Relative Growth and Sexual Dimorphism in the Red Frog Crab *Ranina ranina* (Decapoda: Raninidae)

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The relative growth of several body parts and the morphology of pleopods were examined in reared and captured individuals of *Ranina ranina*. Sexual dimorphism occurred in the pleopods at instar I, on the abdomen of individuals over 34mm carapace length, and on the cheliped in individuals over 70mm carapace. In females puberty molt was estimated to occur at 40-45mm carapace length, using the relative growth of abdomen width. In males the relationship between dactylus or propodus length of the cheliped and the carapace length was described by two or three power regression equations. The point of contact of the logarithmically transformed linear equations was 26 and 74mm in dactylus length and 73mm in propodus length. A growth-reproduction model of *R. ranina* based on changes in the relative growth is discussed.

The red frog crab *Ranina ranina* Linnaeus is a commercially important crab found on sandy bottoms in the Indo-West Pacific.\(^1,2\) Some aspects of the reproductive biology of *R. ranina* have been reported, including information on the reproductive cycle, ovigerous season, and minimum size to maturity in Hawaii, Japan, the Philippines, and Australia.\(^3-8\) However, information on the relationship between growth and reproduction is fragmentary.

The relative growth of several body parts shows different patterns, associated with sex and maturity in Decapoda.\(^9,10\) Hartnoll\(^11\) summarized relative growth patterns and growth rates in brachyuran crabs.

In the present study the time of appearance of the secondary sexual characters was examined, using the relative growth and morphology of pleopods to show the relationship between growth and reproduction in *R. ranina*. In addition, a model for a growth-reproductive pattern is discussed.

Materials and Methods

A total of 307 female and 301 male crabs were captured by trapping at a depth of 15-40m off Hachijo-jima (33°08'N, 139°48'E), an island located 290km south of Tokyo, from 1986 to 1991. Wet body weight (BW) was weighed, and carapace length (CL), abdomen width (AW), and dactylus and propodus length of the left cheliped (DL, PL) were measured after collection. A definition of the lengths and width is given in Fig. 1.

In addition, 10 juvenile crabs of instar I obtained from larval rearing in 1989 were reared individually to instar IV in 30l plastic containers at 25.0-28.2°C and a salinity of 32-34. Shellfish, squid and/or krill were given daily as a food. The exuviae and dead juveniles were fixed with 10% neutralized formalin for at least two days and preserved in 70% ethanol. The CL, AW, DL, and PL of specimens were also measured for

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Fig. 2. Frequency distributions of the carapace length in males and females of *Ranina ranina* collected from off Hachijo-jima Island. Asterisks indicate averages.

Fig. 3. The relationship between carapace length and body weight in males and females of *Ranina ranina*.

Fig. 4. Abdomen width and dactylus and propodus length of the cheliped plotted against carapace length in female and male *Ranina ranina*.

Analysis of the relative growth, and the morphology of the pleopods was examined for sexual dimorphism.

**Results**

**Relative Growth**

The CL of the field-caught animals ranged from 38.7 to 132.0 mm in males and from 44.8 to 124.0 mm in females. The males were significantly larger than the females on average in total individuals of each sex (t-test, P<0.01) and dominant in individuals over 100 mm carapace (Fig. 2). The relationship between CL and BW was similar in both sexes (ANCOVA, Ps>0.01) and was described by a power equation (Fig. 3):

\[ BW = 0.00016 \cdot CL^{3.16} \]

\[ (r=0.992, n=581, t-test, P<0.01). \]

The shape of the abdomen showed sexual dimorphism: the female had a wider abdomen compared to that of the male in field-caught animals (Fig. 4). The relationship between CL and AW was described by a single linear regression equation in each sex:

female: \[ AW = -9.22 + 0.467 \cdot CL \]

\[ (r=0.977, n=269, t-test, P<0.01) \]
Table 1. Regression equations for the relative growth of several body parts to carapace length in R. ranina

<table>
<thead>
<tr>
<th>Sex</th>
<th>Dependent variable</th>
<th>Carapace length (mm)</th>
<th>Regression equation</th>
<th>( r )</th>
<th>( P )</th>
<th>( n )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Type*^1</td>
<td>Intercept (a)</td>
<td>Slope (b)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>AW</td>
<td>&lt;42</td>
<td>L</td>
<td>-0.97</td>
<td>0.268</td>
<td>0.997</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;42</td>
<td>L</td>
<td>-9.19</td>
<td>0.466</td>
<td>0.972</td>
</tr>
<tr>
<td>Male</td>
<td>DL</td>
<td>&lt;26</td>
<td>P</td>
<td>-1.05</td>
<td>0.848</td>
<td>0.983</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26=&lt;, &gt;74</td>
<td>P</td>
<td>-2.41</td>
<td>1.282</td>
<td>0.956</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;74</td>
<td>P</td>
<td>-3.96</td>
<td>1.642</td>
<td>0.963</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>&lt;73</td>
<td>P</td>
<td>-1.50</td>
<td>1.166</td>
<td>0.996</td>
</tr>
<tr>
<td></td>
<td></td>
<td>73=&lt;</td>
<td>P</td>
<td>-2.69</td>
<td>1.444</td>
<td>0.973</td>
</tr>
</tbody>
</table>

*^1 AW: abdomen width; DL: dactylus length of cheliped; PL: propodus length of cheliped.
*^2 L: linear regression equation, \( y=a+bx \); P: power regression equation, \( ln(y)=a+b \ln(x) \).

male: \( AW = -1.12 + 0.229 \cdot CL \) 
\((r=0.987, n=276, t\text{-test, } P<0.01)\).

These two lines were significantly different (ANCOVA, \( P<0.01 \)). The CL at the point of contact of the two lines was 34.0 mm. The point of contact was determined by solving the two equations.

Regression equations for relative growth in several body parts in the female and male are shown in Table 1. The relative growth of DL and PL to CL was similar in males and females up to 70 mm CL. However, the relationship between CL and DL or PL was significantly different in both sexes above 70 mm CL (ANCOVA, \( P<0.01 \)) (Fig. 4).

The relative growth in AW in females could be described by two linear equations, of which the point of contact was 41.5 mm CL (Fig. 5). The regression equations between CL and AW in individuals greater and less than 41.5 mm CL were respectively:

\( AW = -0.974 + 0.268 \cdot CL \) 
\((r=0.997, n=10, t\text{-test, } P<0.01, \text{ CL}<41.5 \text{ mm})\)

\( AW = -9.187 + 0.466 \cdot CL \) 
\((r=0.972, n=269, t\text{-test, } P<0.01, \text{ CL}>41.5 \text{ mm})\).

These two lines were significantly different (ANCOVA, \( P<0.01 \)).

In males the relative growth in DL and PL compared to CL was described by three and two significantly different power regression equations (ANCOVA, \( P<0.01 \)). CL at the point of contact of the linear equations, logarithmically transformed from the power equations, was 26.0 and 73.7 mm in DL, and 73.3 mm in PL (Fig. 6).

Fig. 5. Relative growth of abdomen width of females, plotted against carapace length in R. ranina.

Development of Pleopod

The average intermolt period was 23.4 days at instar I, 43.0 days at instar II, and 41.6 days at instar III. The carapace length at instars I-IV was 10.2, 12.2, 14.8, and 19.3 mm, respectively. The first to fourth pleopods of the female developed on the second to fifth abdominal somites, respectively (Fig. 7A). The endopod of the pleopod elongated, but the uropod became more vestigial with each instar (Fig. 7C, E). In the male the ventro-middle part of the first abdominal somite protruded and the first gonopod occurred as a protuberance near the border of the first and second abdominal somites (Fig. 7B). The exopod of the first pleopod thinned and shortened at instar II and disappeared by instar III, whereas the endopod elongated with each instar and formed the second gonopod (Fig. 7D, F). The second to fourth pleopods and uropod degenerated and disappeared by instar III.
Fig. 6. Relative growth of dactylus and propodus length of the cheliped of males, plotted against carapace length in Ranina ranina. Closed triangles indicate the point of contact of the two regression equations.

Discussion

Examination of the timing of the development of sexual dimorphism is important in understanding reproduction. Sexual dimorphism is related to reproductive activity, such as mating and oviposition in brachyuran crabs. In males a large cheliped is believed to be advantageous for combat and courtship. The female abdomen becomes wider than that of the male for oviposition. In R. ranina males the teeth of the carapace became larger and flattened. In addition, the male propodus of the cheliped becomes larger in individuals above 70 mm CL in R. ranina in Hawaii. Similarly, the male dactylus and propodus of the cheliped were larger in individuals above 70 mm CL in the present study. The female abdomen broadens above 34 mm CL compared to that of the male. Furthermore, sexual dimorphism was evident from juvenile crabs of instar I in the pleopods. In R. ranina sexual dimorphism in the pleopods appeared in an earlier instar than in other crabs, Callinectes sapidus and Rhithropanopeus harrisi. The early occurrence of the sexual dimorphism is probably related to the large size of the instar 1 juvenile crab.

In R. ranina the relative growth of the female abdomen width could be described using two different linear equations. Relative growth is generally described by a power equation, in other words the growth is allometric. However, in R. ranina the relative growth of the abdomen width was isometric, as in Ovalipes punctatus and Tiarinia cornigera because it was best described by a linear equation. The cause of isometric growth of the abdomen width is unclear.
compared to carapace length or width often change with maturity.\textsuperscript{10} Ecdysis immediately before maturity is defined as puberty molt. Puberty molt was estimated to occur in females at 42 mm CL, based on the point of contact of the two linear regression equations. Individuals with a 41.9 mm carapace (instar VIII) grew to 52.7 mm in a single ecdysis in \textit{R. ranina} reared in the laboratory (Ashidate, in press). The minimum size of females with external eggs or developing ovaries was 50 mm in the Philippines,\textsuperscript{5} 54 mm in Hawaii,\textsuperscript{4} and 55 mm CL in Japan (Minagawa, unpublished). The size at the puberty molt estimated using the relative growth data corresponds well with these values.

In \textit{R. ranina} a female bears eggs more than once during the spawning season, which is from June to September in Japan.\textsuperscript{7} Following spawning, the female and male crabs molt in October.\textsuperscript{12} A hypothesis for the female and male growth-reproductive patterns is given in Fig. 8. The relative growth pattern in females indicates that the puberty molt occurs at a single instar or a narrow range of size, since no duplication was observed in the two lines which showed prepuberty and postpuberty. Therefore, almost all crabs have a puberty molt at approximately 40–45 mm carapace (instar VIII) and first bear eggs at instar IX (ca. 55–60 mm carapace). After this, the female spawns several times during the spawning season and molts in autumn. These oviposition and growth cycles are repeated every year, as in \textit{Canver pagurus},\textsuperscript{17} because 90–95\% of the females were ovigerous at the first spawning of the year.\textsuperscript{1,17}

In males three different logarithmically transformed linear regression equations were used to describe the relative growth of the dactylus, bordered at 26 and 73 mm. Sperm were already present in the testis and poorly developed vas deferens in individuals of 39 mm carapace, but sperm was first found in the ejaculatory duct at 55 mm carapace.\textsuperscript{8} Sexual maturity in males probably occurs in individuals over 26 mm carapace (instar V),\textsuperscript{8} estimated by the relative growth in dactylus length. However, whether all individuals between 26 and 55 mm carapace are sexually mature is uncertain because of the lack of data of individuals around 30 mm carapace. Functional maturity would occur in individuals greater than 73 mm carapace in \textit{R. ranina}, as estimated by the relative growth of the dactylus and propodus (Fig. 8). However, histological examination and experiments on mating are necessary to confirm this hypothesis, since the size of males which can first participate in mating is unclear.

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References


