather than a *K*-strategy (Pianka[14]) compared among these five species of *Palaemon*.

Although the breeding season of *P. gravieri* is from March to October, ovigerous females appeared from August to October, derived from the large-sized females incubating at the beginning of the breeding season, March to July (Fig. 1 and Table 1). Omori and Chida[4] observed a phenomenon similar to this for *P. macrodactylus i.e.*, larger females of two year-old began to spawn earlier and then followed by medium-sized ones of one year-old, and then, the earlier cohorts from the two year-old females spawned. Youngest ovigerous female of *P. macrodactylus* can produce more offsprings under an environmental condition and its reproductive mode was regarded as a kind of mixed strategy of Levines[5, 15, 16]. The present species, *P. gravieri,* will also be categorized as having this mixed reproductive strategy that permits a better adaptive function in fluctuating environments.

P. gravieri larvae that hatched from young females from August to October did not form a distinguishable component as a newly recruited group after August (Fig. 1). This group, however, was probably included among a part of smaller members in parents' component of the minority in number and the high growth rate.

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大阪湾におけるナイカイスジエビ *Palaemon gravieri* の個体群生態

荒木　晶・林　健一

大阪湾に生息するナイカイスジエビ *Palaemon gravieri* の成長，繁殖様式，胃内容物について研究を行った。6月に幼生が着底したとして，その後 t カ月目の頭胸甲長 Lt (mm) は，雄では，$Lt=10.46(1-\exp(-3.865(0.08333t-0.009012+0.1560\sin(0.5236t-5.865))))$，雌では，$Lt=24.47(1-\exp(-0.6764(0.08333t+0.4103+0.1523\sin(0.5236t-6.347))))$ であり，また，寿命は雌雄とも約1年であった。抱卵期は3月～10月にわたるが，このうち8月～10月に抱卵していた雌は，先に3月～7月に抱卵する大型の雌より産み出された個体と考えられた。抱卵個体の頭胸甲長X(mm)と抱卵数Yとの間には，$Y=0.07487X^{4.136}$（$n=43$, $r=0.919$, $P<0.001$）の関係があった。胃内容物は，本種が腐肉食者であることを示した。