Thesis for the Degree of Master of Science

Reproduction and growth of the caridean hinge beak shrimp, *Rhynchocinetes uritai* (Kubo, 1942) (Caridea, Rhynchocinetidae) from the East Sea of Korea.

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February 2015

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A thesis submitted in partial fulfillment of the requirements
for the degree of

Master of Science

In Department of Marine Biology, The Graduate School,
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February 27, 2015

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Growth and reproduction of the caridean hinge beak shrimp, *Rhynchocinetes uritai* De Kubo, 1942 (Caridea, Rhynchocinetidae) from the East Sea of Korea.

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Abstract

Biological knowledge of the hinge beak shrimp, *Rhynchocinetes uritai* in Korean waters is scarce. The objective of this work is to provide the information on size structure, size at maturity and growth of the hinge beak shrimp. We registered 1787 into two consecutive sampling seasons (2012-2013), ratio of females to males was significantly greater ratio 1: 0.25, with predominance of females on larger class sizes, using natural log transformed cephalothorax length-wet weight (LWR) relationships estimated were lnBW = 2.4063 lnCL -5.6628 and lnBw = 2.417lnCL -5.7675 for females and males respectively. The gonadosomatic index (GSI) varied monthly with maximum in September (5.12) and minimum April 2013 (0), the highest values of the GSI coincide with the breeding period, there was significant difference between the mean GSI of females with non-eyed and eyed egg, indicating *R. uritai* is a consecutive breeder. There was no significant difference in the slope of the regressions of number of egg versus carapace length between females carrying non-eyed and eyed egg stages ($F = 0.4$, $P>0.05$) whereas there was a significant difference in intercepts ($F = 24.16$, $P< 0.05$), indicating there was brood loos between the two egg stages. Egg volume increased 90% as eggs developed from non-eyed to eyed stage. Based on dry weight in early stages, reproductive output was determined as 0.22±0.016. mean size at sexual maturity of females was $CL_{50} = 8.45$ mm. the von Bertalanffy growth parameters were $L\infty = 14.89$mm, $C = 0.2$, $WP = 0.25$, $\varphi' = 2.01$ for males and $L_{\infty} = 21.43$mm, $C = 0.7$, $WP = 0.65$, $\varphi' = 2.15$ for females.

1. Introduction

Within the decapod crustaceans, the caridean shrimps are a particularly diverse group ecologically (Bauer 2004). The Rhynchocinetidae shrimps common in shallow warm waters of Japan and southern coasts of Korea (Maihara 2002), characterized by having a movable rostrum, are currently represented by two genera Cinetorhynchus and Rhynchocinetes. The shrimps of Rhynchocinetes are widely distributed through the Indo-Pacific (Okuno 1997); nevertheless, only one species R. uritai (Kubo, 1942) is reported in Korean waters (Kim and Kim 1997).

R. uritai like most shrimp, it is nocturnal hides in the crevices and caves of coral rocks at day, those habitats provide safe cover from predators. However, it is a carnivorous shrimp and it feeds actively on the surface of the rocks at night on detritus, phytoplankton and zooplankton. This cryptic behavior strongly resembles those of R. rigens (Okuno 1994) and of R. hendersoni by (Okuno 1993).

Comprehensive research includes studies on ecology and reproduction (Berglund 1981) Growth and reproduction are important aspects of the ecology and life history of species, in crustaceans, they have been quantified by several measurements (Anger and Moreira 1998).

Growth may be quantified as increase in total body length and reproduction is frequently measured in terms of fecundity (Corey and Reid 1991).
Previous studies on R. uritai were all descriptive of total larval stages (Maihara 2002), first zoeal stage (Yang and Park 2004), distinction of other similar Rhynchocinetidae species (Okuno and Takeda 1992) or describing the mating system and protendry (Bauer and Thiel 2011).
There was a leak of information on growth and reproduction and population structure of this family. Therefore, the present works investigates and describe the biology and ecology of R. uritai reproduction and growth in the study area. Revealing information on sex ratio, length frequency distribution of population, monthly gonadosomatic index (GSI) of females and the size and weight of eggs (Kim et al. 2008), reproductive biology with respect to monthly proportions of ovigerous females and mean length at sexual maturity. Estimate of seasonal von Bertalanffy growth parameters for each sex using length frequency data.

2- Material and methods

2-1. Reproduction

2-1-1. sample collection

Rhynchocinetes uritai specimens were sampled monthly from Nasa-ri fishing sea port anchorage walls (35°21’15 N, 129°20’26 E) during March 2012 until May 2013. Samples were collected using hand net, in depths of 2 to 3 m during night for 3 to 4 hours, then preserved in 10% neutralized formalin solution.

Fig. 1. Map of sampling site in the East Sea of Korea.

Fig. 2. Rhynchocinetes uritai De Kubo, 1942. a. female and b. male.

2-1-2. Sex ratio

Samples were identified by using shrimp of Korean waters by (Cha et al. 2001) separated according to sex and measured. Sex was determined under a light microscope (Zeiss Stemi SV-6) by morphometric examination based on the presence or absence and shape of appendix masculine on the endopodite of the second pleopod (Bauer and Thiel 2011), and gonads form. Individuals smaller than minimum sex-able size were counted as males since morphologically similar with young males. Male to female to transitional sex ratio was determined from all samples collected.

2-1-3. Length frequency distribution

Population structure was determined based on the size frequency distributions of all individuals classified on male, female or transitional. Size frequency distribution of each sex was constructed using 1-mm length intervals of carapace length (CL), measured from the base of the eyestalk to posterior edge of the carapace.

2-1-4. Morphometric relationship

Morphometric relationship was investigated between carapace length (CL) and body weight (BW). CL was measured with the same method as used on size frequency distribution measurement, while BW was measured using digital balance to the nearest 0.01g after all remain water is removed from shrimp body. The relationship between CL and BW were analyzed linear regression using natural log (ln) transformed data and calculated separately for males and females, presented by allometric graph on both sexes separately. Linear regression test was using this following equation:

$$\ln BW = a + b \ln CL$$

Where, *a* was intercept and b was slope. For the relationship body weight and carapace length, the pattern was established by the *b*-value slope ($b=3$ isometry; $b<3$, negative allometry and $b>3$, positive allometry). Pooled regressions are given only when differences between the slopes or intercepts of separate regressions were statistically not significant.

Intra specific variation in morphometric relation between different sexes was indicated using slopes value differences between regressions of two sexes. According to (Anger and Moreira 1998), different intercepts are difficult to be interpreted, because this parameter may represent an extrapolation below the range measured, and its comparison may have little biological meaning. By contrast, the slope should be a more useful growth parameter, indicating a different degree of dependence among size dimensions (Anger and Moreira, 1998).

2-1-5. ovarian examination and gonadosomatic index

The ovarian stages were determined according to Bauer's (1986) illustrations of size and shape in proportion to the gastric mill and thoracic cavity, and external appearance of the ovary. In present study, the ovarian stages were determined by modified Bauer's illustrations (table 1). Four main stages of development were established: immature (stage 1, 2); maturing (stage 3); ripe (stage 4); spent. Body and ovarian dry weight by drying at 80°C for 48 h and weighing to the nearest 0.0001g using an electronic digital balance. GSI was determined by the following formula;

$$\mathrm{GSI} = \frac{\text{ovarian dry weight}}{\text{body dry weight}} \times 100$$

Table 1. Ovary stage modified from Bauer (1986)

Stage	description according to Bauer (1986)	gonads color	present study
Stage 1	no noticeable development	transparent	Immature
Stage 2	vitellogenic oocytes distinct but ovary small	white milky	
Stage 3	ovary filling at least half the space above the cardiac stomach	yellow	Maturing
Stage 4	ovary completely filling that space	orange	Ripe
	Similar shape with stage 1 but vestige of breeding	Yellowish White.	Spent

2-1-6. Egg size

Egg size of ovigerous females was recorded as two stages: (1) eyed egg (fig. 3a); and (2) non eyed egg fig (fig. 3b). Eggs were carefully removed from pleopods using fine forceps and counted.

For egg volume calculation, 15 egg were selected from each female before egg drying to be measured.

These were measured along the major and minor axes using light microscope (Zeiss Stemi SV-6) and image-pro plus version 4.1 (magnification 8x) to the nearest 0.01 mm the eggs were treated as ellipsoids, and the volume (V) of eggs was calculated by using the following equation

$$V = {}^{4}/_{3}\pi\, r_1\, r_2^{2}$$

Were r_1 is half the major axis and r_2 is half the minor axis.

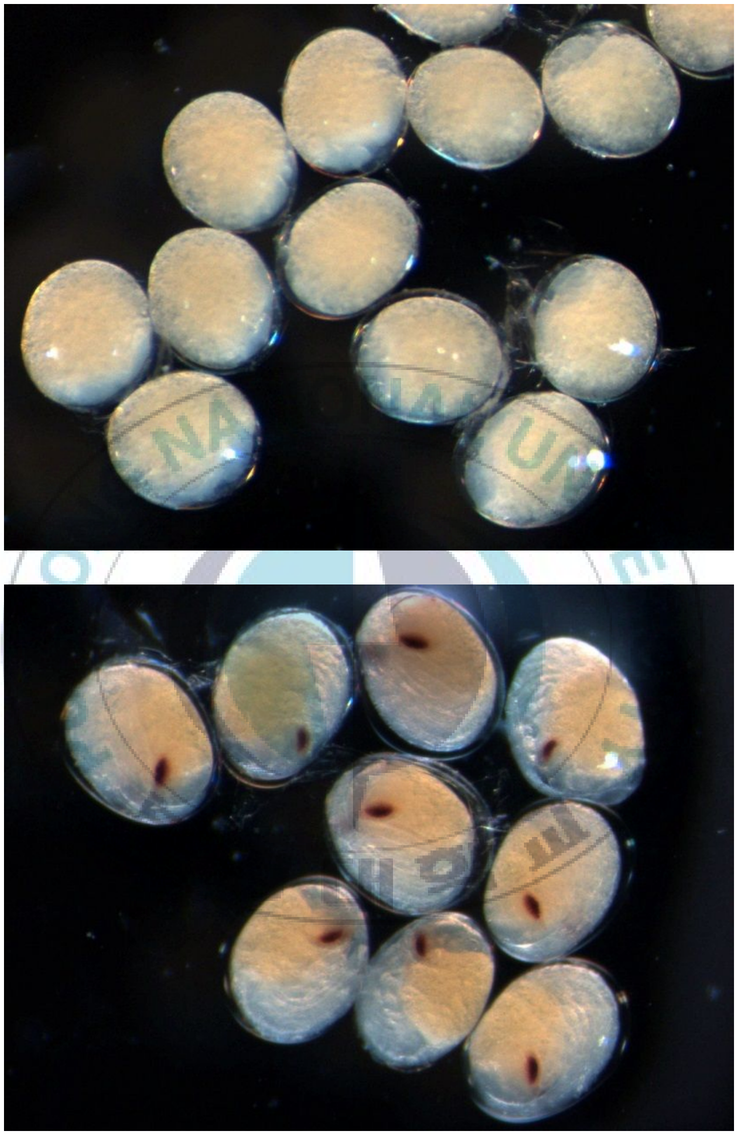

Fig. 3. a, non-eyed stage and; b, eyed stage eggs of *Rhynchocinetes uritai* De Kubo, 1942.

2-1-7. Relationship between body size and number of eggs

Body size was represented by carapace length (CL). The number of eggs (EN)-CL relationship was estimated using data of 50 females with non-eyed eggs and 15 females with 15 eyed eggs. The size and fecundity data were natural log (ln) transformed so that the data conform more closely to the assumptions of linear regression analysis regarding homogeneity of error variance over the range equation (bird and prairie, 1985 cited in Anger and Moirea, 1998). Linear regression test on ln transformed data of CL and EN was used to find the relation between number of eggs and body size, with following equation:

$$\ln EN = a + b \ln CL$$

Where, *a* was intercept and b was slope, consider a constant rate of increase. For the relationship number of eggs and carapace length, the pattern of allometry was established with the same method on body weight-carapace length relationship. Slope and intercept of both non- and eyed–egg stages linear regression were compared to investigate brood mortality.

2-1-8. Fecundity and reproductive output (RO)

The evaluation of fecundity becomes necessary because it is considered a measure of the reproductive fitness of Crustacea (Nazari et al., 2003) Fecundity was measured by the average of the number of eggs (EN) in non-eyed eggs stage attached to the pleopods of females. Non-eyed egg stage was used when brood loss observed during incubation period as reported on other caridean shrimps (Oh and Hartnoll, 1999; Bilgin and Samsun, 2006). Otherwise, number of eggs from both egg stages was pooled and the average number was used to determined fecundity.

Reproductive output (RO) was calculated using ovigerous females with non-eyed stage. Eggs were stripped carefully from pleopods of females. Both female body and eggs were dried at 80°C during 48 h and weight to estimate RO, which calculated by following formula (Kim et al., 2008):

RO = Egg dry weight / Female dry body weight

2-1-9. Size at sexual maturity (CL_{50})

The proportion of sexually mature females, based on the number of non-ovigerous females exceeding stage 2 in ovary development was obtained for each size class. A logistic curve may be fitted to the proportion of sexually mature females by carapace length. Adapting Campbell (1985) gives:

$$P = \frac{1}{(1 + \mathrm{e}^{-(a+b.CL)})}$$

Where a and b are parameters. The parameter estimation of this equation was made by correlation analysis of variable P and CL after linearization.

2-2. Growth

Histograms of CL by sex were constructed for each month, using a class interval of 1 mm. Hasselblad (1966) To estimate the growth parameters of *R.uritai* in the East sea of Korea, the seasonalized von Bertalanffy growth function was fitted to the mean CL of the resolved normal distributions on the monthly histograms separated by sex (Sparre and Venema 1992).

$$L_t = L_\infty[1 - e^{[-K(t-t_0)-\frac{CK}{2\pi}\sin 2\pi(t-t_s)]}]$$

Where L_t is CL at age t (years), L_∞ is the mean length of an infinitely old shrimp (asymptotic length), k is the growth coefficient (rate of growth towards the asymptote), t_0 is the time (years) when CL would have been zero on the modelled growth trajectory, and t_s is the start of a sinusoid growth oscillation with respect to t = 0. The growth is slowest at time $t_s + 0.5$ (winter point, WP). The parameter c, the amplitude of seasonal oscillations, takes values between 0 (no seasonality of growth rate) and 1 (growth rate becomes 0 at WP). The parameter t_0 cannot be obtained solely from length–frequency data. To estimate t_0, we used a CL of L_n = 0.36 mm at the first zoeal stage, after hatching under rearing conditions (Hoi and Park 2004), t_0 was estimated using the relation described by Lopes Veiga (1979).

$$t_0 = \frac{1}{K}\left(\ln\frac{L_\infty - L_n}{L_\infty}\right)$$

The growth performance index (φ') was estimated using the equation of (Pauly and Munro, 1984):

$$\varphi' = 2\log_{10} L_\infty + \log_{10} K$$

Statistical analysis

The difference in length frequency distribution between the two sexes were determined with Kolmogorov-Smirnov two sample test. Chi-squared test was used to determine if the observed ratio of males to female sex ratio was differed from the expected 1:1 ratio. Kruskal-wallis test was used to investigate the monthly mean variation on GSI. Student *t*-test was used to investigate the difference in egg volume and the difference of GSI values between non-eyed egg and eyed egg stages. Linear regression analysis with use of natural log transformed data was used to investigate the relationship between carapace length-body weight on each sex and carapace length –fecundity on both egg stages. Analysis of covariance (ANCOVA) was used to compare the difference in slope and intercept of regressions on relation between; 1) body weight and carapace length of non-eyed eggs. MINITAB (v.16) and SPSS (v.21) were used for all the statistical analysis and mean value was presented with 95% confidence limit.

3. Results

3-1. Sex ratio

Of the 1787 specimens (266 males, 440 transitionals and 1081 females), percentage of female (60.5%) was significantly greater than that of males (14.9%), with a ratio 1:0.25 ($\chi^2 = 38.248$, df = 14, $P < 0.001$) (Fig4).

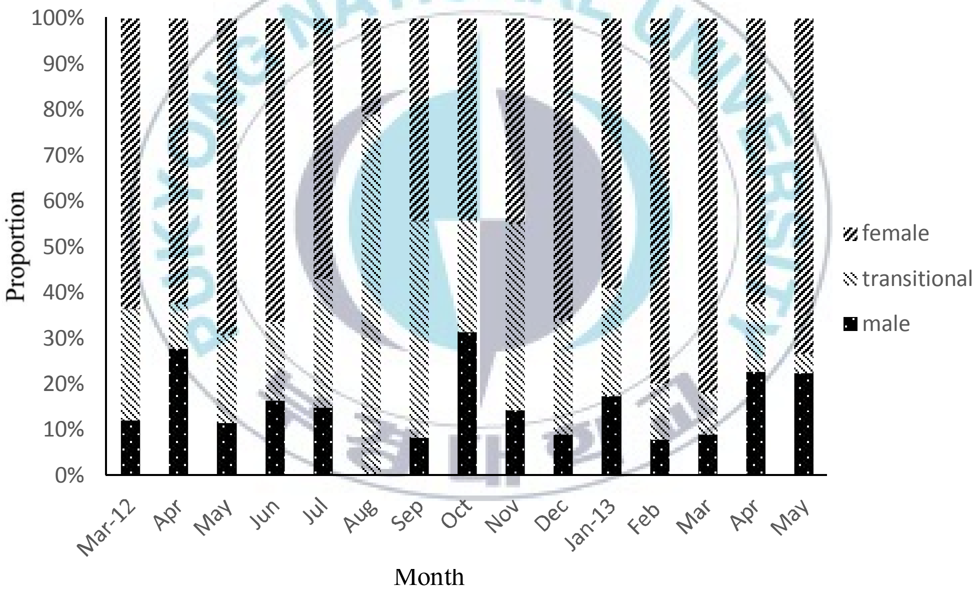

Fig. 4. Sex ratio of *Rhynchocinetes uritai* De Kubo, 1942 in the East Sea of Korea.

3-2. Size frequency distribution

A total 1787 shrimps (266 male and 1081 female) were collected during sampling period from Mar 2012 to May 2013. Kolmogorov-Smirnov two samples test for normality of distribution revealed significant difference in the size frequency distributions of males and females ($P< 0.001$). Females were predominant in larger size classes, whereas males in smaller size, transitionals were a mixture of the two classes (Fig. 5).

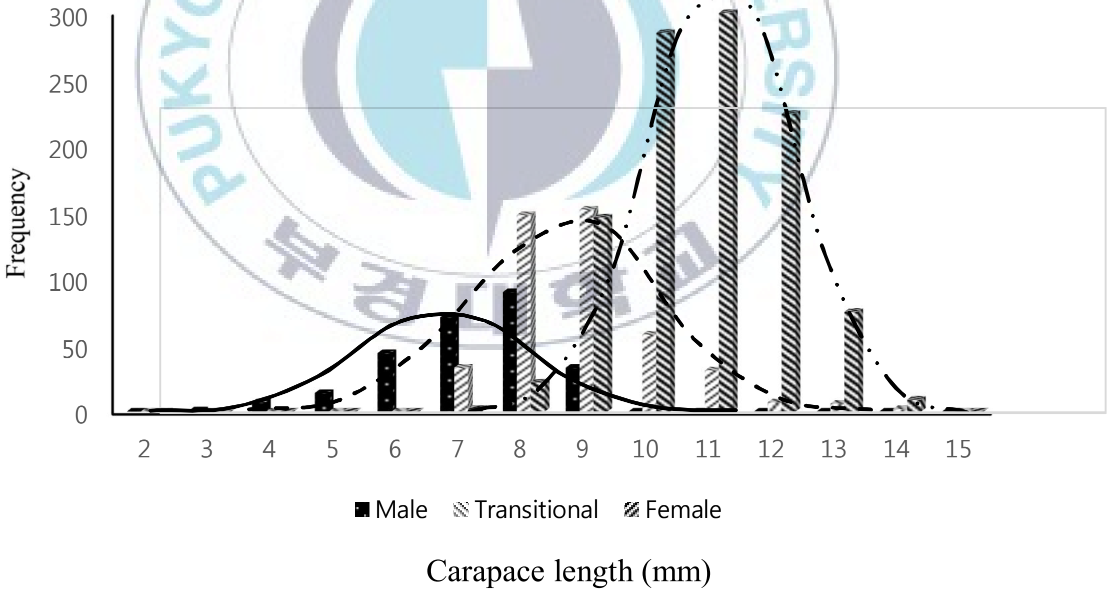

Fig. 5. Length frequency distribution of males and females of *Rhynchocinetes uritai* De Kubo, 1942 in the East Sea of Korea.

3-3. Morphometric relationship

Females were larger in size with a mean 11.25 ± 0.037 mm, ranged from 7.41 to 14.54 mm, while that of males was 7.75 ± 0.07 mm, ranged from 3.95 to 11.57 mm. Mean body weight of females was 2.14 ± 0.93g ranged from 0.35 to 2.33 g and males 0.47 ± 0.01 g ranged from 0.06-1.16g.

The relationship between body weight (BW) and carapace length (CL) was analyzed by linear regression using natural log transformed data of both variable on each sex (Table 2).

Table 2. Linear regression of body weight (BW) and carapace length (CL) of females and males, mean± standard error of BW (g) and CL (mm) of *Rhynchocinetes uritai* De Kubo, 1942 in the East Sea of Korea.

	Linear regression	BW	CL
Female	lnBW = 2.4063(± 0.076) lnCL -5.6628 (n = 1081, r^2 =0.731, $P < 0.001$)	2.14 ± 0.93g	11.25 ± 0.037mm
Male	lnBw = 2.417 (± 0.069) lnCL - 5.7675 (n = 266, r2 = 0.822, $P < 0.001$)	0.47 ± 0.01g	7.75 ± 0.07mm
Transitional	lnBw = 2.124 (±0.068) lnCL - 5.0406 (n = 440, r2 = 0.822, $P < 0.001$)	0.79 ± 0.015g	9.38 ± 0.06mm

The relationship between body weight and carapace length was negative allometric for both males and females *R.uritai* expressed by the slope on linear regressions of both male and female, which is smaller than 3 (Fig. 6).

Sex specific difference in morphometric relationship among body weight and carapace length of *R. uritai* was indicated based on significant difference on slope of regression of body weight versus carapace length between natural log transformed data of male and female (ANCOVA: F = 11.29, $df = 1$, $P < 0.05$).

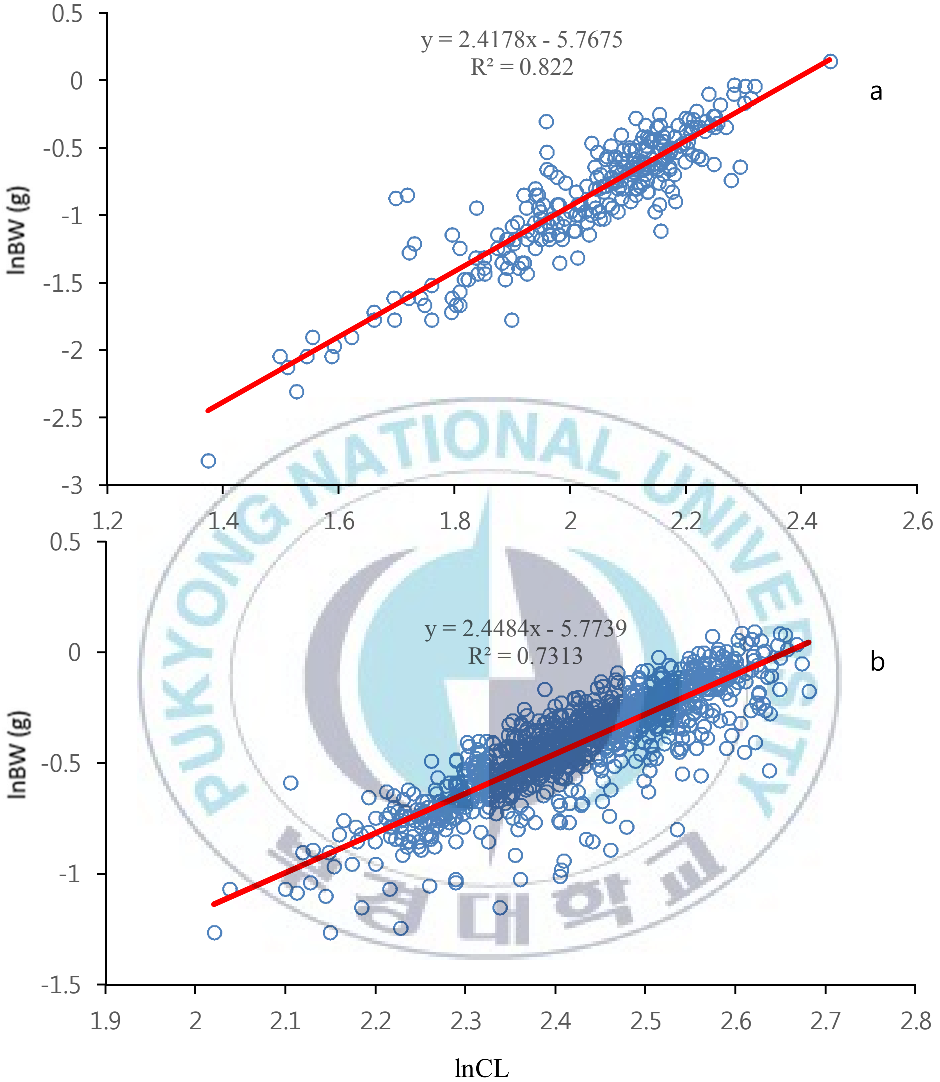

Fig. 6. Relationship between body weight (BW, g) and carapace length (CL, mm) with ln-ln transformed data in (a) males; (b) females of *Rhynchocinetes uritai* De Kubo, 1942 in the East sea of Korea.

3-4. Breeding period

Breeding period was determined by the occurrence of ovigerous females. Ovigerous females of *Rhynchocinetes uritai* in Nasari fishing seaport breakwater were present between March and October (Fig. 7a). The GSI started to increase in March, reached the peak in September (fig. 7b); GSI values varied significantly between months (H = 42.95, df = 14, $P < 0.001$).

GSI values of females with non-eyed and eyed egg stages were significantly different (student t-test, $P<0.001$).

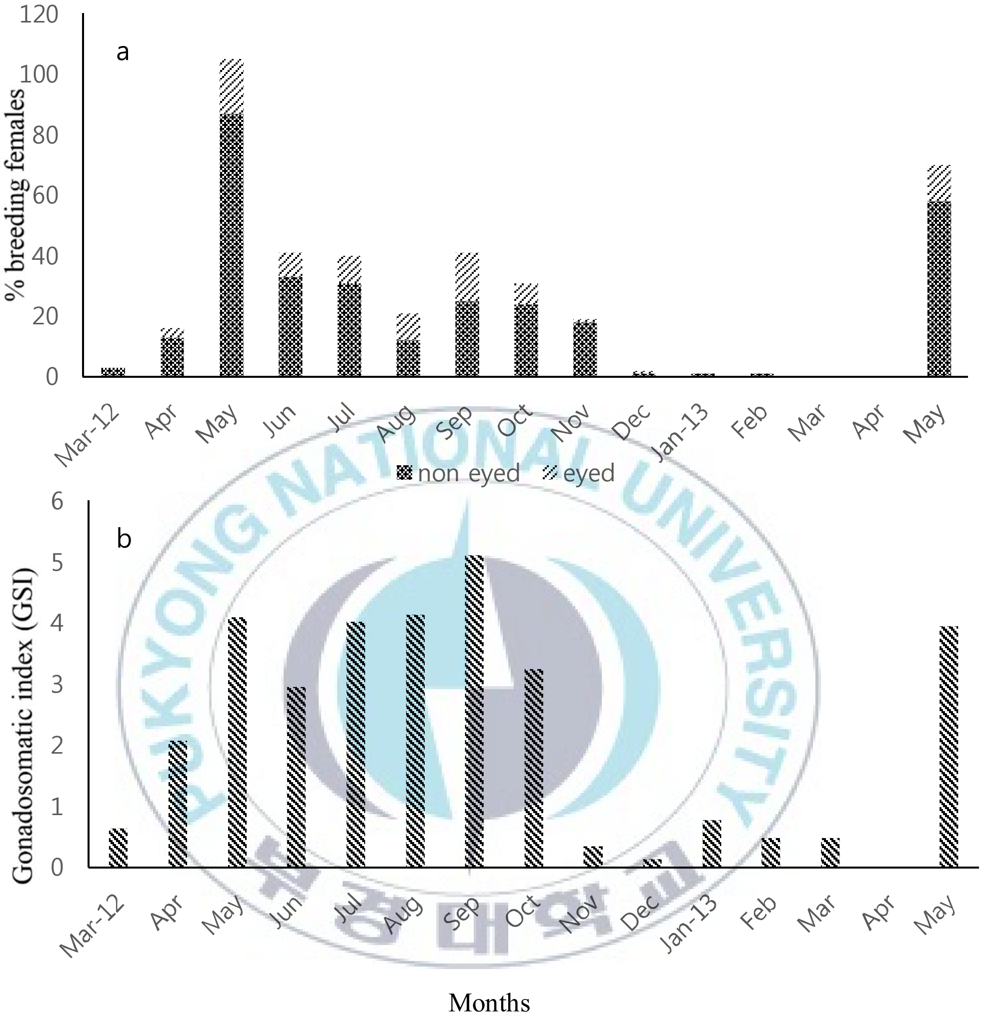

Fig. 7. Monthly variation of *Rhynchocinetes uritai* De Kubo, 1942; in the East Sea of Korea. a: in the proportion of ovigerous females with different egg stages; b: monthly variation in gonadosomatic index (GSI) (bar graphic).

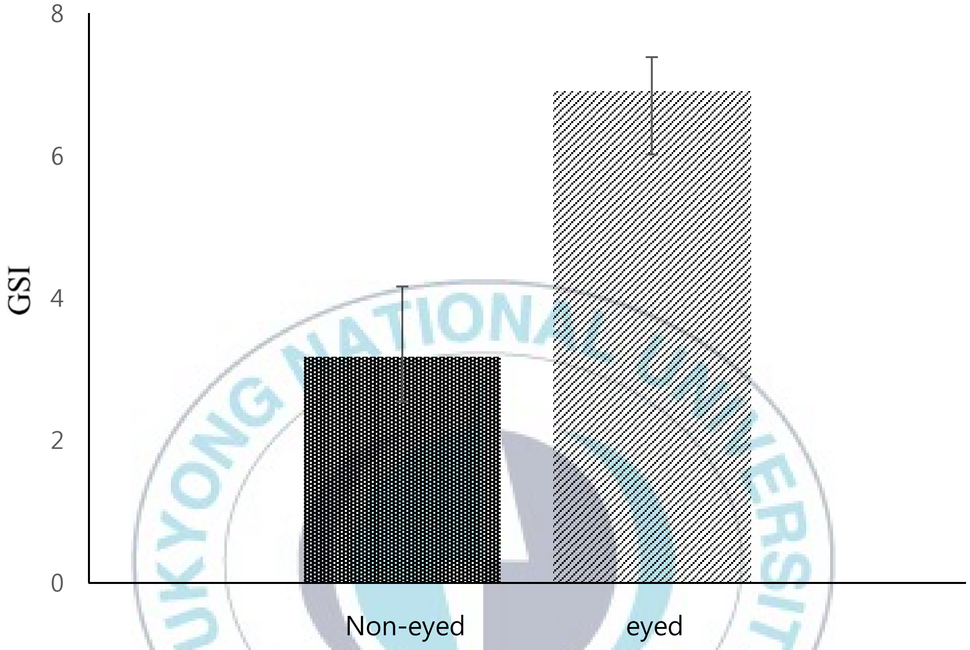

Fig. 8. Mean gonad somatic index (GSI) of females with non-eyed and eyed egg stage ($P<0.001$), of *Rhynchocinetes uritai* De Kubo, 1942 in the East Sea of Korea.

3-5. Fecundity and reproductive output

In ovigerous females, 289 females with mean carapace length 11.58±0.07 ranged from 8.89 to 14.54 mm, were carried 3098±60 non eyed eggs, ranged from 935 to 4763, and 152 females with mean carapace length 11.38±0.09 mm, ranged from 9.46 to 14.34 mm, were carried 2941±56.75 eyed eggs ranged from 1619 to 4401. Mean egg volume of eyed eggs (n = 4335, 0.11 mm^3) was significantly larger than that of non-eyed eggs (n = 2280, 0.06 mm^3) (student *t*-test, $P<0.001$).

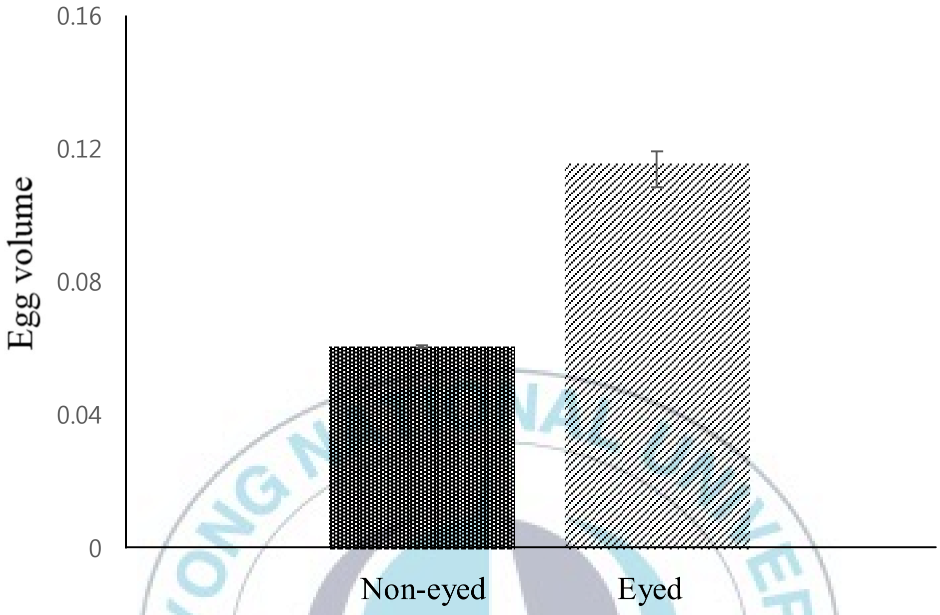

Fig. 9. Mean egg volume for non-eyed and eyed egg stage (P<0.001), of *Rhynchocinetes uritai* De Kubo, 1942. In the East Sea of Korea.

Ln transformed values of carapace length and number of eggs in females with non-eyed and eyed egg stages show statistically significant linear relationships (table 3).

Based on the 95% confidence interval, in non-eyed stage the slope of the regression is approximately 3, which imply that the relationship between the variables is isometric, and in eyed stage the slope of the regression is less than 3, which imply a negative allometry between variables. ANCOVA revealed no significant difference between the slopes (F = 0.4, $P>0.05$), whereas there was a significant difference in intercepts (F = 24.16, $P< 0.05$), indicating there was brood loos between the two egg stages.

Reproductive output (±standard deviation) was 0.22(±0.016) (n = 320).

Table 3. Linear regression of carapace length in non-eyed and eyed egg stages, mean±standard error of carapace length (CL) (mm) and number of eggs (EN) of *Rhynchocinetes uritai* De Kubo, 1942; in the East sea of Korea.

Egg stage	linear regression	95% confidence interval
Non-eyed	$\ln EN = 2.909 \ln CL + 0.865$ ($n = 240$, $r^2 = 0.6269$, $p<0.001$)	2.909±0.26
Eyed	$\ln EN = 2.163 \ln CL + 2.699$ ($n = 80$, $r^2 = 0.8442$, $p<0.001$)	2.163±0.21

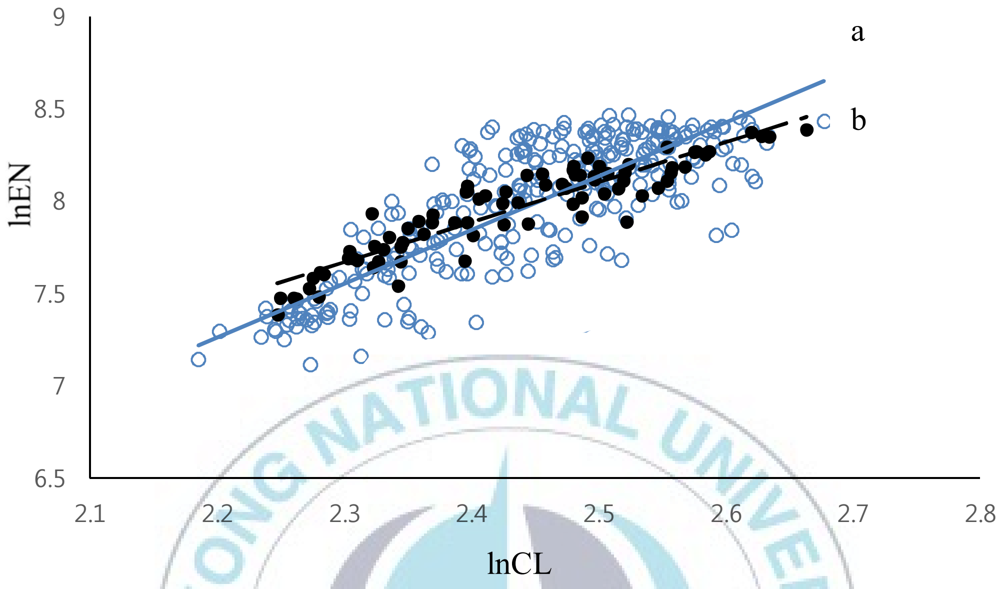

Fig. 10. Relationship between egg number (EN) and carapace length (CL) on *Rhynchocinetes uritai* De Kubo, 1942; with a, the non-eyed egg stage; b, the eyed egg stage.

3-6. Size at sexual maturity (CL_{50})

During study period, the 1060 of female *Rhynchocinetes uritai* used in the analysis ranged from 8.03 mm to 14.54 mm (CL).the proportion of mature females by length class increased logistically with length (fig. 11). The size at which 50% of females reached maturity correspond to 8.45mm.

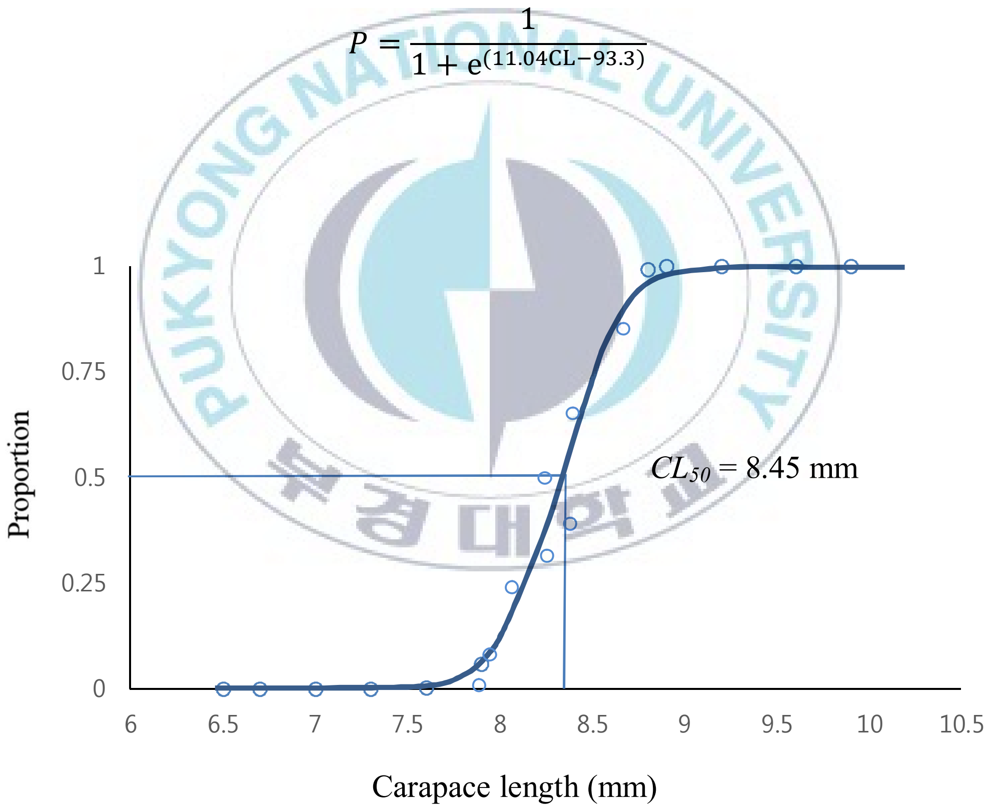

Fig. 11. Logistic function fitting proportion of mature females to carapace length of *Rhynchocinetes uritai* De Kubo, 1942; in the East Sea of Korea.

3-7. Growth

The seasonalized von Bertalanffy growth function parameters were estimated by ELEFAN for each sex (Fig.12) (Table 4). The parameter of asymptotic length (L_∞) in females (21.43 mm CL) is higher than in males (14.89 mm CL) however, the parameter of growth coefficient (K) in females (0.31yr^{-1}) is lower than in males (0.46yr^{-1}). The von Bertalanffy growth equations corresponding to (Fig. 12):

Male :

$$L_t = 11.77[1 - e^{[-0.6(t-0.05)-\frac{0.2X0.6}{2\pi} sin\, 2\pi(t-0.25)]}]$$

Female:

$$L_t = 18.1[1 - e^{[-0.41(t-0.05)-\frac{0.7X0.41}{2\pi} sin\, 2\pi(t-0.15)]}]$$

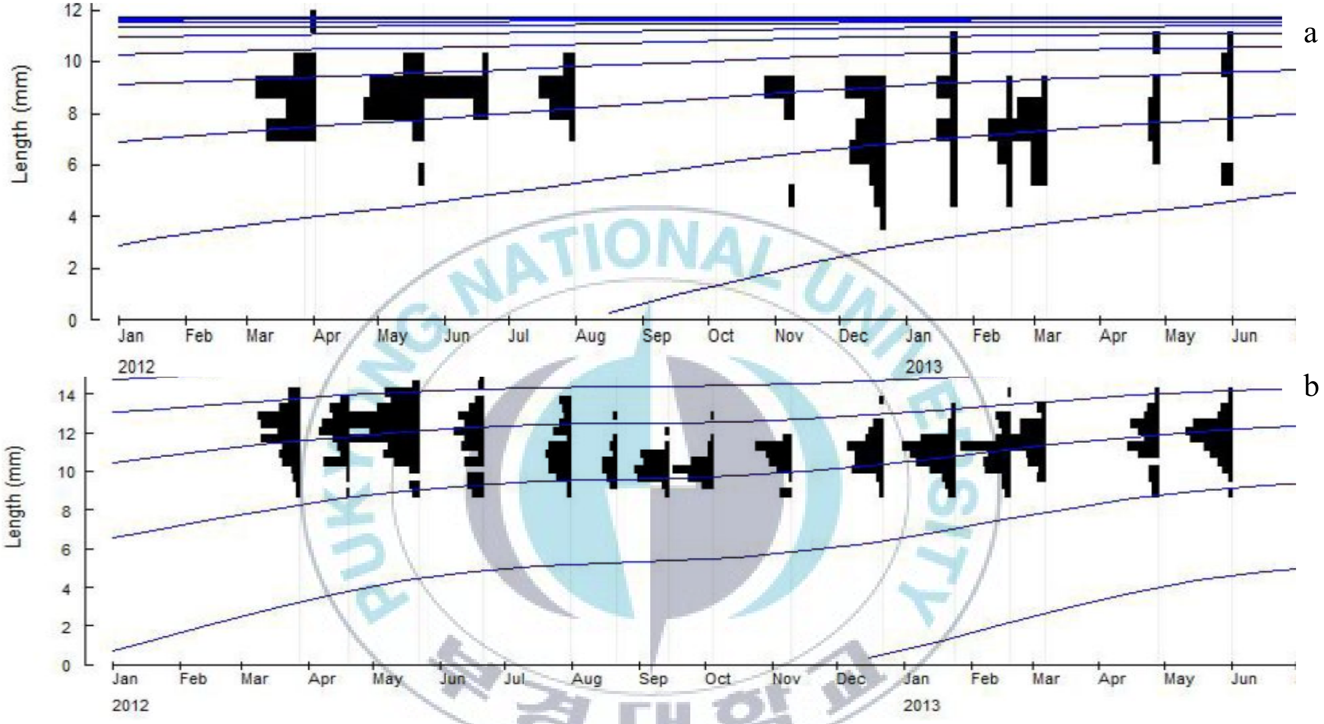

Fig. 12. Length-frequency distribution of males (a) and females (b) of *Rhynchocinetes uritai* with seasonal von Bertalanffy growth curves.

Table 4. Parameter estimation of ELEFAN analysis of length frequency distribution for males and females: L_∞: asymptotic length (mm); *K*: growth coefficient (yr^{-1}); *C*: amplitude of growth oscillation; *WP*: winter point; *φ'*: growth performance index; R_n: score function**.**

	Males	Females
L_∞	11.77	18.1
K	0.6	0.41
C	0.2	0.7
WP	0.25	0.65
φ'	1.91	2.12
R_n	0.347	0.209

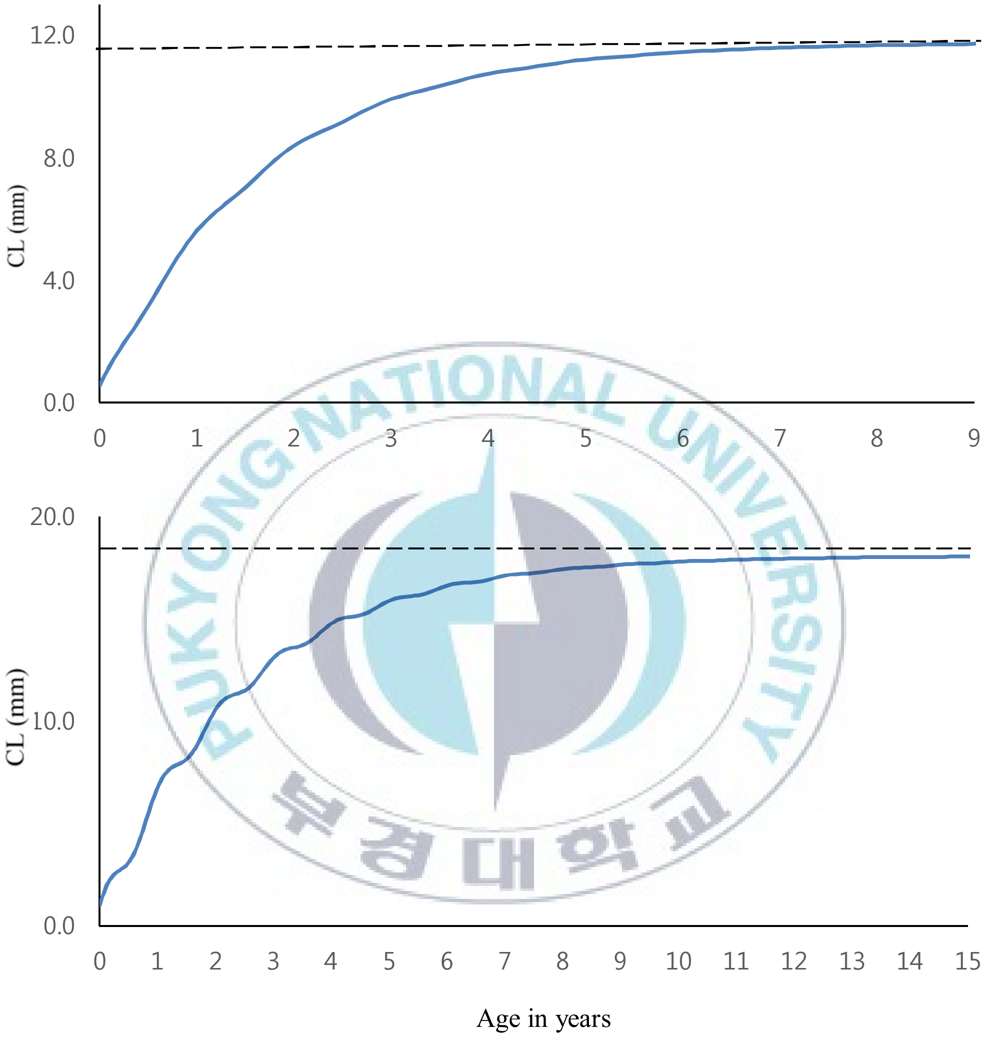

Fig. 13. The von Bertalanffy length-based growth curve. L_∞ is represented by the dashed line, a: male; b: female.

4. Discussion

4-1. Sex ratio

The sex ratio of the *R. uritai* population in the East Sea of Korea was in favor of females; Sex ratio in a shrimp population may be related to the growth of the population (Oh et al. 2008). Unequal sex ratio in crustacean populations is a prevalent phenomenon (Lizárraga-Cubedo et al. 2008), seasonal pattern and life history differences between sexes may also explain the variation of sex ratio (Oh et al. 2008). Higher proportions of females to males wasn't yet recorded in other Rhynchocinetid species, while it was reported as a characteristic of other caridean shrimps; hippolytid shrimp *Lebbeus groenlandicus* (Bae and Oh 2014), *Hippolyte inermis* (Cobos et al. 2005), *Hippolyte zostericola* (Roma´n-Contreras 2005), *Tozeuma carolinense* (Ewald 1969) and *Heptacarpu futilirostris* (Oya 1987).

4-2. Length frequency distribution

Size frequency distribution based on carapace length (CL) of *Rhynchocinetes uritai* in the East Sea of Korea, shows that females were significantly predominant in larger size classes, whereas males in smaller size (Bauer and Thiel 2011). The size frequency distribution displays the classic portrait of a purely protandrous species, individuals first mature sexually as males and later change sex to females (Bauer 2004). It is common among shrimps that females tend to exceed males in size (Lloyd and Yonge 1947; Siegel et al. 2008). In support of this, we observed transitional individuals of intermediate size which show a mix of male and female sexual characteristics. They had appendix masculina on the second pleopods and an appendix interna on the first pleopods as do caridean males (Bauer 2004). These transitional individuals exhibit reduced lateral lobe of the endopod of the first pleopod, and definite female incubatory characters "breeding dress", consisting of expanded pleopod flanges and pleonal pleura (Chace 1997; Bauer 2004; Bauer and Thiel 2011).

Large size on females is a reproductive strategy reflected on mating system, capacity of large brood size production (Hartnoll 1985) and egg carrying

(Berglund 1981, Manent and Abella-Gutierrez 2006). The small size on males provide them with more mobility capacities, low predation risk, energy needs and habitat requirements (Berglund 1981; Correa and Thiel 2003; Bauer 2004). The form of sexual dimorphism of a species often suggests the possibility of sequential hermaphroditism. Size-frequency distributions composed of small males and larger females, with little overlap in size and a lack of small (juvenile) females, is suggestive, although not conclusive, evidence of protandry (Bauer 2004).

4-3. Morphometric relationship

Both sex showed slope values smaller than 3 indicating negative allometry relationship between carapace length and body weight. It explains that body weight increase allometrically as the carapace length increase. Female and male slopes were approximately similar, that may be interpreted as similar body weight gain rate between males and females. Although the majority of caridean studied to date are gonochoristic (separate sexes), there are numerous species with protandric hermaphroditism in which individuals first develop as a male phase (MP) and then change sex to a female phase (FP) (Bauer 2000; Correa and Thiel 2003).

Significant difference on slope of regression of body weight versus carapace length between natural log transformed data of males and females, is more an evidence of sexual dimorphism between sexes, many species present sexual dimorphism with smaller males and larger females (Bauer and Abdalla 2000; Correa and Thiel 2003), While the reproductive success function of females is always positively correlated with size (the larger the females, the larger the clutch size). Mating systems and its success, may be a function of male size, primarily affect the shape of the male function and thus represent an important source of variation leading to the observed diversity in sexual systems of caridean shrimps (Correa and Thiel 2003). Rhynchocinetidae sexual dimorphism, mating systems, and sexual systems can only be speculated at this time. Comparative as well as experimental studies have indicated that, independent of phylogeny, factors such as predation pressure, food and spatial resources, trophic ecology, and social organization may cause such variation (Bauer 2000; Pitcher et al. 2005, Brown et al. 2010).

4-4. Breeding period

Reproductive potential of a species is mainly determined by reproductive pattern and crustaceans represent a wide range of these reproductive patterns (Bauer 2004). Based on monthly variation in the proportion of ovigerous females and GSI, the breeding period of *R. uritai* was determined to be from May to February due to absence of females during March and April 2013, with a peak of breeding females in May and a peak of GSI in September, in sum intense breeding is observed during spring summer and fall. Although we estimate that absence of ovigerous females in April and March 2013 results of low catchability; which depends on many factors: sensory capabilities and behavioral response to the sampling gear (Wassenberg and Hilll 1990) environmental factors including temperature and wind (Chittelborough 1970).

We assume a continuous reproduction. Based on observations, females appear to produce successive broods, i.e., undergo a parturial molt soon after releasing larvae from a previous spawning, incubation time of two weeks appears typical for caridean shrimps (Bauer 2004).

4-5. Fecundity and reproductive output

Fecundity is the number of offspring produced per organism in a given time (Daintih 2010). It is a phenotypic characteristic that is affected by numerous factors and intensities and by specific features of different environments (Hines 1991). The allometric relationship between egg number and carapace length of *R. uritai* was significantly positive, that implies that relative egg number is greater at larger body size. In general, clutch size is highly correlated with the size of individuals (Chockley and Mary 2003). Fecundity is also strongly affected inter-specifically by egg size. Furthermore, fecundity, as well as breeding frequency, are characteristics directly related to a species life strategy (Oh and Hartnoll 2004).

In present study the eyed eggs volume was significantly greater than non-eyed eggs stage. Kubo (1942) reported egg sizes in *R. uritai* that were approximately similar to those reported here for non-eyed eggs, while results from reared *R. uritai* eggs were smaller (Bauer and Thiel 2011). However, the two studies did not stated the developmental stage of eggs. The early-stage embryo size observed is among the smallest reported for a caridean species (Bauer and cash, 1991; Corey and Reid, 1991; Bauer, 2004). The egg volume increased between non-eyed and eyed egg stages with high rate (90%), comparing to other caridean species: *Macrobrachium* spp. between 28% -38% (potiuna 2003; Nazari et al.2003). *Atya scabra* 30.9% (Galvão and Bueno 2000). *Atya margaritacea* 30.8% (Martínez Mayén et al. 2000).

Other aspects of female reproductive biology appear typical of a small-sized species from a shallow warm- temperate marine habitat (Bauer 2004). ANCOVA revealed significant difference in the number of eggs in the two egg stages as function of carapace length. This indicate that there was brood loss. Brood loss in decapods may be induced by numerous factors: aborted development, mechanical loss due to abrasion, maternal cannibalism, embryo predation and parasitism (Kuris 1991; Oh and Hartnoll 1999).

Reproductive output (RO) is a life history trait demonstrating various numbers and sizes of larvae (Hartnoll 1985), it is expressed as the biomass of the productive products per unit biomass of the female (Pianka 1972; Thessalou-Legaki and Kiortsis 1997). In caridean females, the number of eggs per brood is a function of body size (Corey and Reid 1991). *R. uritai* brood weight represented 22% of female body weight. This study shows RO was higher than other caridians in Korean waters (Oh et al. 2008), which ranged from 12 to 20% (Table 5).

Table 5. Comparison of reproductive output (RO) for a variety of Caridean shrimps.

Family	Species	RO	Source
Crangonidae	*Argis lar* (Owen, 1839)	0.12	Seo, Oh et al. (2012)
Hippolytidae	*Lebbeus groenlandicus* (Fabricius, 1775)	0.18	Bae (2014)
Palaemonidae	*Palaemon gravieri* (Yu, 1930)	0.12	Kim (2005)
	Exopalaemon modestus (Heller, 1862)	0.17	Oh and Suh et al. (2002)
Rhynchocinetidae	*Rhynchocinetes uritai* (Kubo, 1942)	0.22	present study

4-6. Size at sexual maturity

The classical method to estimate size at first maturity is based on fitting a logistic function and calculating the size class, where a randomly chosen individual has 50% chance of being mature (Somerton and Meyers 1983). In this study, estimated CL_{50} was 8.45 mm. In general, geographic variations affect the size at sexual maturity (Oh and Hartnoll 2004), predation and environment parameters (Linzey et al. 2003).

4-7. Growth

Growth investigation of *R. uritai* using von Bertalanffy growth parameters showed that females have higher $L\infty$ and lower K in inversion with males. That reflected on growth performance index (φ') that was higher in females than in males. The growth performance index (φ') is preferred for growth comparison between sexes (Munro 1984). Comparison of growth performance index of *R. uritai* to other caridean families, showed that growth performance index of *R. uritai* are the smallest within the caridean shrimps of Korean waters, and that caridean females have greater growth performance index than males. That difference in the growth performance index between two sexes, indicate that females grew faster and reached a larger size at age than males. Numerous records from literature mentioned sexual differences in growth for freshwater and marine decapods (Oh et al. 2008).

The growth season of *R. uritai* is extended during spring, summer and fall. Winter point WP of males is 0.25, which from February to March the slowest growth period that coincide with low male numbers. We assume also that males tend to keep energy, therefore it can be used to produce a large amount of sperm (Paschoal et al. 2013), for successful breeding period in May, where we noted the peak of ovigerous females. Winter point of females is 0.6, which from Jun to Jully and may be extended; in reason it coincides with the breeding period and increasing GSI values. And might be explained by expanding less energy into growth a successful breeding. A female caridean, however, must grow to a Greater size in order to produce the large, energetically-expensive, vitellogenic oocytes (Bauer 2000).

Table 6. Comparison of growth performance index (φ') for a variety of caridean shrimps.

Family	Species	φ'		Source
		Male	female	
Crangonidae	*Argis lar* (Owen, 1839)	-	3.14	Seo et al. (2012)
Hippolytidae	*Lebbeus groenlandicus*(Fabricius, 1775)	2.86	2.89	Bae (2014)
Palaemonidae	*Palaemon gravieri* (Yu, 1930)	2.38	2.63	Kim (2005)
	Exopalaemon modestus (Heller, 1862)	2.32	2.42	Oh et al. (2002)
Rhynchocinetidae	*Rhynchocinetes uritai* (Kubo, 1942)	1.91	2.12	present study

Acknowledgement

Alhamdulillah, with this words I finish my thesis. I would like to express my deepest and sincerest gratitude to my advisor, Professor Chul-woong Oh, for his excellent guidance, caring, patience, and providing me with an excellent atmosphere for doing research, a person who deserves all my respect. To all our department professors, professor Hong for his warm visits and advices, the National Institute for International Educational Development (NIIED) for providing financial support on my master program study; the department of marine biology of Pukyong National University; the evaluator chairman and member; Professor hyun-woo Kim and Dr. Mi-Hyang Kim for their interesting remarks and helpful comments .

I thank my fellow lab mates for the moments we spent together, for the help and for the smile Inok, Ho-Jin, Jeong-Yun, Hanna, kyeong-Tea, Han-ju, Seong-eun and Ah-Reum, also to Hye-Min, Hyeong-Gi and jung-Hun.

Finally, to my family parents, brothers, sister and uncles for the love and support. To my future wife and her family for the great warm love.

May the Almighty God richly bless all of you.

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